Science Teaching and Learning: Exploring Barriers Experienced by Science Students with Learning Disabilities and their Science Instructors in a CEGEP Setting.

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PhD in Education

August 2019

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Doctor of Philosophy in Education

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GENERAL ABSTRACT

Science is for *all* individuals regardless of their gender, cultural background, social circumstances, or career aspirations (AAAS, 1993; Achieve Inc., 2013; CMEC, 1997; 2013; MELS, 2007). Yet, not all students are offered equal opportunities and the required support to learn and perform well in science. Specifically, students with learning disabilities (LD) are continuously lagging behind in science, and scoring significantly lower grades as compared to their typically achieving peers across the elementary, secondary, and postsecondary settings. Moreover, Canadian students with LD are more likely to drop out of postsecondary science programs than their typically achieving peers. In addition to being underrepresented in STEM (Science, Technology, Engineering, and Mathematics) programs, individuals with LD are less likely to be employed, and tend to experience depression and anxiety as compared to typically achieving individuals. Yet, research studies aiming at investigating the difficulties faced by postsecondary students with LD in learning science are sparse to non-existent. It is critical that barriers experienced by students with LD are explored and understood in order to design and implement effective intervention-based programs geared towards their academic success and retention in college STEM programs.

Therefore, the salient objective of this manuscript-based dissertation is to explore the difficulties encountered by postsecondary science students with LD in engaging with, and learning science. Another key objective of this research endeavour is to investigate the barriers encountered by college science instructors in teaching and academically supporting students with LD. It is well documented that college instructors are instrumental in facilitating the inclusion of students with LD by employing differentiated instructional practices. Additionally, students with LD have identified college instructors as central to their academic success. Thus, it is imperative

that the challenges faced by these instructors are explored, identified, and addressed so that they can effectively work with their students with LD and support them in their pursuit of science.

This dissertation draws on a qualitative research approach and comprises three interrelated manuscripts exploring the barriers encountered by students with LD in learning science, and difficulties experienced by science instructors in teaching science to students with LD at Mountain CEGEP (Collège d'Enseignement Général et Professionnel). Drawing on Bronfenbrenner's ecological model as a theoretical lens, this dissertation offers a comprehensive examination of the interconnections between within-individual (i.e., internal) and environmental barriers faced by college instructors and students with LD in science education.

Rooted in autoethnography, the first manuscript explores my perspectives and experiences as a special needs educator and CEGEP biology instructor working with science students with LD and their instructors. Based on my interactions with students with LD, I document the challenges that they encountered in the CEGEP setting. As well, I share my views on the struggles faced by college science instructors in attempting to enact an inclusive environment to meet the needs of their students with LD. Manuscript one also critically analyzes and reflects upon dominant disability frameworks (i.e., medical and social models of disability) by drawing on my journey as a practitioner-researcher. Recognizing the limitations of both the medical and social models of disability in this analysis, I discuss the importance of drawing on Bronfenbrenner's (2005) ecological model to inform my practice in supporting students with LD and to conceptualize my doctoral thesis.

Manuscript two investigates the perspectives of 18 CEGEP science instructors on the challenges that they face while teaching students with LD both inside and outside of their classrooms. Data was gathered through individual semi-structured interviews, which were

subsequently analyzed through the constant comparative method. From the analysis, three overarching barriers emerged which include: instructors' insufficient knowledge and skills in teaching and supporting students with LD; lack of support in working with students with LD; and their difficulty in establishing relationships with students with LD.

Lastly, manuscript three examines the views of 11 CEGEP science students with LD on their difficulties in learning science. In addition to participating in semi-structured interviews, 5 of the 11 students participated in a photovoice project. Not only did they photograph artefacts and spaces that represented barriers they encountered in learning science, but they also engaged in writing journals and participating in individual semi-structured interviews for the photovoice project. Analysis of data revealed that students with LD faced the following barriers: learning difficulties due to their respective disabilities; perceptions of being academically disadvantaged in comparison to their peers; fast pace of instruction; undifferentiated teaching approaches; and lack of consistency and structure in teaching approaches.

Altogether, the findings from these three interconnected studies offer multiple perspectives on the barriers that exist for students with LD in college science classrooms, as well as issues experienced by science instructors in teaching students with LD. The implications of these findings for further research and practice are also discussed in each manuscript and remaining chapters of the thesis.

RESUME

La science est pour tout le monde, indépendamment de leur sexe, de leur origine culturelle, de leur situation sociale, ou de leurs buts professionnels (AAAS, 1993; Achieve Inc., 2013; CMEC, 1997; 2013; MELS, 2007). Pourtant, tous les étudiants n'ont pas la possibilité d'apprendre et de bien performer en sciences. Plus précisément, les élèves ayant des troubles d'apprentissage obtiennent des notes nettement inférieures comparativement à leurs pairs qui n'ont pas de troubles d'apprentissages dans les milieux primaire, secondaire, et postsecondaire au Canada. De plus, au Canada, les étudiants ayant des troubles d'apprentissage (TA) sont susceptibles au décrochage scolaire comparativement à leurs pairs n'ayant pas de TA. En sus d'êtres sous-représentées en sciences, les personnes atteintes des TA sont à risques d'être au chômage, et d'éprouver de la dépression et l'anxiété comparativement aux individus n'ayant pas de troubles d'apprentissage. Néanmoins, les études visant à comprendre et documenter les difficultés rencontrées par les étudiants ayant des TA au postsecondaires sont peu nombreuses. Il est essentiel de comprendre et documenter les obstacles que rencontrent les étudiants atteints de TA afin de concevoir des interventions efficaces visant à améliorer leur apprentissage en sciences.

Par conséquent, l'objectif saillant de cette thèse est d'explorer les difficultés rencontrées en sciences par les étudiants ayant des TA au collégial. Un autre objectif clé de cette recherche est d'étudier les obstacles rencontrés par les professeur(e)s en sciences collégiales dans l'enseignement et le soutien académique des étudiants ayant des TA. Il est bien documenté que ces enseignants jouent un rôle déterminant dans l'inclusion des élèves ayant des TA. De plus, les étudiants atteints de TA ont identifié les instructeurs au collégial comme étant au cœur de leur

réussite scolaire. Il est donc impératif que les défis auxquels sont confrontés ces instructeurs soient explorés et identifiés.

En adoptant une approche qualitative, cette thèse, qui comprend trois manuscrits interreliés, explore les obstacles rencontrés par les étudiants atteints de TA en sciences, et les difficultés rencontrées par les professeur(e)s en sciences pour enseigner et aider leurs étudiants ayant des TA au Cégep de la Montagne (Collège d'Enseignement Général et Professionnel). En s'appuyant sur le modèle écologique de Bronfenbrenner comme cadre théorique, cette thèse offre un examen détaillé des problèmes internes et environnementales auxquelles sont confrontés les instructeurs et les étudiants ayant des TA au collégial dans l'enseignement et l'apprentissage des sciences.

S'appuyant sur l'autoethnographie, le premier manuscrit explore les perspectives et les expériences de l'auteur en tant que pédagogue en éducation spécialisée et professeure en biologie au collégial. En me basant sur les interactions avec mes étudiants atteints de TA, je documente les défis rencontrés dans leur adaptation et apprentissage au collégial. De plus, je partage mon point de vue sur les difficultés auxquelles sont confrontés les professeur(e)s en sciences au collégial pour créer un environnement inclusif pour les étudiants ayant des TA. En lien avec mon expérience et parcours en tant que praticienne – chercheure, j'offre aussi une analyse critique des cadres théoriques tels que le modèle médical du handicap ainsi que le modèle social du handicap. Reconnaissant les limites des modèles médicaux et sociaux du handicap dans cette analyse, je discute de l'importance de s'appuyer sur le modèle écologique de Bronfenbrenner (2005) pour conceptualiser ma thèse de doctorat.

Le deuxième manuscrit examine les perspectives de 18 professeurs en sciences au collégial sur les défis auxquels ils sont confrontés lorsqu'ils enseignent aux élèves atteints de TA.

Les données ont été recueillies au moyen d'entrevues individuelles semi-structurées, qui ont ensuite été analysées par le biais de la méthode comparative constante. De l'analyse, trois obstacles généraux sont apparus, notamment : les connaissances et les compétences insuffisantes des instructeurs en matière d'enseignement et de soutien pour les étudiants ayant des TA; le manque de soutien pour travailler avec les étudiants atteints de TA; et des difficultés à établir des relations de travail productives avec les étudiants atteints de TA.

Le troisième manuscrit examine les perspectives de 11 étudiants ayant des TA sur leurs difficultés à apprendre les sciences en sciences au cégep. En plus de participer à des entrevues semi-structurées, 5 des 11 étudiants ont participé à un projet de photovoice. Non seulement ont-ils photographié des artefacts et des espaces qui représentaient des obstacles qu'ils rencontraient dans l'apprentissage des sciences, mais ils se sont également engagés dans la rédaction de journaux de bord et des entrevues individuelles semi-structurées pour le projet de photovoice. L'analyse des données a révélé que les élèves atteints de TA font face aux obstacles suivants : difficultés d'apprentissage en raison de leurs incapacités respectives; la perception d'être désavantagé sur le plan scolaire par rapport à leurs pairs; rythme rapide de l'instruction; approches pédagogiques indifférenciées; et le manque de cohérence et de structure dans les approches d'enseignement.

En somme, les résultats de ces trois études interconnectées offrent de multiples perspectives sur les obstacles qui existent pour les étudiants atteints de TA en sciences au collégial, ainsi que pour leurs enseignants. Les implications de ces résultats pour la recherche et la pratique sont également discutées dans chaque manuscrit.

Dedication

To my late grandmother – Deepwantee Bissessur
who taught me that life is about falling down, getting up no matter what, and battling our way through...

To my mother – Vijayalutchmee Bissessur-Gokool
who taught me that life is about resilience, persistence, courage, hardwork, ambition, dedication and following my dreams no matter how impossible they seem…

To my thesis advisor and mentor – Dr. Anila Asghar
who taught me about writing, embracing my difference and believing in my abilities…

To my daughters – Anya and Arya
who taught me about miracles and love…

To my students with special needs,
Never give up! Never let anyone tell you that you cannot do it!
Believe in yourselves and reach for the stars!

"Education is what remains after one has forgotten what one has learned in school."

- Albert Einstein

Acknowledgements

First and foremost, I am sincerely grateful and thankful to my thesis supervisor and mentor, Dr. Anila Asghar for her investment, dedication, commitment, and patience in supporting me to conceptualize, conduct, and write my doctoral research project. Dr. Asghar has always encouraged me to pursue my ideas and helped me in clarifying my perspectives whenever my ideas, thoughts, and views got blurry. Not only did I grow as a researcher and a writer under Dr. Asghar's supervision, I also matured in my reflections about research, teaching, and life – always learning new things from her. Dr. Asghar, you took me under your wings and supported me when no one would. You believed in my abilities, embraced my differences, and helped me re-build my self-confidence when I was completely shattered - this doctoral journey would not have been complete without you. I value all the years that I have spent working with you and learning from you.

I would also like to thank Dr. Carolyn Turner and Dr. Jessica Toste for helping me during my comprehensive exams. They were always available to answer my questions and help me in my reflections. I am also deeply indebted to my current committee members Dr. Ingrid Sladeczek and Dr. Julien Mercier for their continuous support towards my doctoral thesis. I am grateful for their insightful feedback on the initial draft of my thesis.

My deep appreciation goes to my colleagues and friends – Amy Eujin Kim and Elaine Ying Huang – who read drafts of my manuscripts, offered feedback, and supported me through their words of encouragement. I would also like to express my thanks to my colleagues: Constantinos (Costas) Yanniris and Heather McPherson for their encouragement and kind words whenever things seemed impossible. Thank you to Thomas Layton-Smythe for helping me edit my thesis.

I am deeply thankful to Dr. Lise Winer who has supported me in pursuing my doctoral studies during dark times when nothing seemed possible. A special thanks to Dr. Claudia Mitchell (who inspired me with autoethnography and visual methodologies), Dr. Susan Allnutt (who co-taught the class with Dr. Mitchell and offered constructive feedback on my assignments), Dr. Mela Sarkar (who taught me about annotated bibliography and how to craft a doctoral SSHRC proposal), Dr. Doreen Starke-Meyerring (who taught me about free writing and writing discourses), Dr. Lynn Butler-Kisber (who taught me about qualitative data analysis), Dr. Robert Savage (whose class inspired me to draw on Bronfenbrenner's ecological model for my thesis), and Dr. Karen Cohen-Gazith (who taught me about the nature of LD and how to best support students with LD in elementary settings). Overall, you inspired me and enriched my knowledge through your hands-on and insightful courses. Your courses helped me in conceptualizing and conducting my doctoral research study, and for that I am eternally grateful.

I am very grateful and thankful to Dr. Marta Kobiela for all her support since I entered the program. As a science graduate, my journey in adapting to DISE's ideologies was very hard but she supported me with your kind words of encouragement and discussed science/math educational theories with me. She also helped me in editing my SSHRC doctoral proposal. And in her role as GPD, she offered me the opportunity to teach a course in DISE, helped me get the signature from the chair when I needed to submit my thesis, and organized my doctoral defence.

I am also thankful to Mr. Michael Lariviere who is highly supportive of graduate students in DISE. He promptly answered my questions and helped me navigate through the doctoral program in DISE. I am grateful to Jennifer Wallace and Ms. Diane Rabey for their constant support, encouragement and smiles. Thanks to Uzma Majeed who helped me in applying for a small grant to fund activities in my classroom in DISE.

To all the students and instructors at Mountain CEGEP who participated in my study – thank you for your time and dedication towards my project. This endeavour would not have been possible without you. Through your participation in my doctoral study, you have contributed in deepening our understanding on disability-related issues in science education at the CEGEP level in Quebec.

My family has been an important part of this tumultuous journey. My mother – Vijayalutchmee Bissessur-Gokool – was my rock throughout my doctoral studies. She always listened to my worries and cheered me up. Her confidence in me and kind words motivated and inspired me to work hard and achieve the impossible. I am indebted to her for coming to Canada several times and taking care of my daughters and my home so that I can work to support my family and also write my thesis. My dad has also been a great source of support – always giving me good advice and comforting me when I felt lost.

My journey would not be complete without thanking some key family members who invested their time and energy in my studies. I would like to thank my late uncle Bhimsen Gokool who got me enrolled in primary school. My three cousins: Shivrani Ori, Indranee Ori, and Kiran Ori supported me through all the phases of my studies. By discussing with my cousin, Shivrani, I developed a love for plants and agriculture. I fell in love with English and writing because of time spent with my cousin Indranee discussing books and the literature. I am thankful to my aunt Kantee Gokool, who tutored me in various subjects when I was in primary school. An immense thank you to my aunt, Chitra Gokool, who tutored me in various subjects, and also supported in finding a job when I graduated from University. My uncle, Dharamveer Gokool, tutored me in English and I learnt so much from him. I am also grateful to my uncle, Dr. Dhuneeroy Vijay Bissessur, for spending time in helping me with biology at the college level.

I am grateful to be the recipient of the Fonds de recherche du Québec – Société et culture (FRQSC) doctoral research scholarship. I am also thankful to have received the Social Sciences Humanities Research Council (SSHRC) Doctoral Fellowship to pursue my doctoral studies. I would also like to highlight the financial support that I have received from the Faculty of Education, McGill University and the Department of Integrated Studies in Education.

Contribution of Authors and Notes on Writing Style

This doctoral thesis is grounded in a manuscript-based approach format, which has been written according to the guidelines offered by the Graduate Postdoctoral Study (GPS), McGill University. I have conceptualized each of the study (i.e., designed the research studies, formulated the research questions, selected the theoretical framework, recruited participants, conducted the data collection and analysis, interpreted the findings) and written this thesis in its entirety. I am the primary author of all the chapters including chapter 3 (Manuscript 1) which has been published in the journal titled: *Educational Research for Social Change*. Chapter 4 (Manuscript 2) is co-authored with Dr. Anila Asghar and has been published by the *Journal of Teaching and Teacher Education*. Manuscript 3 (Chapter 5) is in preparation for submission to the *Journal of Research in Science Teaching*. As my doctoral supervisor, Dr. Asghar has served in an advisory capacity throughout my doctoral journey and during the conceptualization of these studies, formulation of the research questions, refining of the themes during data interpretation for the manuscripts, and editing of the manuscripts. Dr. Asghar has also supported me to address reviewers' comments for Chapter 4 (Manuscript 2). In terms of writing style and as with every manuscript-based thesis, there is repetition in the text. Each manuscript has been conceptualized by focusing on the writing style suggested by the respective journals in which the manuscripts have been submitted. As such, the writing style of the manuscripts differs slightly from one another.

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Chapter 1: General Introduction

Research Problem and Study Objectives

The Learning Disabilities Association of Canada (2015, para 1–2) defines learning disabilities (LD) as follows:

> Learning Disabilities refer to a number of disorders which may affect the acquisition, organization, retention, understanding or use of verbal or nonverbal information. These disorders affect learning in individuals who otherwise demonstrate at least average abilities essential for thinking and/or reasoning. As such, learning disabilities are distinct from global intellectual deficiency. Learning disabilities result from impairments in one or more processes related to perceiving, thinking, remembering or learning. These include, but are not limited to: language processing; phonological processing; visual spatial processing; processing speed; memory and attention; and executive functions (e.g. planning and decision-making).

LD is one of the fastest growing types of disabilities in Canada with a 40 % increase in the number of Canadians aged 15 diagnosed between 2001 and 2006, (Learning Disabilities Association of Canada, 2018). Alarmingly, only 35.6 % of individuals with LD complete their postsecondary education as compared to 61.1 % of typically achieving individuals (Bizier, Till, & Nicholls, 2015). Students with LD are more likely to drop-out of postsecondary institutions as compared to their typically achieving peers (Bizier, Till, & Nicholls, 2015; Canadian Human Rights Commission, 2017). Moreover, individuals with LD are more vulnerable to social and employment issues (Bizier, Till, & Nicholls, 2015; Canadian Human Rights Commission, 2017). Studies have shown that Canadians with LD who have failed and dropped out from their educational institutions are less likely to be employed (Bizier, Till, & Nicholls, 2015; Shier, Graham & Jones, 2009) and are at higher risks of experiencing depression, negative moods, and feelings of loneliness (Bizier, Till, & Nicholls, 2015; Lackaye & Margalit, 2006; Wilson et al. 2009).

High drop-out rates among students with LD might indicate that the Canadian education system is failing to meet the needs of diverse learners. This is especially true for students with LD in Science, Technology, Engineering, and Mathematics (STEM) programs who are continuously and persistently lagging behind in comparison to their typically achieving peers (National Assessment of Educational Progress [NAEP], 2015; Street et al., 2012). In particular, postsecondary students with disabilities[1] — including those with LD — are more likely to be underrepresented and to drop-out of STEM disciplines as compared to students with disabilities in non-STEM programs in both the US and Canada (De Cesarei, 2014; National Science Foundation, National Center for Science and Engineering Statistics, 2017; Street et al., 2012; Thurston, Shuman, Middendorf, & Johnson, 2017). For example, a lower percentage of students with disabilities including those with LD (23.3 %) enrolled in undergraduate STEM disciplines (e.g., engineering, life sciences) as compared to a higher percentage of students with disabilities (76.5 %) who opted for non-STEM disciplines (e.g., business, education) (National Science Foundation, National Center for Science and Engineering Statistics, 2017).

As compared to typically achieving students, students with disabilities including those with LD tend to struggle more in STEM courses, where nearly 50 % of them obtained a grade of C+ or lower in general Chemistry (Street et al., 2012). Furthermore, as reported by De Cesarei (2014), the number of students in higher education who are willing to disclose their LD is significantly lower in the sciences than in the social sciences, which suggests that STEM disciplines might present unique challenges for postsecondary students with LD.

[1] Students with disabilities include those with physical disabilities (e.g., visually impaired students, those using wheelchairs); developmental disabilities (e.g., autism), learning disabilities (e.g., impairment in reading and written expression), and mental health issues (e.g., depression and anxiety).

In an effort to provide an equal and a fair education to all science learners—including those with LD—it is crucial to understand their difficulties and stressors in accessing science instruction and in becoming scientifically literate. Unfortunately, research on barriers affecting the engagement, learning, and academic achievement of science students with LD has been overlooked in the science and the special needs literatures as shown in Table 1. For example, Martínez-Álvarez (2017) deplores the lack of research in the teaching and learning processes for students with LD in science fields such as geosciences. In the same vein, Koomen (2016, p. 322) also highlights that the perspectives of students with LD are “not found in the current literature” and stories of students with LD on their learning experiences and ways to best support their journey in the sciences are lacking. Similarly, Trauth-Nare (2016) argues that students with LD have received little attention in the science education literature, and as such, their needs are not being effectively met in mainstream science classrooms.

Most recently, Murtaza (2018) discussed that the viewpoints and experiences of Canadian science students with LD with regards to learning science have been neglected in the literature surrounding science and special needs education. In his doctoral thesis, Murtaza (2018) interviewed Canadian undergraduate students (n = 8) with LD to document their experiences in learning science in mainstream high school science classrooms. To the best of my knowledge, Murtaza (2018) is the first comprehensive study to report that Canadian high school science students with LD experience major barriers in understanding their LD, and employing strategies to overcome their issues in learning science.

Additionally, I conducted an extensive literature search in various databases, and individual science and special needs education journals, and reached to the conclusion that research on difficulties faced by science students with LD at the elementary, high school, and postsecondary levels, especially in CEGEP[2] institutions is sparse to non-existent. Specifically, I searched various databases (e.g., PsycInfo; ERIC) and individual journals in the fields of science and special needs education (e.g., Journal of Learning Disabilities, Remedial and Special Education; Journal of Research in Science Teaching; Cultural Studies in Science Education; Journal of Postsecondary Education and Disability; amongst others). I used various key terms namely: “learning disabilities”; “difficulties”; “barriers”; “issues”; and the search yielded very few articles that are relevant to barriers experienced by students with disabilities (including those with LD). In Table 1, I present some of the results that yielded from searching the literature in specific journals on students with LD and their associated difficulties in learning. As shown in Table 1, most of the peer-reviewed articles spanning from 1990-2019 focused majorly on strategies employed in teaching students with disabilities including those with LD.

It is alarming to note that research on issues faced by students with LD has not been well-documented in both science education journals (e.g., Journal of Research in Science Teaching; Cultural Studies in Science Education) and special needs education journals (Remedial and Special Education; and Journal of Learning disabilities). For example, in the Journal of Learning Disabilities, over the past 30 years, only 11 out of 121 articles (i.e., less than 1%) depicted barriers experienced by students with disabilities in classroom settings, excluding students with LD in STEM. Alarmingly, in the Remedial and Special Education journal, only 10 out of 230 articles (i.e., less than 1%) focused on barriers for students with disabilities in various areas excluding STEM education. Research on students with LD in STEM fields is even sparser in science education journals as compared to special education journals. For instance, out of the 21

[2] After completing Grade 11 at secondary schools, students have the opportunity to attend CEGEPs, which are colleges that offer two-year pre-university programs, three-year career programs, and technical programs in Quebec (Jackson, 2013).

articles on disabilities that emerged from the peer-reviewed journal Cultural Studies in Science Education, only 3 documented barriers faced by elementary and high school students in science learning. While reviewing articles in the Journal of Research in Science Teaching, none of the 20 studies explored barriers experienced by science students with LD. Overall, across these four journals, out of a total of 392 peer-reviewed manuscripts, only 24 (i.e., less than 1%) focused on difficulties experienced by students with disabilities (sometimes excluding students with LD and STEM education) in elementary and high school classrooms.

It is worthwhile to note that a higher percentage of studies (i.e., 34 % in Remedial and Special Education journal, and 24 % in the Journal of Learning Disabilities) have focused on intervention-based practices to improve the learning and academic achievement of students with disabilities; rather than exploring the issues experienced by these learners in their engagement and learning of taught concepts.

Yet, the interventions for science students with disabilities have yielded inconsistent results. For example, four studies (i.e., Mastropieri, Scruggs, & Graetz, 2003; Mastropieri et al., 2006; McDuffie, Mastropieri, & Scruggs, 2009; Simpkins, Mastropieri, & Scruggs, 2009) employed almost identical game-based learning techniques in their peer-tutoring intervention-based strategy to improve the learning outcomes for science students with LD. Yet, out of these four studies, only one study (Mastropieri, Scruggs, & Graetz, 2003) has reported significant improvement in the academic achievement of science students with LD. For one study (i.e., Mastropieri et al., 2006), there was no significant improvement in the academic achievement of science students with LD as compared to their typically achieving peers. For the other two studies (i.e., Simpkins, Mastropieri, & Scruggs, 2009; McDuffie, Mastropieri, & Scruggs, 2009), the findings were inconsistent such that science students with LD (i.e., Simpkins, Mastropieri, &

Scruggs, 2009; McDuffie, Mastropieri, & Scruggs, 2009) tended to perform as well as their peers on certain assessments (e.g., immediate recall tests) but not others (e.g., end-of-year exams).

It is to be noted than none of these studies have attempted to identify the specific learning issues encountered by the students with disabilities participating in the interventions. It is reasonable to assume that intervention-based practices in science education were not successful because researchers could not fully understand the unique challenges that science students with LD faced in their everyday science classrooms. As argued by Mulvey, Chiu, Ghosh, and Bell (2016), most of these intervention-based studies were completed more than a decade ago, "leaving much unexamined with respect to science instruction for students with special needs" (p. 555). Therefore, future intervention-based studies are much warranted in STEM classrooms to support science students with LD in their learning; but these future studies need to fully investigate the barriers faced by students with LD before designing intervention-based strategies to improve science learning.

Table 1. Analysis of peer-reviewed studies on exploration of barriers faced by students with LD in learning

Peer-reviewed Journals	Years	Total number of articles	Barriers faced by SWD	Barriers and strategies in career de for individuals with disabilities	Barriers and strategies to support teachers, schools, and parents in working with SWD	Teaching strategies for SWD	Theoretical, political, legal, ethical, historical, medical, aspects of disabilities	Studies not focusing on SWD[3]
Journal of Learning Disabilities	1990 - 2019	121	11	6	20	32	46	6
Remedial and Special Education	1990-2019	230	10	5	55	77	51	32
Journal of Research in Science Teaching	1990-2019	20	0	0	5	0	0	15
Cultural Studies in Science Education	2006-2019	21	3	0	0	4	0	14

Because barriers experienced by science students with LD have not been well-explored, our understanding of the issues faced by students with LD in STEM fields is limited. As such, this thesis explores the complexity of barriers affecting the engagement and learning of students with LD in science. Sánchez (1999, p. 351) also emphasizes the need to "give voice to the unheard stories of voiceless communities" alike students with LD, whose voices have been overlooked and need to be heard especially on critical issues impacting their journeys in science classrooms (Koomen, 2016; Martínez-Álvarez, 2017; Murtaza, 2018; Trauth-Nare, 2016). As pointed out by Koomen (2016, p. 323), science students with LD "are experts in their own learning", and their voices are crucial in informing science educators and researchers about "ways that we might encourage, mentor, and support" their learning in STEM programs. Such is the case in this thesis, which values the voices of students with LD and views them as experts in

[3] These studies focused on English Second Language learners, gender, cultural, and ethnic differences between diverse learners.

their learning. In sum, by developing a comprehensive understanding of the barriers experienced by CEGEP students with LD, researchers might explore effective measures to address the barriers, and support students' engagement, learning, and academic achievement within the sciences.

Instructors are instrumental in facilitating the inclusion of students with disabilities including those with LD within the classroom settings and in ensuring their academic success (Hansen, 2013; Havel, Raymond, & Dagenais, 2017; Jenson, Petri, Day, Truman, & Duffy, 2011; Nguyen, Fichten, Barile, & Levesque, 2006; Stegemann, 2016). In a study conducted by Jenson and colleagues (2011), college students with disabilities including those with LD in STEM voiced that science instructors have "the most impact on their ability to experience success" in their courses (p. 275). One study which looked at the experiences of CEGEP students with disabilities including those with LD in Quebec identified college instructors as being the most significant factor in determining their academic success (Nguyen, Fichten, Barile, & Levesque, 2006). As such, it is crucial to examine the challenges faced by CEGEP science instructors in teaching and supporting their students with LD. Yet, very few studies have explored the difficulties experienced by science instructors in teaching their students with LD. For instance, none out of the 21 articles in the Cultural Studies in Science Education journal explored science instructors' views in teaching students with LD.

As such, one objective of this thesis is to also gather the views of CEGEP science instructors on the barriers that make teaching science students with LD a challenging task for them. By documenting the difficulties experienced by science instructors in making science accessible for students with LD, effective strategies and solutions can be explored to support instructors in teaching diverse learners effectively. For example, science instructors might lack the knowledge and skills to adapt science instruction for their students with LD. As such, future research could focus on exploring useful strategies to supporting instructors in designing and implementing better pedagogical practices to meet the needs of their students with LD.

Overall, examining the teaching and learning barriers that students with LD encounter in STEM disciplines is meaningful for science instructors, special needs educators, college administrators, service providers, policy makers, and science and special education researchers. Therefore, this thesis seeks to: (a) explore the barriers experienced by CEGEP science students with LD in learning science, and (b) investigate the difficulties faced by college science instructors in teaching students with LD. Most specifically, this thesis focuses on the following research questions: (a) *What types of barriers do college students feel they encounter in learning science?* (b) *In what ways do they think these barriers impact their learning and success in college science programs?* (c) *What types of barriers do college science instructors believe that they experience in teaching and supporting their students with LD?* (d) *What challenges do science teachers feel they face in providing academic assistance to their students with LD outside of the classroom setting and during office hours?*

In line with the above research questions, this thesis is centered in capturing the “insider” views of the participants and is committed to document their unique perspectives, their multiple constructed realities, their emotions, their heartfelt dilemmas, and their innermost turmoil surrounding challenges in teaching and learning practices for science students with LD. As such, a qualitative research approach has been adopted to explore the above research questions. Qualitative research is geared towards answering questions “about experience, meaning and perspective, most often from the standpoint of the participant” (Hammarberg, Kirkman, & de

Lacey, 2016, p. 499) which is well-suited to explore the research questions for this thesis. The qualitative approach is further described in later sections of this thesis.

In the following sections, I begin by describing and discussing the theoretical framework informing the study. I also discuss the research setting in which the study took place. Then, I describe the participants who took part in the study, followed by an outline of the methodology that informed and guided my doctoral thesis. Next, I offer an overview of the data collection techniques employed to collect the participants' views on disability-related issues at the CEGEP level. Lastly, I offer a summary of Chapters 3 (Manuscript 1), 4 (Manuscript 2), and 5 (Manuscript 3).

Bronfenbrenner's Ecological Model: Overarching Framework

To better understand the complex interactions between teachers, students with LD, and special needs educators on barriers impacting science teaching and learning at the CEGEP level, I drew on Bronfenbrenner's (2005) process-person-context model. The process-person-context model involves three interconnected spheres: "(a) the context in which an individual's development is taking place; (b) the personal characteristics (biological or psychological) of the persons present in the context; and (c) the process through which their development is brought about" (p. 78; italics in original). The tenets of Bronfenbrenner's ecological model (2015) are discussed in Chapter 3 of this thesis. In this section, I highlight the ways in which Bronfenbrenner's ecological model (2015) informed previous research endeavours. I also focus on the importance of Bronfenbrenner's ecological model (2015) in allowing researchers to explore different ecological systems that impact human development.

Bronfenbrenner's ecological model has previously been used as a theoretical and analytical lens in both empirical and non-empirical studies (i.e., reviews of literature) across various areas including education, nutrition, sexual and reproductive health, youth violence, and cyberbullying (Brunsting, Sreckovic, & Lane, 2014; Cross et al., 2015; Curtis et al., 2015; Hodges, Smith, Tidwell, & Berry, 2013; Hong, Huang, Sabri, & Kim, 2010; Pilgrim & Blum, 2012; Ruppar, Allcock, & Gonsier-Gerdin, 2017; Strayhorn, 2010; Sugimoto-Matsuda & Braun, 2013). Researchers, employing Bronfenbrenner's ecological model in their studies, argued that it is a robust and multi-conceptual framework which can be used to interpret interconnected social and individual factors shaping human development (Brunsting et al., 2014; Cross et al., 2015; Curtis et al., 2015; Ruppar et al., 2017; Strayhorn, 2010). Bronfenbrenner's ecological model allows for a comprehensive and detailed analysis of various interrelated systems spanning from "individual level variables (e.g., age, gender), classroom level variables (e.g., student disability, challenging behaviour), school level variables (e.g., administrative support, workload), and state and district level variables (e.g., preservice training, salary)" affecting students' development (Brunsting et al., 2014, p. 687). By analyzing the systemic factors impeding students' academic development, researchers are better positioned to develop effective strategies to better address these issues across all the ecological systems.

In their recent critical literature review, Ruppar and colleagues (2017) sought to analyze the factors which facilitated or inhibited students' with disabilities access to general school curriculum by using Bronfenbrenner's ecological model as a theoretical lens. Analyzing relevant empirical studies, the researchers categorized each variable affecting students' access to education within Bronfenbrenner's micro-, meso-, exo-, and macrosystems (Ruppar et al., 2017). For example, within the microsystem, variables such as students' disability types and students' social interactions (i.e., with special education teachers, paraprofessionals, and other peers) were shown to either restrict or facilitate student inclusion within the classroom.

Within the mesosystem, Individualized Education Plan (IEP) team members (i.e., teachers, parents, paraprofessionals) interact with students with disabilities within different microsystems (i.e., teachers and paraprofessionals interact with students in the classroom, while parents interact with students at home). The IEP team members play a crucial role in determining the students' needs and appropriate accommodation provisions. Power dynamics between the IEP team members (teachers vs. parents) can either positively or negatively impact the academic supports and accommodations offered to the students with disabilities.

Within the exosystem, teachers' experiences, education, and prior knowledge about inclusion of students with disabilities also affect students' learning and academic progress. Finally, the macrosystem—which involves policies and laws relating to inclusive practices and rights for students with disabilities—also affects equitable access to curricula for these students, as compared to their typically achieving peers. In summary, Ruppar and colleagues (2017) offer a comprehensive portrait of the ways in which within-individual and contextual barriers operating from within different subsystems impact the academic success of students with disabilities.

Bronfenbrenner's ecological model has also been used in empirical studies which illuminate some of the issues faced by other minority groups such as African American students. In Strayhorn's (2010) study, the author sought to explore the factors affecting African American high school students' (n = 1, 7666) achievement in mathematics. Strayhorn (2010) drew on Bronfenbrenner's ecological model to construct a richer and more complex portrait of multiple, interconnecting within-individual and contextual factors which affect math achievement for African American students (Strayhorn, 2010). After analyzing the survey data, Strayhorn (2010) concluded that within individual factors—namely gender and environmental factors (such as parental involvement and teachers' perceptions)—were influential in determining math achievement for African American students.

Other researchers have also drawn on Bronfenbrenner's ecological model to inform their studies on teacher education (Cross & Hong, 2012; Haritos, 2004; Lopez & Pereira, 2012). In her classical study, Haritos (2004) examined pre-service teachers' (n = 47) views and highlighted the numerous challenges they experienced during their field placements and in their teacher education program courses at their respective universities. The author categorized the challenges experienced by these instructors within the micro-, meso-, and macrosystems of Bronfenbrenner's (2005) ecological model to illustrate the complexity of barriers affecting their teaching career, and offer strategies to mitigate the resulting difficulties in each system. For example, barriers identified by pre-service teachers within the microsystem (i.e., the classroom) included a lack of teaching supplies and overcrowding in classrooms. Low parental involvement emerged as a mesosystemic barrier, since not all parents cooperated with teachers in applying appropriate disciplinary measures within the home environment for students who had been misbehaving in class. Other stressors — such as a lack of school funding and low teacher salaries — were categorized as macrosystemic challenges discouraging pre-service teachers from embarking into the teaching profession.

Unfortunately, to my knowledge, no study has drawn on the ecological model to explore within-individual and contextual barriers impacting the learning, engagement, and academic achievement of students with LD in science education. Yet, as evidenced by various studies, Bronfenbrenner's ecological model invites researchers to depict a comprehensive and complete picture of the within-individual and environmental factors affecting human development (Brunsting, Sreckovic, & Lane, 2014; Cross et al., 2015; Curtis et al., 2015; Hodges, Smith, Tidwell, & Berry, 2013; Hong, Huang, Sabri, & Kim, 2010; Pilgrim & Blum, 2012; Ruppar, Allcock, & Gonsier-Gerdin, 2017; Strayhorn, 2010; Sugimoto-Matsuda & Braun, 2013). Therefore, I draw on Bronfenbrenner's ecological model as a lens to inform my doctoral study. In the next section, I discuss the ways that Bronfenbrenner's ecological model informed my doctoral study.

Applying Bronfenbrenner's Ecological Model in my Doctoral Study

As discussed in Chapter 3, Bronfenbrenner's ecological model was revolutionary in transforming my teaching practice to comprehend barriers experienced by students with LD, and to meet their particular academic needs. While working closely with students with LD, it became even more apparent that the issues they experienced encompassed a multitude of within-individual and contextual factors, which are embedded within a multi-layered web of complexity. As evident in Amber's case, Bronfenbrenner's ecological model permitted me to map all the possible barriers that a student with LD might experience in a learning situation.

Situating students with LD at the heart of Bronfenbrenner's ecological model allowed me to discuss the role of within-individual issues, and contextual (i.e., environmental and social) issues, as well as depicting the intersections between individual and contextual barriers that negatively affected students' pursuit of scholarship within the sciences. Moreover, utilizing the ecological model allowed me to move away from traditional theoretical approaches (i.e., medical and social models of disability) used in previous research inquiries that explore a limited range of factors located at either the within-individual or contextual levels instead of attempting to explore barriers across ecological systems. Bronfenbrenner's ecological model transcends the medical model of disability which attributes issues experienced by students with LD exclusively to their within-individual deficits (i.e., their learning disabilities), as well as the social model of disability which focuses only on environmental and social issues experienced by students with LD (Lindsay, 2005; Terzi, 2004).

Within the microsystem of Bronfenbrenner's ecological model, instructors play an influential role in shaping and supporting the learning process of science students with LD. In the present inquiry, Bronfenbrenner's ecological framework invites us to consider that barriers experienced by science instructors in regards to teaching and enacting support mechanisms for students with LD might stem from various subsystems (e.g., science classrooms, administration unit, amongst others). By employing Bronfenbrenner's theoretical framework for my study, teachers' perspectives on the barriers stemming from the college setting as a whole were gathered; this distinguishes the present study from past literature, which focused exclusively on barriers within only one microsystem—the science classroom—impeding science teachers' practices with their students with disabilities (Norman, Caseau, & Stefanich, 1998; Mumba, Banda, Chabalengula and Dolenc 2015).

In my role as a CEGEP instructor, I have become an agent of change, bringing about transformations within classroom settings and during one-on-one tutorial sessions with my students. These progressions were only attainable once I employed Bronfenbrenner's (2005) ecological model to analyze the barriers, which were preventing me from facilitating a just and equitable science education for my diverse learners. Similarly, in my doctoral thesis, I invited CEGEP science instructors to share with me their issues in teaching and supporting students with LD. By examining teachers' perspectives on their struggles in teaching science students with LD—in addition to analyzing the barriers encountered by these students in learning science—the present thesis deconstructs the multi-layered and interwoven tapestry of teaching and learning barriers associated with science education at the CEGEP level.

Research Setting: Mountain CEGEP

The research study took place in a CEGEP (pseudonym: Mountain CEGEP) located in Montreal, Quebec. After completing Grade 11 in their secondary schools, students have the opportunity to attend CEGEPs, which are colleges that offer two-year pre-university programs, three-year career programs, and technical programs (Jackson, 2013). Most CEGEPs offer pre-university programs in health sciences, pure and applied science, social sciences, and art. Science-related career and technical programs include nursing, dental hygiene, respiratory and anaesthesia technology, agricultural sciences, and pre-hospital emergency care.

Programs offered at the CEGEP level (including at Mountain CEGEP) are grounded in a competency-based approach with competencies being defined as “complex situational skill[s] that rel[y]… on the effective deployment and combination of a variety of internal and external resources within a given family of situations” (Côté, 2012, p. 2; Tardif, 2006). The “deployment and combination of a variety of internal and external resources” include “adapting, generating ideas, making choices, acting independently, showing sound judgement, seeking out solutions, [and]… justifying one’s ideas” when confronted with a challenging learning activity (Côté, 2012, p. 2). Science activities and projects at the CEGEP level require students to draw on five competencies relevant for college education in Quebec: problem solving (i.e., analyzing a situational problem, testing possible solutions to solve the problem, and using a flexible approach to solve the problem), exercising creativity (i.e., being open to multiple ways to make sense of a situation or solve a problem, and being able to adopt diverse strategies in doing so), adapting to new situations (i.e., using relevant prior knowledge and strategies to solve new problems), exercising a sense of responsibility, and communicating effectively (i.e., demonstrating knowledge about different modes of communication and how to use them appropriately) (Côté, 2012). An example of a competency-based learning activity might include CEGEP students in science classes undertaking an independent project of their choice, wherein they need to formulate research questions, generate hypotheses, make predictions, decide upon methodologies, collect and analyze data, and discuss their findings (Côté, 2012).

Acquiring these above-mentioned competencies can be particularly challenging for students with disabilities including those with LD. Empirical studies have demonstrated that science students with LD encounter significant difficulties in retrieving prior knowledge, in using critical thinking and reasoning, in generating hypotheses, in making predictions, and in applying constructed knowledge to new contexts, as compared to their typically achieving peers in science classrooms (Mastropieri, Scruggs, Boon, & Carter-Butcher, 2001; Scruggs & Mastropieri, 1994; Scruggs, Mastropieri, Bakken, & Brigham 1993; Therrien, Benson, Hughes, & Morris, 2017).

Despite the challenges they experience in the sciences, many students with disabilities[4] including those with LD decide to enroll in CEGEP science programs and pursue science careers. To enroll in a CEGEP science program, a student must have a score greater than 70 % in chemistry, physics, and mathematics at the secondary level. If the student does not meet the academic requirements to be accepted in their selected programs, they have the option to enroll in a 1-2 semester(s) pathway program, designed to support them in obtaining the relevant prerequisites required for the program of their choice. Based on my experience as a special needs educator and biology instructor at the CEGEP level, and those of my colleagues in the Office for Students with Disabilities (OSD), students with disabilities at Mountain CEGEP tend

[4] Unfortunately, in Quebec, the literature tends to mainly focus on students with disabilities (i.e., those with LD, developmental disabilities, mental health issues) and does not specify difficulties experienced by students with LD. For this reason, in the following sections, I discuss issues surrounding disability at the CEGEP level by referring to students with disabilities including those with LD.

to enroll in pathway programs because they lack the pre-requisites needed to be directly accepted in the science programs. After 1 - 2 semesters in the pathway programs, most of the students with disabilities meet the requirements for the science programs.

Once enrolled in the program of their choice, students with disabilities are eligible to apply for reasonable accommodation at the CEGEP. The *Commission des droits de la personne et des droits de la jeunesse,* under the Charter of Human Rights and Freedom (1976), defines reasonable accommodation as a "means used to put an end to any situation of discrimination based on disability, religion, age, or any other ground prohibited by the Charter" (para 1). Since providing reasonable accommodation is an obligation, employers and service providers are mandated by law to explore and implement strategies and solutions (e.g., adapting a practice, granting an exemption to a person facing discrimination) so that individuals can fully exercise their rights to participate equitably within society (Commission des droits de la personne et des droits de la jeunesse, 2012). The *Commission des droits de la personne et des droits de la jeunesse* (2012) recommends the provision of necessary learning tools for students with learning disorders as a means of accommodating their academic needs.

As highlighted by Ministère de l'Éducation et de l'Enseignement supérieur [MEES] (2018), accommodations provided to students with disabilities including those with LD in secondary schools are similar to those offered within various college settings including Mountain CEGEP. Examples of possible accommodation measures offered to students with disabilities at Mountain CEGEP as well as other CEGEPs in Montreal include: extra-time for tests and exams, the use of a quiet room to take tests and exams, extensions of deadlines for assignments, specialized equipment and software (e.g., dragon naturally speaking software), remedial tutoring, and support in reviewing learning strategies, and effective working methods (MEES, 2018).

After these students' psychoeducational reports or medical notes are evaluated and their needs are assessed, appropriate accommodations are put in place by the office for students with disabilities (OSD) staff, in collaboration with each student at Mountain CEGEP. With permission from the students, OSD staff members at Mountain CEGEP are mandated to inform class instructors via email or internal mail of the students' accommodations. Under no circumstances should OSD staff members disclose the disability of the students to CEGEP instructors unless consent and authorization are provided—in writing—by the students. It should be noted that, in Quebec, the *Charter of Human Rights and Freedoms* ensures the protection of the individuals' right to privacy, such that their disabilities are not to be disclosed unless authorized by the individuals (Bouchard & Leblanc, 2016). Human rights legislation for individuals with disabilities will be further discussed in Chapters 2 and 3.

Bouchard and Leblanc (2016) indicate that college students with disabilities in Quebec are unwilling to have their disabilities disclosed based on their concern that their classmates might feel that they are receiving a preferential treatment in the form of special accommodations. Moreover, in my experience as a special needs educator and those of my colleagues in the OSD at Mountain CEGEP, many students with disabilities including those with LD expressed concerns about their instructors' negative perceptions and prejudices in regards to their disabilities. Consequently, these students were hesitant in sharing their diagnosis with their instructors.

In Mountain CEGEP, including other CEGEPs, college instructors face numerous challenges in meeting the unique needs of students with disabilities including those with LD. For instance, when Quebec college instructors receive accommodation letters from the OSD office, many of them raise questions in regards to the appropriate accommodation measures for students with disabilities. These questions are as follows:

> Do [CEGEP instructors] have to give more time for assessment? Do [CEGEP instructors] have to allow students to be evaluated outside of the classroom? Do computerized spell checkers and help with revision not actually give to disabled students an edge? How should [CEGEP instructors] react when students seem not to understand the material or finish their exams much later than their classmates? (Beaumont & Lavallée, 2012, p. 2).

The above questions posed by CEGEP instructors in Quebec seem to indicate that they might not fully comprehend the concept of disability and the legal obligations to accommodate students with disabilities. Even more alarming, these instructors might not be adequately prepared to provide appropriate learning supports to their student with disabilities including those with LD. In my experience as a special needs educator advocating on behalf of students with disabilities including those with LD, many instructors at the CEGEP level often express discomfort and confusion in providing accommodation and learning supports for their students with disabilities including those with LD.

As highlighted by Beaumont and Lavallée (2012), CEGEP instructors in Quebec require a better understanding of disabilities including those with LD, information on their students' disabilities, training and support to work with such students, and the opportunity to collaborate with other members (e.g., staff from the OSD) of the college to enact inclusive practices and accommodations for the students. Among potential intervention-based strategies, CEGEP instructors have expressed the need to be involved in determining appropriate accommodations for students with disabilities including those with LD, given that they are responsible for teaching courses and assessing students (Bouchard & Leblanc, 2016).

In summary, disability-related issues at the CEGEP level are complex, and as such, many CEGEP instructors possess insufficient knowledge concerning the most effective means of responding to the needs of their students with disabilities including those with LD. Yet, some Quebec CEGEP instructors are motivated to receive training and to work towards supporting their students (Beaumont & Lavallée, 2012; Bouchard & Leblanc, 2016). On the other hand, some CEGEP instructors argue that accommodating students with disabilities including those with LD (e.g., offering outside-class support and assessment) significantly increases teacher workloads, and suggest that instructors should be remunerated for this additional work (Bouchard & Leblanc, 2016). Furthermore, CEGEP students with disabilities including those with LD in Quebec are reluctant to share their specific diagnosis due to concerns surrounding possible stigma and prejudice (Bouchard & Leblanc, 2016).

Participants

A total of 29 participants (18 college science instructors and 11 students with LD) took part in this research. The science instructors were from the departments of biology (n = 7), chemistry (n = 6), and physics (n = 5), and each had more than five years of experience working at Mountain CEGEP. The 18 college science instructors had some familiarity in teaching students with LD. The science instructors either possessed a Master’s or doctoral degree in the subject area that they were teaching. The profiles (e.g., level of education, gender) of the science instructors are detailed in Chapter 4.

The 11 science students who participated in this research study were diagnosed with multiple learning disabilities including: impairment in reading and written expression, impairment in mathematics, dysorthographia, and auditory processing disorders. In most cases, these students’ learning disabilities occurred comorbidly with attention deficit disorder (ADD), or attention deficit hyperactivity disorder (ADHD), and some also experienced anxiety issues and panic attacks in addition to their LD. The students' diagnoses and characteristics (e.g., gender) are further described in Chapter 5. The students participated in semi-structured interviews as well as photovoice projects which are detailed in Chapter 5 of this thesis.

Prior to the research study, I worked closely with the 18 science instructors and 11 students as a special science and math educator since 2009. I informed teachers about the accommodations (e.g., extra time on tests and exams, access to computers and software such as dragon naturally speaking, scribes, and note-takers) that their students were eligible to have on the basis of their special needs. I also made myself available for any questions they might have about their students who required accommodations. As part of my role, I also met with the instructors on a regular basis to discuss the most effective approaches in teaching students with LD in science. During these meetings, the instructors shared issues they had been experiencing in effectively teaching students with LD, and I was able to offer strategies on how to best work with these students so as to support them in learning the material.

As a special needs educator in science and mathematics, I first met the 11 students when they came to register for their accommodation at the office for students with disabilities (OSD) during the fall semesters of 2011/2012 and 2013/2014. My first meetings with them consisted of reviewing their psycho-educational reports and letters from their psychologists, which were employed in determining the accommodations which would meet their specific needs. Additionally, I was also responsible to offer remedial tutorials to the students in biology, chemistry, physics, and mathematics courses. Throughout the semester, I also had weekly meetings with them on study skills and time management strategies. In 2013, I invited them to participate in my study so as to develop a comprehensive understanding of their struggles as science learners at the CEGEP level. Overall, I was able to establish good working relationships with the participants.

General Methodology

This thesis drew on a qualitative research approach to explore the perspectives of science students with LD and their instructors regarding the barriers they experience in learning and teaching science respectively. The qualitative approach focuses on exploring, understanding and interpreting the experiences of participants as meaning-making agents, and aims towards in-depth and comprehensive understandings of social phenomena (Barnes & De Beer, 2003; O'Neil & Koekemoer, 2016; Steynberg & Veldsman, 2011).

The present study draws on the constructivist-interpretivist paradigm, which makes sense of, "the world as constructed, interpreted, and experienced by people in their interactions with each other and with wider social systems" (Fleming, Glass, Fujisaki, & Toner, 2010; Kelly, Dowling & Millar, 2018; O'Neil & Koekemoer, 2016; Ponterotto, 2005; Tay, Chan, Vogt, & Mohamed, 2016; Tubey, Rotich, & Bengat, 2015, p. 224; Tuli, 2010, p. 100). In particular, this study draws on participants' views and mindsets to gain insight into the meaning they attribute to their experience with disability-related issues in their social world (i.e., within their CEGEP setting) (Fleming et al., 2010; Kelly, Dowling & Millar, 2018; O'Neil & Koekemoer, 2016; Ponterotto, 2005; Tay, Chan, Vogt, & Mohamed, 2016; Tubey, Rotich, & Bengat, 2015, p. 224; Tuli, 2010, p. 100). Specifically, I am interested in understanding the ways in which my participants attribute meaning to, and make sense of disability-related issues that impact their teaching and learning practices at the CEGEP level. In the following, I explain the tenets of the social constructivist lens in addition to the interpretivist lens, and discuss how the social constructivist - interpretivist lens has shaped the conceptualization of this research.

Social constructivism views reality as socially, culturally, and temporally constructed such that individuals shape subjective meanings of their experiences as they navigate their social world (Creswell, 2013; Crotty, 1998; Kelly et al., 2018; O'Neil & Koekemoer, 2016; Ponterotto, 2005; Tubey et al., 2015; Tuli, 2010). In particular, constructivism "points up to the unique experience of each of us" and highlights that "each one's way of making sense of the world is as valid and worthy of respect as any other" (Crotty, 1998, p. 58). Therefore, meanings constructed by individuals about social phenomena are complex, varied, and multidimensional (Creswell, 2013; Crotty, 1998; Kelly et al., 2018; O'Neil & Koekemoer, 2016; Ponterotto, 2005; Tubey et al., 2015; Tuli, 2010). According to social constructivism, individuals construct their own realities, and these multiple realities co-exist within our social world (Ponterotto, 2005). These multiple realities, which are partly constructed through interactions between the researcher and research participants, are subjective and are affected by the context (i.e., individuals' unique experience and perceptions, and the social environment) (Ponterotto, 2005).

Drawing on the tenets of social constructivism discussed above, each participant (i.e., teacher and student) taking part in my doctoral study has constructed their own unique reality based upon their own experiences regarding disability-related issues. Each of their uniquely constructed meanings is considered as significant and valid. In other words, I value the perspectives of each of my participants on the ways that disability-related issues affected their practices in CEGEP settings. For example, some teachers might have worked with students who have reading disabilities. Yet, each of these teachers has constructed their own unique view on their issues in teaching students with reading disabilities. While for one teacher, issues encountered might relate to an insufficient knowledge of differentiated teaching strategies in supporting students with reading disabilities to learn science. For another teacher, the issue encountered might be in constructing a meaningful working relationship with the student with LD in the science classroom.

Similar to constructivism, interpretivism "views reality and meaning making as socially constructed" and suggests that people construct their own meaning of their social realities (Tubey et al., 2015, p. 225). Interpretivism mainly focuses on "culturally derived and historically situated interpretations of the social world" (Crotty, 1998, p. 67). As discussed by Kelly and colleagues (2018, p. 3), interpretivism aims to achieve a subjective interpretation of lived experiences such that the role of the researcher is to act as an interpreter of the meanings ascribed by participants to the social phenomena being investigated (O'Neil & Koekemoer, 2016). In line with the tenets of interpretivism, I undertook the role of the interpreter by analyzing participants' processes of meaning-making about their views on disability-related issues. I analyzed and interpreted the issues experienced by the participants as within-individual and environmental barriers, which is in line with Bronfenbrenner's ecological model as detailed in Chapters 3 and 5.

In sum, constructivist-interpretivist researchers believe that each participant constructs his/her own unique reality as he/she interacts in their social world. Since, there is no single truth, each reality, constructed by the researcher and individual participant, is unique and meaningful, and multiple realities co-exist in the social world (Ponterotto, 2005; Tubey et al., 2015; Tuli, 2010). In the constructivist-interpretivist paradigm, the researcher's own realities, values, daily experiences, and interactions with participants form an integral part of the research process and need to be acknowledged and described as well (Creswell, 2013; Crotty, 1998; Ponterotto, 2005; Tubey et al., 2015; Tuli, 2010). My experiences, as a special needs educator and college biology instructor, have allowed me to construct and interpret my views regarding disability-related issues at the CEGEP level, which are described and discussed in Chapter 3.

In additional to a constructivist-interpretivist methodological approach, I drew on autoethnography as a methodolology to document my experiences as a practitioner-researcher in Chapter 3. Broadly, autoethnography is an "autobiographical genre of writing and research" that embeds "multiple layers of consciousness" by connecting the personal to the social, cultural, and political (Ellis, 2004, p. 37). In particular, autoethnography is "a research method that uses personal experience ("auto") to describe and interpret ("graphy") cultural texts, experiences, beliefs, and practices ("ethno")" (Adams, Ellis, & Jones, 2017, p. 1). Starr (2010) highlights that the researcher's "own experience is the focal point from which a new understanding of the culture in question is revealed through a holistic view that encompasses the research, writing, analysis and dissemination as a bridge between the personal and the cultural/political/social" (p. 3). As such, within the present autoethnographic exploration, I draw upon my personal experiences and observations in order to analyze, describe, and interpret my emerging understanding of the multiple ways in which disability-related barriers impact students' learning and instructors' teaching experiences at the college level.

Additionally, autoethnography "offers a way of giving voice to personal experience for the purpose of extending sociological understanding" (Wall 2008, p. 38) and to "formulate and refine theoretical understandings of social processes" (Anderson, 2006, p. 387). Drawing on autoethnography as a means of connecting my practice to the broader social context, I highlight the ways in which the disability discourses (i.e., the medical model of disability, the social model of disability, and the ecological model) have influenced, challenged, and transformed my professional practice while working with students with disabilities. I also focus on the ways these models of disability have informed my doctoral study.

While there are many other forms of autoethnography which are beyond the scope of this paper to discuss (e.g., reflexive autoethnography, narrative autoethnography, amongst others), I employ two main autoethnographic approaches—analytical (Anderson, 2006; Anderson, 2011) and evocative (Ellis, 2004). I drew on these two forms of autoethnography in reconstructing my experiences as a practitioner-researcher while working with students with LD. In the following section, I describe the tenets of analytical and evocative autoethnography respectively, and the ways in which these approaches have been employed within the present study.

Coined by Anderson (2006), analytical autoethnography focuses on the researcher's unique insights into the research problem within the social world being studied (Anderson, 2006, p. 389; Anderson, 2011; Deberry-Spence, 2010). Simultaneously, analytical autoethnography allowed me to take into account other insiders' "interpretations, attitudes, and feelings" (Anderson, 2006, p. 389; Anderson, 2011; Deberry-Spence, 2010). In the context of the present study, the social world being studied refers to the colleges where I worked as a special needs educator and biology instructor. The term "insiders" refers to my colleagues (i.e., other special needs educators and instructors) and students who form part of the college's microsystems. In conducting analytical autoethnography, Anderson (2006) proposes five key features which include: "(1) complete member researcher (CMR) status, (2) analytical reflexivity, (3) narrative visibility to the researcher's self, (4) dialogue with informants beyond the self, and (5) commitment to theoretical analysis" (Anderson, 2006, p. 378).

As highlighted by Anderson (2006), the "first and most obvious feature of autoethnography is that the researcher is a complete member in the social world under study…"

(p. 379). As a member and participant in the community under study, the autoethnographer is present within the study setting for extended periods of time, thereby allowing for detailed observation of daily activities and documentation of complex interactions. In the present inquiry, I served as a complete member researcher for five years in my role as a special needs educator in science and math while working at the CEGEP where the study took place. As a special needs educator, my tasks included offering accommodation and remedial tutoring to science students with LD. As well, I also worked closely with CEGEP science instructors to discuss issues that they were facing in teaching their students with LD. Moreover, I was also responsible for providing science instructors with useful strategies which might be employed in better supporting their students with LD. My status as a complete member researcher is also apparent in the data when I refer to my experiences as a special needs educator, instructor, and researcher.

Another key component of analytical autoethnography is analytical reflexivity, which Anderson (2006) defines as: “an awareness of [the]…reciprocal influence between ethnographers and their settings and informants. It entails self-conscious introspection guided by a desire to better understand both self and others through examining one’s actions and perceptions in reference to, and dialogue with, those of others” (p. 382). Throughout my text, I examine my “actions and perceptions” surrounding college level disability issues by engaging in dialogues and activities with “others” (i.e., students with LD and teachers). For example, by listening to the multiple voices of students with LD and focusing on their interests (e.g., arts and craft), I, the special needs educator, designed and implemented learning strategies (e.g., using arts and craft to build biological models) to meet the unique needs of these students. By paying close attention to my students’ voices, I demonstrated “my desire to better understand” their needs and alter my practice to help them in understanding science concepts.

As also discussed by Anderson (2006), “ethnographers have focused outward, on understanding and making understandable to others a social world beyond themselves” (p. 382). To this end, I also draw on existing disability studies literature and relate it to my own experiences in managing the ongoing needs of my science students with LD. For example, in my role as a special needs educator, many students with LD disclosed to me the burden they experienced in being negatively labelled and stigmatized by their teachers and peers on the basis of their disabilities. Similar to my experience, empirical studies also consistently reported that teachers tend to have lower academic expectations for their students ascribed an LD label as compared to their students with no labels (Denhart, 2008; Osterholm, Nash, & Kritsonis, 2007; Shifrer, 2013). As such, I focused “outward” and beyond my social world by linking my experience to the broader literature and disability discourses.

The third tenet of analytical autoethnography emphasizes the need for the active researcher to be made visible within the text. According to Anderson (2006), an active researcher is a “full-fledged member” of the social world being studied and “cannot always sit observantly on the sidelines” (p. 384). Specifically, the active researcher should participate in the social world and fully interact with the actors constructing the social world. During my research, I interacted fully with students with disabilities, other teachers, and learning specialists while navigating within my roles as a special needs educator and biology instructor. Being an active researcher also involves persuading others to adopt new practices by challenging existing ones (Anderson, 2006). In my role as a special needs educator, I occasionally found myself in conflict with teachers who refused to offer accommodations (e.g., extra time on quizzes) to their students with disabilities. I managed to persuade them by explaining the legal obligations which require teachers to offer fair and equitable education to all students. For example, I drew on the legal frameworks and legislations – Act to secure Handicapped Persons in the Exercise of their Rights with a View to Achieving Social, School and Workplace Integration (2011), the Commission des droits de la personne et des droits de la jeunesse, and the Quebec Charter of Human Rights and Freedoms and emphasized to teachers both the legal and social obligations of Quebec's CEGEPs to accommodate students with disabilities (Raymond, 2012; Havel, Raymond, & Dagenais, 2017).

Being visible in the text required me to "incorporate my subjective experience into the ethnographic work" such that I "recount[ed]… my own experiences and thoughts as well as those of others" (Anderson, 2006, p. 384). Anderson (2006) suggests that autoethnographers should "openly discuss changes in their beliefs and relationships, thus revealing themselves as people grappling with issues relevant to membership and participation in fluid rather than static worlds" (p. 384). In order to be visible within the text, I drew on my own experiences and shared my views on working with students with disabilities. The pronoun – "I" – also makes me visible in the text as I narrate my experiences on disability related issues. I also examine the ways in which my views and practice changed and evolved as I continuously interacted with students with disabilities and CEGEP science instructors.

The fourth tenet of analytical autoethnography calls "for dialogue with 'data' or 'others'" (Anderson, 2006, p. 386). Analytical autoethnography invites researchers to reach beyond their subjective experiences by inviting others to share their views on the phenomena being studied. In addition to documenting the researcher's own observations and insights, Anderson (2006) highlights the importance of interviewing diverse stakeholders so as to gain in-depth insights on the subject matter being explored from a multiplicity of viewpoints. For example, in addition to detailing my own personal observations on the ways in which disabilities impact students with

LD, I also interviewed 11 students with LD who recounted their difficulties in learning science at the college level. Moreover, 5 of the 11 students participated in a photovoice project, which consisted of photographing representative examples of barriers that impeded their learning in science. The journeys of these science students with learning disabilities are explored further in chapter 5 of this thesis.

Additionally, I interviewed 18 science college instructors to develop a comprehensive understanding of their barriers in teaching and supporting students with LD in science. In chapter 4, I describe these teachers' challenges in greater detail. By analyzing my own experiences and the perspectives of 'others' (i.e., college science instructors and students with LD), I offer a comprehensive portrait of common disability-related struggles encountered both by instructors and students in CEGEP level science classrooms. For example, one such issue emerging from my observations and interviews included science instructors' difficulties in using differentiated teaching strategies to better support the academic needs of their students with LD.

The fifth feature of autoethnography – commitment to theoretical analysis – consists of "using empirical evidence to formulate and refine theoretical understandings of social processes" (Anderson, 2006, p. 387). Specifically, Anderson (2006) invites researchers to draw on empirical evidence (e.g., researchers' own experiences and interview responses from participants) to develop, refine, and extend theoretical frameworks. Consistent with Anderson's (2006) focus on theoretical analysis, observations and empirical data collected during the study were analyzed in critiquing dominant theoretical frameworks—in particular, the medical and social models of disability—and to draw attention to limitations associated with these theoretical models. In this autoethnographic analysis, I discuss the ways in which Bronfenbrenner's ecological model could serve as a theoretical lens to deepen my understanding of the barriers faced by both students with LD and teachers in science education.

In summary, analytical autoethnography invites me to position myself as a "complete member researcher" and to "make myself visible explicitly in the text" by openly discussing my personal views and experiences regarding disability issues (Anderson, 2006; Weaver-Hightower, 2012, p. 463). In particular, I "textually acknowledge" and "reflexively assess" the ways in which I, the practitioner-researcher, have transformed my views, practices, and understanding of disability-related issues in college settings (Anderson, 2006, p. 385). Analytical autoethnography also invites me to "use empirical data to gain insight into some broader set of social phenomena than those provided by the data themselves" (Anderson, 2006, p. 387; Weaver-Hightower, 2012). As discussed earlier, I have drawn on empirical data (i.e., interviews and photovoice projects) to document barriers in teaching and learning science at the CEGEP level. Moreover, I have embedded arguments from the broader literature on disability discourses, special needs, and inclusive education to support my own views on barriers that students with LD and instructors encounter at the CEGEP level.

I also form part of the "world" that I am studying as I have worked closely with students with LD as a special needs educator and a teacher. Consequently, in this inquiry, I draw on evocative autoethnography (also known as heartful or emotional autoethnography) which is the process of narrating "a story that readers [can]… enter and feel part of," such that the story "evoke[s]…readers to feel and think about [their]… lives in relation to yours" (Ellis, 1999, p. 674). Narrating "meaningful and evocative" stories about issues that matter involves calling upon our personal "sensory and emotional" experiences while interacting within the social world under study (Ellis, 2004, p. 46).

As also emphasized by Hokkanen (2017), documenting the “embodied, emotional experiences” of the researcher enriches our understanding of actions and practices adopted within the social setting in which the study is taking place (p. 24). Specifically, emotions such as “thrill, joy, triumph, fear, relief, anger and sadness experienced during events” drive practitioner-researchers to “take actions that are considered unusual or extreme, also in either a negative or positive way” (Buckley, 2015, p. 1-2). I can recall one particularly intense memory of intense frustration and disappointment during my work as a special needs educator. Specifically, a mathematics teacher with whom I was working categorically refused to offer extra time for a class quiz to a student with processing and attention deficit disorders. My frustration, disappointment, and also my anger have led me to take the extreme action of reporting the teacher to the academic dean, which engendered negative consequences for the teacher. At other moments, I experienced grief and sadness when my students with LD shared their distress of feeling trapped within the medical model of disability. But, at other times, I also expressed feelings of joy and excitement when my students with LD overcame their challenges to succeed academically.

In order to narrate a selective, emotionally-driven story “about what happened written from a particular point of view at a particular point in time for a particular purpose” (Ellis, 1999, p. 673), the researcher draws upon field notes drawn to construct scenes and dialogues (Ellis, 1999). To effectively narrate the story in the field journals, Ellis (1999) suggests using “a process of emotional recall” which involves “imagining being back in the scene emotionally and physically” (Ellis, 1999, p. 675). The process of journaling allows the researcher to “revisit the scene emotionally” and to “access lived emotions” which emerged within the particular context being investigated (Ellis, 1999, p. 675), as well as detailing intimate thoughts, actions, reflections, and practices which were being experienced at the time. Drawing on Ellis's (1999) techniques of field journaling, I also systematically documented my journey and emotions experienced during my interactions with others in my journals during my dissertation research. My field journals included conversations I had with teachers and students with LD, and also my personal observations regarding my students with LD during remedial tutorials.

My field journals, in addition to my reflection logs and teaching diaries, were used to construct reflexive vignettes. Written in the first-person, reflexive vignettes are defined as "short stories, scenarios, depictions of situations, accounts using imagery, and recollection of actions. They are explored and styled contextually, and include visual or written texts" (Hunter, 2012, p. 92). Vignettes are used to locate the self within a specific social context and allow the practitioner-researcher to explore his/her positionality with respect to biases, beliefs, and personal experiences while exploring a social phenomenon (Pitard, 2017). Reflexive vignettes also represent vivid portrayals of daily events that elicit powerful emotions and empathy from readers (Humphreys, 2005). In line with Pitard (2017) and Humphreys (2005), my reflexive vignettes contained my dilemmas as I struggled to understand my students with LD, and find strategies to best support their engagement in science. My reflexive vignettes also depicted my "fights" and highlighted tensions between other teachers and me (i.e., special needs educator). In addition to these difficult moments, I also documented particular emotional scenes in which my students with LD shared with me their success on science tests.

In crafting my autoethnographic essay, I also adopted the literary genre of creative nonfiction, which seeks to construct stories stemming from empirical data, but which also fictionalizes certain elements therein (Smith, McGannon, & Williams, 2015). These stories – "fictional in form but factual in content" (Smith et al., 2015, p. 60) – were collected by documenting participants' authentic voices through interviews and photovoice projects. Then, these stories were reinterpreted through my own narrative voice in the form of reflexive vignettes (Smith et al., 2015). For instance, one vignette (story of Zeal)—which described a student's discomfort in informing his teachers about his accommodations– also represented the condensed recollections of numerous other participants who also experienced similar negative reactions from their instructors based on their disabilities and accommodation needs. These reflective vignettes allowed me to reflect on disability discourses and to make sense of the difficulties faced by both students with LD and teachers in science classrooms.

In addition to vignettes, Mitchell and Weber (1999, p. 74) highlighted that photographs "play a very important role in framing our sense of the past and shaping the course of our future." Drawing on Mitchell and Weber's (1999) ideology, I have used photographs taken by students in my classrooms and during tutorials. These photographs informed "a process of emotional recall" providing access to lived emotions, events, and actions that occurred at a particular point in time (Ellis, 1999, p. 675). In this autoethnographic essay, I also used photographs to showcase events (e.g., shared teaching moments with my students with LD) that held value and were meaningful to me. These photographs also helped me in creating reflexive vignettes.

As highlighted by Sikes (2015), "researching, writing about and re-presenting lives carries a heavy ethical burden regardless of whatever methodology, specific data collection methods, or presentational styles are adopted" (p. 1). Even in autoethnography — a form of research which intertwines the stories of the practitioner-researcher with those of the participants — protection of participants' identities, respect for their anonymity, and consideration for the voluntary nature of their participation are essential (Ellis, 2007; Sikes, 2015). As outlined by

Mitchell (2011), it is crucial to obtain permission for using images and even more critical to respect the wishes and rights of the photographers, who might not give full permission to use all of their photos in our research. Prior to collecting data, ethical approval to conduct this study was granted by McGill's ethics' committee and the college's research ethics board where the study took place. Consent was obtained from each student and teacher to participate in the interviews and photovoice projects, and to share any resultant observations and findings. All the students gave full permission to use all the photographs, which are co-shared between the students, who are the producers of the photographs, and me as the practitioner-researcher.

In summary, through the autoethnographic lens, I reveal my vulnerable self and intimate thoughts on the ways that my personal experiences, my professional observations, and commonly held disability discourses have shaped my experiences as a practitioner-researcher. I discuss the developmental trajectory of my personal research lens as I evaluated both the medical and social models of disability (discussed in Chapter 3), and as I finally adopted Bronfenbrenner's ecological model (discussed in Chapter 3) as a lens to conceptualize and understand the individual, social, and environmental factors that engender various academic barriers for students with LD and their science instructors within the CEGEP setting.

Data Collection and Analysis

Consistent with the constructivist-interpretivist paradigm, I interviewed multiple participants (i.e., 18 science instructors and 11 science students with LD) over a period of two years to capture their diverse realities. These realities have been co-constructed by the researcher and the participants during our individualized conversations. Semi-structured interviews were employed as the primary sources of qualitative data collection in this study as they "allow all participants to be asked the same questions within a flexible framework" (Dearnley, 2005, p. 25).

As emphasized by Rabionet (2011), qualitative interviewing “is a flexible and powerful tool to capture the voices and the ways that people make meaning of their experiences” (Rabionet, 2011, p. 563) – which is in line with the tenets of the constructivist-interpretivist paradigm.

Semi-structured interviewing uses broad and open-ended questions to investigate the topic of interest (Pathak & Intratak, 2012; Seidman, 2006; Whiting, 2008). The flexible nature of open-ended questions encouraged both participating science instructors and students to reflect on their experiences and emotions by sharing their perspectives on the issues they faced in the sciences (Seidman, 2006; Whiting, 2008). One example of an open-ended question asked to individual students with LD was as follows: “What particular problems do you encounter in learning science concepts?” Usually, open-ended questions are followed by prompt questions to further clarify the participants’ experiences. These prompt questions are crucial in cases where participants do not offer detailed views on their experiences spontaneously. An example of a prompt question detailing problems encountered in learning science concepts, might take the following form: “You mentioned that you have trouble paying attention in the science classroom. Can you describe a particular situation when this happened? How did you feel?”

Prior to conducting interviews, it is important to prepare an interview guide by first identifying the topics to be broached during the interview, and by formulating the interview questions (Pathak & Intratat, 2012). To develop a comprehensive understanding of issues experienced by students with LD in learning science, the following broad topics were included in their interview guide (see Appendix E): diagnosis of LD; views about their abilities in science; learning strategies employed in science learning; science learning in the classroom; science instructors’ attitudes, teaching strategies, and support mechanisms; and interview subjects’ views on working with typically achieving peers.

Similarly, to develop insights on barriers encountered by science instructors in teaching students with LD, the following topics (see the interview guide for teachers in Appendix C) were selected: teaching science at the CEGEP level; teaching strategies employed in the classroom; difficulties in teaching science to students with LD; supports required to teach students with LD; and stories/situations about teaching science students with LD. The topics within the interview guides (see Appendices C and E) emerged from mainly informal conversations with students with LD and instructors about disability-related issues in science education; my experience working at the CEGEP; Bronfenbrenner's (2005) ecological model, which reinforces the importance of considering both within-individual and environmental factors in human development; and partly from an analysis of the limited and sparse literature on science teaching and learning for students with disabilities.

In addition to semi-structured interviews, data in the form of photographs and journals were collected. By participating in the photovoice project, 5 students were invited to visually represent their barriers through photography, which aims to "increase their knowledge about the issues that most affect them, [to]… enrich their understandings of their lives within a particular community, [to]… have fun, and [to]…be given an opportunity to express themselves in new and imaginative ways" (McIntyre, 2003, p. 52). Moreover, students use their photographs to write reflexive journals which have been shown to enhance critical thinking and to promote self-awareness surrounding the issues being experienced (Brown & Sorrell, 1993; Callister, 1993; Kea & Backon, 1999; McGuinness & Brien, 2007; O'Rourke, 1998; Patton, Sinclair & Woodward, 1997; Tang, 2002).

To generate a set of common themes from the interviews and photovoice project, a constant comparative analysis method was employed, which is well-suited to analyze various forms of qualitative data (i.e., observations, drawings, photographs, videos) (see Boeije, 2008; Fram, 2013; Leech & Onwuegbuzie, 2008; Mason et al., 2015). The constant comparative analysis method begins with open coding to capture all the views and perspectives shared by individual participants (Maguire & Delahunt, 2017; Saldaňa, 2013). The open coding allowed me to capture some strategies developed by teachers to support their students with LD. Exploring strategies employed by science teachers was not in line with my research questions. But, these instructors' strategies were added to the discussion section in Chapter 4 to demonstrate that science teachers are investing efforts to make science accessible for diverse learners.

During open coding, I assigned codes to sentences and paragraphs within the interview transcripts. A code is usually a short word or phrase which captures and describes a meaningful unit or salient idea expressed by participants (Maguire & Delahunt, 2017; Saldaňa, 2013). Examples of codes generated during data analysis are detailed in Chapters 4 and 5. Codes, representing similar perspectives shared by participants, are collapsed into categories or families of codes, which are then grouped into meaningful themes. Themes emerging from the interview and photovoice data represent the participants' views and perspectives on the issues being investigated in the study (Maguire & Delahunt, 2017). I have thoroughly discussed the ways in which the constant comparative analysis method was employed to examine the data gathered from teachers and students in Chapters 4 and 5.

Summary of Chapters 3 - 5

In this section, I briefly summarize and highlight the interrelationships between the three manuscripts. Below, I begin with an overview of Manuscript 1 (Chapter 3).

Overview of Chapter 3

Chapter 3 takes the form of an autoethnographic exploration focusing on my personal experience and process of self-reflection as a practitioner-researcher interacting with students with LD and science instructors over a period of five years. As defined by Wall (2006), autoethnography is “an emerging qualitative research method that allows the author to write in a highly personalized style drawing on his or her experience to extend understanding about a societal phenomenon” (p. 1). Similarly, Starr (2010) describes autoethnography as involving a process whereby “the researcher’s own experience is the focal point from which a new understanding of the culture in question is revealed through a holistic view that encompasses the research, writing, analysis and dissemination as a bridge between the personal and the cultural/political/social” (p. 3). In chapter 3, my own experience as a practitioner-researcher is the “focal point” inviting me to “extend understanding” of the difficulties faced by students with LD in learning science and the issues that science instructors experienced in teaching students with LD. I engaged in self-reflection regarding disability-related issues at Mountain CEGEP while working closely with students with LD and other science instructors in my capacity as a special needs educator, a biology instructor, and a novice researcher.

While an autoethnographic exploration “offers ways to situate self within the research process and its written product by making self the object of research and by developing a connection between the researcher’s and participants’ lives” (Burnier, 2006, p. 410), it also emphasizes the need to “formulate and refine theoretical understandings of social processes” (Anderson, 2006, p. 387). In other words, autoethnography urges the researchers to use empirical data (e.g., researchers’ own experiences, observations, and interviews from participants) for theoretical development, refinement, and extension (Anderson, 2006). Therefore, in addition to narrating my views and understandings on how disability-related issues impact learning and teaching of science at the college level, I also explored the dominant discourses and theoretical paradigms (i.e., medical and social models of disability) to make sense of disability as a concept. In particular, I discuss my journey as a practitioner-researcher as I navigate the parallel paradigms of the medical model of disability (as a special needs educator), the social model of disability (as a biology instructor), and Bronfenbrenner's ecological model (as a practitioner and researcher).

Overall, this autoethnographic exploration allowed me to reflect on different models of disability (medical and social models) and to make sense of their strengths and limitations not only within my own practice, but also by exploring relevant literature in science and special education. Finally, I emphasize the importance of Bronfenbrenner's (2005) ecological model in transforming and shaping my views as a practitioner-researcher, as it enabled me to make sense of disability as an intersection between both cognitive issues and environmental challenges affecting the learning and academic achievement of science students with LD. As argued by Mitchell (2016, p. 183), autoethnography "can contribute to the ways that we address, build in, and critically engage with positionality in our research (including researching our teaching)." Such was my experience as I navigated across different positions (i.e., special needs education, biology instructor, and novice researcher) as a practitioner-researcher. As such, in this autoethnographic inquiry, I also unveiled the delicate process of attempting to position myself within a disability discourse to inform my doctoral research study, with the objective of transforming and improving science education for students with LD. I found myself at the heart of constant stress and tension as I navigated opposing discourses: the medical and social models of disability. Drawing from my dual identities as a practitioner-researcher, I engaged in a reflexive process on the potential application of the social and medical models in informing barriers experienced by students with LD.

Overview of Chapter 4

In seeking to develop a comprehensive understanding of the difficulties experienced by CEGEP science instructors in teaching students with LD, Chapter 4 focuses on the following research questions: (1) *What types of barriers do college science instructors believe that they experience in teaching and supporting their students with LD?* (2) *What challenges do science teachers feel they face in providing academic assistance to their students with LD outside of the classroom setting and during office hours?*

Specifically, Chapter 4 draws on semi-structured interviews with 18 science instructors (7 biology instructors, 6 chemistry instructors, and 5 physics instructors) to explore the above-mentioned research questions. While Bronfenbrenner's (2005) ecological model serves as an overarching framework to conceptualize my doctoral thesis, I have drawn on Ertmer's (1999) framework describing first-order and second-order barriers to construct a more meaningful understanding of the issues encountered by the participants. In particular, Ertmer's (1999) framework permitted me to categorize barriers experienced by instructors as being first-order (i.e., external to the teachers and present in the environment) or second-order (i.e., internal to the teachers, such as pedagogical beliefs about teaching students with LD). Such categorizations were essential to help identify second-order barriers, since these barriers, in particular, are difficult to overcome, given that they represent "long-held beliefs, attitudes, and conceptualizations that represent important aspects of individual sense-making" (Alleman, Holly, & Costello, 2013, p. 2). By differentiating between first-order and second-order barriers, appropriate strategies could be designed and implemented to address these barriers more effectively. For example, first-order barriers stemming from the environment (e.g., lack of hands-on materials and resources to teach students with LD) could be discussed with college administrators so that budgets to purchase differentiated materials for diverse learners could be allocated to science departments. To better address second-order barriers, professional development programs could support teachers in overcoming their long-held prejudicial beliefs about teaching students with disabilities, and to consequently embrace more inclusive practices.

Taken together, Chapter 3 and Chapter 4 complement each other and offer insights into the diverse types of barriers that CEGEP science instructors face in teaching students with LD. Specifically, Chapter 3 draws on my personal experiences as a special needs educator and highlights my own perspectives on issues that various science instructors have shared with me regarding teaching their students with LD. Complementarily, Chapter 4 portrays the authentic voices of science instructors regarding the challenges they encountered in making science accessible to their students with LD.

Overview of Chapter 5

Chapter 5 explores the views of science students with LD and highlights the issues they face in learning science at the CEGEP level. Listening to the voices of students with LD on their barriers was crucial so as to inform effective intervention-based strategies that could support their engagement and learning in science. Moreover, the barriers described by science students could also support their science instructors in making adjustments to their teaching practice, which might potentially improve the learning experiences of these diverse learners. To explore barriers experienced by science students with LD, Chapter 5 asks the following questions: (1) *What types of barriers do college students feel they encounter in learning science?* (2) *In what ways do they think these barriers impact their learning and success in college science programs?*

In Chapter 5, I drew on semi-structured interviews and the photovoice approach to empower the voices of CEGEP science students with LD, and to explore their struggles in learning science. As explained by Povee, Bishop, and Roberts (2014), photovoice "aims to capture the reality of people's lives and make these realities accessible to others using photographic images" (p. 895). Previously, the photovoice approach has been employed to capture the voices of vulnerable individuals, who have been historically marginalized and mostly excluded from society, such as those with HIV/AIDS (Mitchell, DeLange, Molestane, Stuart, & Buthelezi, 2005; Molestane et al., 2007; Sun, Nall, & Rhodes, 2019), and/or disabilities (Agarwal, Moya, Yasui, & Seymour, 2015; Booth & Booth, 2003; Carnahan, 2006; Mitchell, de Lange, & Nguyen, 2016). Similarly, students with LD have been marginalized from STEM fields, and their voices have been mostly ignored in both the science and special needs literature (Koomen, 2016; Martínez-Álvarez, 2017; Murtaza, 2018; Trauth-Nare, 2016).

Overall, the photovoice approach was selected in this study to capture students' views of their learning barriers which were otherwise inaccessible through traditional semi-structured interviews. Specifically, I was unable to observe and make sense of the students' difficulties in their labs. However, during the photovoice project, students took photographs of lab components that were difficult for them, permitting me to develop an in-depth understanding of their struggles. In addition to taking photographs, the participants were invited to write journals on the barriers depicted in the images, as well as participating in semi-structured interviews to further discuss the photographs. Chapter 5 was informed by Bronfenbrenner's (2005) ecological model which emphasises the importance of documenting both within-individual and environmental factors in human development, especially as these both of these factors might impair students' learning in science.

In sum, Chapters 3, 4, and 5 bring together multiple perspectives (i.e., the views of the special educator, teachers, and students with LD) to offer a comprehensive understanding of the multiple and complex learning and teaching barriers experienced by students with LD and their teachers at Mountain CEGEP.

Chapter 2: Review of Literature

Science for Every Student

The importance of science in our society has led education policy developers, science educators, and scientists to conclude that scientific literacy is vital for *all* students' well-being and their full participation in our social world (CMEC, 1997; Gräber, Nentwig, Koballa, & Evans, 2011; Feinstein, 2011; Holbrook & Rannikmae, 2009; Januszyk, Miller, & Lee, 2016; Lee, Miller, & Januszyk, 2014). As emphasized by Asghar, Sladeczek, Mercier, and Beaudoin (2017), "contemporary developments in science and technology have…significantly shap[ed]…our lives personally, socially, politically, and professionally" (p. 239). Indeed, science related-issues impact our daily lives in a variety of ways, from recalls of contaminated meat from the global marketplace, to viral infections causing deadly flu, from the effects of climate change and the availability of clean water, to the menace of nuclear and biological weapons. These issues—amongst others— affect all individuals in either positive (e.g., new drugs to treat diseases) or negative ways (e.g., contaminated meat causes health issues and deaths). As such, individuals are regularly faced with science-related decisions and practices impacting their health, food supplies, use of technologies, and energy use (OECD, 2015). Therefore, developing science literary is crucial for all individuals to make informed science-based decisions in their daily lives (Gräber, Nentwig, Koballa, & Evans, 2011; Hicks, MacDonald, & Martin, 2017; Holbrook & Rannikmae, 2009; OECD, 2015).

Science education programs and policies in Canada and the US further emphasize that science is for *all* individuals regardless of their gender, cultural background, social circumstances, or career aspirations (AAAS, 1993; Achieve Inc., 2013; CMEC, 1997; 2013; MELS, 2007). This concept – Science for all and Science for Every Student – has been endorsed in Canada since 1984 and is defined as follows:

> A first-class science education for every student: those in elementary schools as well as those in secondary schools; girls as well as boys; the most able students and those less able; those having special interests in science and scientific careers and those without these interests; students in all regions and provinces; francophones, anglophones, and those of native ancestry (Science Council of Canada, 1984, p. 10)

In Canada, scientific literacy is understood as "an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities; to become lifelong learners; and to maintain a sense of wonder about the world around them" (CMEC, 1997, p. 4; CMEC, 2013; CMEC, 2016). To develop scientific literacy and support inclusive practices for all learners, science students need to engage in inquiry-based, hands-on activities to develop a deeper and more meaningful understanding of scientific, technological, and engineering concepts (AAAS, 1993; Achieve Inc, 2013; CMEC, 1997; MELS, 2007). Inquiry-based approaches, which involve students in formulating questions, making and testing predictions, developing hypotheses, collecting data, and drawing inferences, have shown to improve engagement and learning when compared to lecture-based and text-book-driven traditional teaching approaches (Asghar et al., 2017; Colburn, 2008; Geier et al., 2008; Hmelo-Silver, Duncan & Chin, 2007).

These approaches are consistent with constructivism, such that inquiry-based learning environments encourage students to challenge their existing intuitive cognitive structures of natural phenomena so as to build a deeper understanding of the scientifically accepted models (Piaget, 1972, 1985; Piaget & Inhelder, 1969). In this way, science students engage in critical thinking and reasoning, which are life-long skills and can be flexibly applied to their daily lives, rather than merely memorizing and regurgitating scientific facts.

In Quebec's secondary schools, science instruction is guided by competencies related to hands-on, inquiry-based teaching approaches (MELS, 2007). Documented in the Quebec Education Program (QEP), hands-on, inquiry-based approaches are guided by three competencies to support students in developing scientific literacy. To develop competency 1, students seek answers or solutions by asking questions and solving problems through "observations, hands-on activities, measurements, construction or experimentation" in labs, workshops or the real world (MELS, 2007, p. 3).

For competency 2, students make "most of his/her knowledge of science and technology" by applying their knowledge of science concepts in dealing with a diversity of societal and environmental problems (MELS, 2007, p. 2). To enact competency 2, diverse teaching approaches (e.g., case studies, debates, projects) and classroom activities are used by teachers to meet the different learning needs of diverse learners (MELS, 2007).

Competency 3 involves encouraging students to communicate in "languages used in science and technology" and using "conventions associated with these fields" (MELS, 2007, p. 18). To help students in achieving competency 3, teachers enact situations that allow students to "exchange scientific or technological information" in writing or orally by sharing their work with peers, discussing with experts (e.g., scientists) to find answers to their questions, or participating in science fair exhibits (MELS, 2007, p. 18). The three competencies mandate the enactment of multiple teaching and assessment practices to support the inclusion and engagement of all learners.

While Quebec's secondary system focuses on three interrelated competencies to support scientific literacy for diverse learners, Quebec's CEGEP system has no specific science education policies or frameworks that encourage active learning with hands-on approaches for science students. However, the policy on education success, enacted in 2017 by Quebec's Ministère de l'Éducation et de l'Enseignement supérieur (MEES), emphasizes that the academic needs of all students (i.e., from early childhood to postsecondary levels), irrespective of their "handicaps, social maladjustments or learning difficulties" need to be considered and met by early intervention programs (MEES, 2017, p. 21). The initiative for the policy on education success was driven by the significantly lower academic success rate of students with handicaps, social maladjustments or learning difficulties as compared to their typically achieving peers. As reported by MEES (2017), only 48.3 % of students with handicaps, social maladjustments, or learning difficulties obtain their high school diploma before the age of 20, which is 34.1 % less than their typically achieving peers.

Given the disparity in academic achievement between students with disabilities and their typically achieving peers, the policy on education success also aims at reducing the gap in academic success between at-risk and typically achieving students by 2030 (MEES, 2017). To offer equal educational opportunities to all students, the policy on education success highlights that educational settings — including science classrooms — should be inclusive and allow diverse learners to engage in developing their knowledge and skills to be "civic-minded, creative, competent, responsible, open to diversity and fully engag[ed]… in the social, cultural, and economic life in Quebec" (MEES, 2017, p. 26).

Overall, the policy on education success (MEES, 2017) and frameworks, such as the *Common Framework of Science Learning Outcomes*, *K to 12* (CMEC, 1997, 2013, 2016), ensure that disadvantaged learners are provided with accommodations to meet their specific needs, and are supported in pursuing their academic goals.

Science Not for All Students

Despite the implementation of science related policies and frameworks which aim towards education for all, disparities still exist within STEM programs for different learners (e.g., girls vs. boys, immigrant vs. non-immigrant students, students with disabilities vs. students with no disabilities) (Aschbacher, Li, & Roth, 2009; Brickhouse, 2001; Brickhouse & Potter, 1999; Chen, 2013; DeCoito, 2016; Roth & Barton, 2004; OECD, 2015).

In a recent review of current research focusing on STEM education in Canada, DeCoito (2016) discusses that most Canadian studies in STEM focused on underrepresented population such as Aboriginal students, females, and immigrants. However, the term “disabilities” does not appear anywhere in DeCoito’s (2016) text, indicating that individuals with disability may be receiving less attention as compared to other underrepresented groups within the sciences. As also recently confirmed by the National Science Foundation (NSF) (2013) and Thurston et al. (2017, p. 50), “data are seriously limited on people with disabilities who study and work in science and engineering” at the postsecondary level.

In the US, however, science achievement for students with disabilities in grade 4, 8, and 12 is well-documented. Specifically, the National Assessment of Educational Progress (NAEP) science assessment initiative, which has been designed to measure students’ knowledge in the physical, life, earth, and space sciences, also takes into account the science performance of students with disabilities including those with LD (NAEP, 2015). As demonstrated in Figure 1, data from the NAEP (2015) indicates that students with disabilities are performing at a significantly lower level on the NAEP science assessment as compared to their typically achieving peers across all grade levels (i.e., grades 4, 8, and 12 respectively). Clearly, students with disabilities — including those with LD — are lagging behind in science as compared to their typically achieving peers. The academic performance of students with disabilities in science tends to decline as grade levels increase (NAEP, 2011).

In line with Canadian policies and frameworks emphasizing the importance of science for all students, it is crucial to develop a comprehensive understanding of the different barriers that diverse learners face in pursuing science. By identifying barriers faced by science students with LD, effective strategies could be explored to improve these students' science achievement. In particular, it is important to investigate the difficulties faced by Canadian science students with LD in accessing postsecondary science curriculum, as this study population has been neglected in Canada and Quebec in comparison to other minority groups (e.g., female students, Aboriginal students).

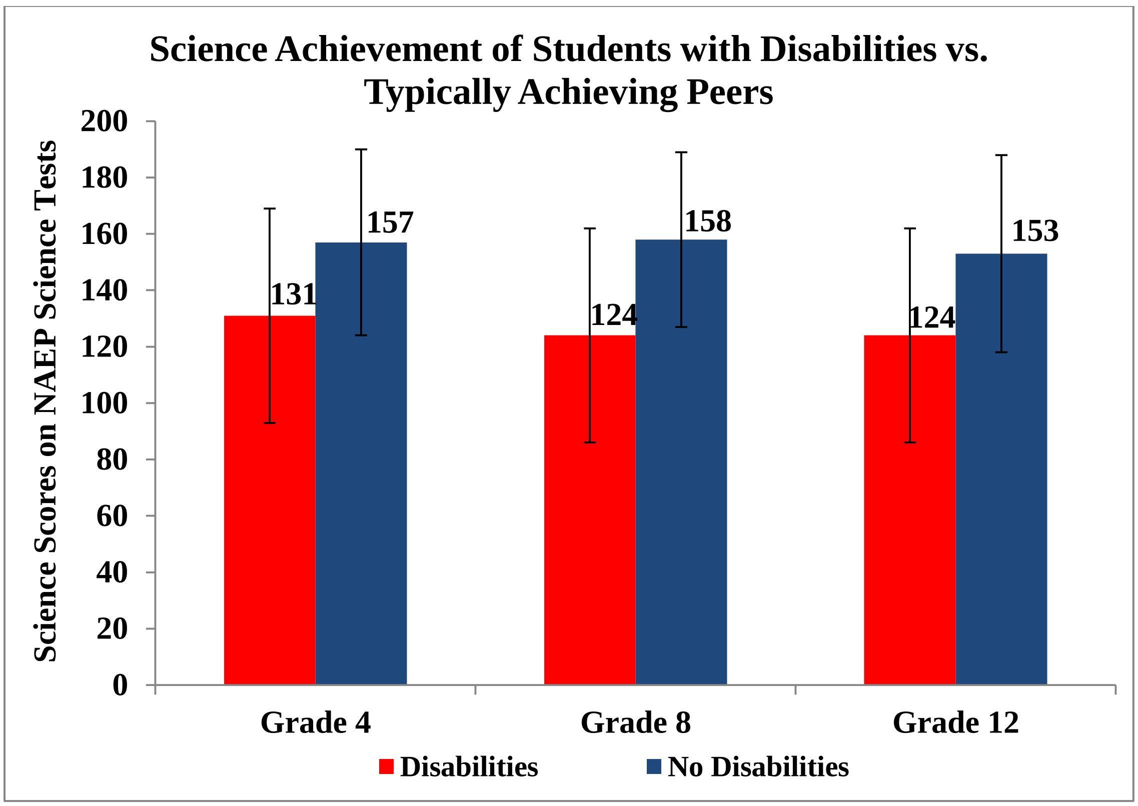

Figure 1. Science Achievement of grade 4, grade 8, and grade 12 students with disabilities vs. students without disabilities on the NAEP science assessment test

Canadian and Quebec Students with Learning Disabilities in Postsecondary Settings

In Canada and Quebec, increasing numbers of students with disabilities[5] (including those with LD) are gaining access to postsecondary educational programs including CEGEP science programs (Beaumont & Lavallée, 2012; Bonneli, Ferland-Raymond, & Campeau, 2010; Ducharme & Montminy, 2012; Havel, Raymond, & Dagenais, 2017). Ducharme and Montminy (2012) reported a 238 % growth in the number of students with disabilities attending CEGEPs between the fall sessions of 2006 and 2008. An overall increase of 34 % was noted in the percentage of students with diagnoses of LD, mental-health problems, and attention deficit disorder (ADD) attending CEGEPs from that same time period (Ducharme & Montminy, 2012). Moreover, during the fall 2006 semester, students with LD, mental-health problems, and ADD represented 45.5 % of all students with disabilities whereas by fall 2009, this percentage had increased to almost 60% (Ducharme & Montminy, 2012). Similarly, in Canada, nearly half of individuals (2 % out of 4.4 %, representing all disability types) between the ages of 15 to 24 self-reported having a learning disability occurring comorbidly with other disabilities (e.g., anxiety, ADD) (Bizier, Till, & Nicholls, 2015).

Although Canadian students with LD are increasingly gaining access to postsecondary education, they are also more likely to drop-out and not complete their postsecondary college diplomas or trade certificates as compared to their typically achieving peers (Bizier, Till, & Nicholls, 2015). Specifically, only 35.6 % of individuals with LD completed their postsecondary education as compared to 61.1 % of typically achieving individuals, as reported by Statistics Canada (Bizier, Till, & Nicholls, 2015). Approximately 98 % of students with LD explained that their LD had negatively affected their academic experience (Bizier, Till, & Nicholls, 2015).

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[5] Students with disabilities include those with physical disabilities (e.g., visually impaired students, those using wheelchairs); developmental disabilities (e.g., autism), learning disabilities (e.g., impairment in reading and written expression), and mental health issues (e.g., depression and anxiety).

Many of these students encountered social problems such as bullying (50 %) and feelings of exclusion from their typically achieving peers (58 %) (Bizier, Till, & Nicholls, 2015). Moreover, 50 % of students self-reported that their LD had caused them to change their programs of study (Bizier, Till, & Nicholls, 2015). 47 % of individuals with LD had interrupted their studies due to difficulties coping within the postsecondary setting (Bizier, Till, & Nicholls, 2015). Almost 64 % chose to take on a less-intensive course workload, choosing instead to complete their postsecondary education over a longer time-frame (Bizier, Till, & Nicholls, 2015).

According to Statistics Canada, due to both educational challenges and difficulties in coping with their learning disabilities, the employment rate for adults with LD is significantly lower than typically achieving individuals (Bizier, Till, & Nicholls, 2015). For instance, approximately 40 % of individuals with LD (ages 25 to 34) were employed, as compared to 82 % of individuals (ages 25 to 34) without an LD (Bizier, Till, & Nicholls, 2015). Among employed individuals with LD, it is common for them to face considerable challenges within their work environment. Up to 55.5 % of them require accommodations within their work settings, the most common being modified work hours (39.1 %) and modified work duties (23.3 %) (Bizier, Till, & Nicholls, 2015).

Altogether, it is clear that Canadians with LD are being left behind and not achieving their academic (e.g., completing their postsecondary education) and professional goals (e.g., finding and maintaining employment), as compared to typically achieving individuals. To make matters worse, individuals with LD often face social issues such as bullying and exclusion, which may negatively affect their self-esteem. Consequently, Canadians with disabilities are statistically at higher risk of committing suicide as a result of the social stigma (e.g., bullying), social exclusion, and isolation that they face (McConnell, Hahn, Savage, Dube, & Park, 2016).

Canadians with disabilities are facing tremendous barriers that prevent them from fully participating in our society. To support their full inclusion in our society, it is crucial that their barriers are adequately understood and effectively dismantled. By findings solutions and strategies to overcome their barriers, they might persist in their academic settings, and reach their educational and professional goals. By reaching their goals, they might be at a lower risk of committing suicide, and experience less bullying and exclusion in our society.

In the following sections, I first outline the legal policies regarding disabilities in general, and then focus on the conceptualization of learning disabilities in the literature. Next, I discuss various definitions of learning disabilities, identification methods, and accommodation strategies that are being used in different Canadian provinces to support individuals with learning disabilities. Then, I discuss the literature on specific barriers encountered by students with LD and the difficulties faced by their teachers in science classrooms. Lastly, I identify gaps within the literature focusing on issues in teaching and learning science with regards to students with LD; and explain how my doctoral thesis addresses some of these gaps.

Disabilities and Disability-related Laws and Policies

The World Health Organization (n.d., para 1, 2016) defines disabilities as:

> an umbrella term, covering impairments, activity limitations, and participation restrictions. An impairment is a problem in body function or structure; an activity limitation is a difficulty encountered by an individual in executing a task or action; while a participation restriction is a problem experienced by an individual in involvement in life situations.

In Quebec, the *Commission des droits de la personne et des droits de la jeunesse* defines disability as the "actual or presumed disadvantage that limits you physically, mentally or psychologically such as being paraplegic, suffering from a mental illness, from visual or hearing difficulties, epilepsy, or addiction to drugs and alcohol. There are means to palliate a disability, such as a wheelchair, a guide dog or service dog, and prosthesis" (2018, para 1)

Both the Ontario's *Human Rights Commission* and the Quebec's *Commission des droits de la personne et des droits de la jeunesse* acknowledge that individuals with disabilities are to be treated fairly without any forms of discrimination and harassment, which is in line with the Canadian *Charter of Human Rights and Freedoms*. Article 10, of the *Charter of Human Rights and Freedoms,* C-12 (2018, p. 4), states that:

> Every person has a right to full and equal recognition and exercise of his human rights and freedoms, without distinction, exclusion or preference based on race, colour, sex, gender identity or expression, pregnancy, sexual orientation, civil status, age except as provided by law, religion, political convictions, language, ethnic or national origin, social condition, a handicap or the use of any means to palliate a handicap. Discrimination exists where such a distinction, exclusion or preference has the effect of nullifying or impairing such right.

Article 10 is further supported by article 10.1 of the Charter (2018, p. 4) such that "No one may harass a person on the basis of any ground mentioned in section 10." Specifically, the *Charter of Human Rights and Freedoms* (section 12) indicates that discrimination has occurred when an individual is treated differently than others (in cases where they are singled out), or are treated according to the same standards as others without appropriate accommodation (in cases where an unfair standard is applied to them). Hence, discrimination can take the form of a policy preventing all employees — including individuals with visual impairment — from bringing their dogs to work (Commission des droits de la personne et des droits de la jeunesse, 2016). By disallowing individuals with visual impairment to bring their dogs to work, the company is effectively excluding these individuals from the work setting, which is against the law. In this case, the visually impaired individuals are being discriminated on the basis of their disabilities by being treated according to the same standard as those who do not have a disability.

Similarly, in educational settings, students with disabilities are protected from discrimination and exclusion in such that they are offered appropriate accommodations (e.g., extra time for tests), according to their needs. Overall, article 10 of the *Charter of Human Rights and Freedoms* emphasizes the legal requirements that educational institutions need to follow in order to provide appropriate accommodations to individuals with disabilities so that they are able to access equal opportunities as those without disabilities.

The *Charter of Human Rights and Freedom* C–12 (article 12) emphasizes that “no one may, through discrimination, refuse to make a juridical act concerning goods or services ordinarily offered to the public” (2018, p. 4). According to Quebec’s *Commission des droits de la personne et des droits de la jeunesse* (2016), goods and services are provided to specific groups of individuals (e.g., students), and juridical acts refer to collective agreements, wills, pensions, or employee benefits plans. Article 12 of the Charter guarantees the rights of students with disabilities through reasonable accommodations so that they have equal opportunities as their typically achieving peers to succeed in their academic pursuit. Reasonable accommodations imply that the provisions offered to students do not cause “undue hardship to the college or its professors” such as “unreasonable costs associated with a request, the impact on the safety of persons in the college, the reality of the physical space and course times, the availability of material and physical resources, compliance with Quebec’s College Education Regulations

(RREC), the impact on other students and teachers and the absence of mitigating measures to satisfy the standard" (Bouchard & Leblanc, 2016, p. 12).

Moreover, article 40 of the Charter of Human Rights and Freedom C – 12 states that: "every person has a right, to the extent and according to the standards provided for by law, to free public education" (2018, p. 8). Article 40 ensures that all students up to age 18 (or 21 for people with disabilities) are offered free education throughout preschool, elementary, high school levels, and in some cases, for students undertaking collegial (CEGEPs), vocational, and adult studies (Commission des droits de la personne et des droits de la jeunesse, 2016).

In sum, the Canadian *Charter of Human Rights and Freedoms* has paved the way for individuals with disabilities to meaningfully participate in society through offering legal protection against all forms of discrimination and harassment in educational settings, within the workplace, and within other social settings.

However, inspite of these legal provisions, students with LD are continuously facing challenges and discrimination at the CEGEP level. In fact, I have personally witnessed them fight with their teachers so that their rights to have accommodations are respected and enacted. Their legal rights to accommodations are often challenged by instructors because the LD concept is difficult to define and conceptualize as discussed in the next section. Because some instructors experience difficulties in making sense of the LD construct, they often question the validity of the students' respective LD, and their rights to certain accommodations. As such, it is crucial that research is conducted to better understand the barriers and needs of students with LD, so as to inform and support teachers in developing an in-depth comprehension of the characteristics of this emerging population. By empowering teachers with knowledge about students with LD, they might be more engaged to understand and respect these students' legal rights and needs for accommodations.

Conceptualizing and Defining Learning Disabilities

For decades, the term 'learning disabilities'—as well as formal diagnoses criteria for LD— have been at the heart of constant debate among scholars. Still, to-date, no consistent definition exists for what constitutes an LD (Roberts, 2012). For example, in Canada, the learning disability definitions and criteria vary considerably from province to province (Roberts, 2012), as will be discussed in more detail in this chapter.

In this section, I begin with a brief history regarding the coining of the term *learning disabilities*. I also outline the multiple definitions of learning disabilities proposed and endorsed over the past decades in the US and Canada. It is to be noted that a detailed history of LD is beyond the scope of the present literature review, however, such a historical survey exists and has been well-described by Hallahan, Pullen, and Ward (2013), in Chapter 2 of the book *Handbook of Learning Disabilities* (2013). The following section describes the period in which the term LD first emerged.

Coined by Dr. Samuel Kirk, an American psychologist and academic, the term *learning disabilities* originally appeared in the first edition of his book: *Educating Exceptional Children*. In his book, Kirk defined LD in the following terms:

> A learning disability refers to a retardation, disorder, or delayed development in one or more of the processes of speech, language, reading, writing, arithmetic, or other school subject resulting from a psychological handicap caused by a possible cerebral dysfunction and/or emotional or behavioral disturbances. It is not the result of mental retardation, sensory deprivation, or cultural and instructional factors. (Kirk, 1962, p. 263)

Kirk publicly used the term *learning disabilities* (LD) for the first time while addressing a group of parents in Chicago on Saturday April 6, 1963 at a conference titled: *The conference on Exploration into Problems of the Perceptually Handicapped Child* (Hallahan & Mercer, 2001). Inspired by Kirk's presentation at the conference, a group of parents immediately formed the Association for Children with Learning Disabilities, which was later renamed and is currently known as the Learning Disabilities Association – the "largest and most influential learning disabilities parent organization" within the US (Hallahan & Mercer, 2001, p. 14).

Kirk's definition of LD suggests that learning disabilities result from biological causes related to neurological processes occurring in the brain, and therefore, students with LD demonstrate symptoms of neurological dysfunction.

Overall, from the early 1960's to the late 1980's, 11 prominently used LD definitions — including that of Kirk (1962) — emerged in the US so as to conceptualize and universalize the LD construct (Hammill, 1990). When comparing and contrasting the 11 definitions of LD, Hammill (1990) noted conceptual categories that they shared in common, which included: (a) underachievement (i.e., deficiency in a particular problem area) and aptitude-achievement discrepancies; (b) central nervous system dysfunction; (c) disruption of psychological processes; (d) lifelong impairment; (e) spoken language (language problems and issues in listening and speaking), academic (i.e., academic problems in reading, writing, spelling, and math), and conceptual problems (i.e., deficiencies in thinking and reasoning) as issues experienced by individuals with LD, and (f) comorbidity of LD with other disabilities (e.g., emotional disturbances).

Some of these conceptual categories are still present in current definitions of LD. For example, in the definition of LD postulated by the Learning Disabilities Association of America

(LDA), emphasis is still placed on LD as a neurological condition affecting academic skills including reading, writing, and/or math. Specifically, the LDA (2018, para 1) defines LD as follows:

> Learning disabilities are neurologically-based processing problems. These processing problems can interfere with learning basic skills such as reading, writing and/or math. They can also interfere with higher level skills such as organization, time planning, abstract reasoning, long or short term memory and attention. It is important to realize that learning disabilities can affect an individual's life beyond academics and can impact relationships with family, friends and in the workplace.

Specific Learning Disorder

Contrasting with scholarly definitions of LD constructs from the past, The *Diagnostics and Statistical Manual of Mental Disorders* (DSM–5, American Psychiatric Association, 2013) uses the term "specific learning disorder" instead of LD. DMS-5 defines specific learning disorder as follows:

> Specific learning disorder is a neurodevelopmental disorder with a biological origin that is the basis for abnormalities at a cognitive level that are associated with behavioural signs of the disorder. The biological origin includes an interaction of genetic, epigenetic, and environmental factors, which affect the brain's ability to perceive or process verbal or non-verbal information efficiently and accurately (DSM-5, 2013, p. 68).

A specific learning disorder (SLD) is categorized under three subtypes including: SLD with impairment in reading, SLD with impairment in written expression, and SLD with impairment in mathematics (DSM-5, 2013, p. 68). An individual coded with an SLD with impairment in reading experiences difficulties in one or more of the following: word reading accuracy, reading rate or fluency, and/or reading comprehension. Individuals with SLD with impairment in written expression have difficulties in spelling accuracy, grammar and punctuation accuracy, and/or clarity or organization of written expression. Individuals, who experience deficits in number sense, memorization of arithmetic facts, accurate or fluent calculation, and/or accurate math reasoning, are likely to have an SLD with impairment in mathematics.

The World Health Organization (WHO, 2016) also adopted a similar approach to the DSM-5 (APA, 2013) by classifying learning disorders by subcategories. In particular, WHO's International Statistical Classification of Diseases and Related Health Problems 10th edition Version 2016 (ICD-10) defines specific learning disorders of scholastic skills as:

> Disorders in which the normal patterns of skill acquisition are disturbed from the early stages of development. This is not simply a consequence of a lack of opportunity to learn, it is not solely a result of mental retardation, and it is not due to any form of acquired brain trauma or disease (WHO, 2015, Chapter 5, para 9).

Specific learning disorders of scholastic skills have been categorized into 4 subtypes: specific reading disorder (i.e., impairments in reading comprehension skill, reading word recognition, oral reading skill, and performance of tasks requiring reading), specific spelling disorder (i.e., impairment in the ability to spell orally and write out words correctly), specific disorder of arithmetical skills (i.e., deficits in skills of addition, subtraction, multiplication, and division), and mixed disorder of scholastic skills (i.e., impairments in two or more of arithmetical, reading, or spelling skills).

To summarize, despite disparate categorizations from the 1960's to the present time, the LD or SLD definitions are generally accepted as involving brain-based dysfunction resulting in impairments in reading, spelling, written expression, and/or arithmetic.

Defining, Identifying, and Accommodating Students with LD in Canadian Provinces

The history of LD in Canada was first mapped by Judith Wiener and Linda Siegel in 1992. According to Wiener and Siegel (1992), LD was first recognized and conceptualized in the late 1950's by Edward Levinson, a psychiatrist working at the Montreal Children's Hospital. Levinson was perplexed when he encountered children experiencing significant academic challenges at school, but who appeared to be functioning with an average intelligence. As such, Levinson sought to find reasons behind the disparity between significant academic difficulties and average intelligence in those children. In order to try to explain their impairments and to explore effective treatments, Levinson collaborated with other psychologists in Canada and the US. Levinson established the Montreal's Children's Hospital Learning Centre, which ran collaboratively with McGill University's department of psychology to work with students experiencing significant academic barriers. The McGill-Montreal Children's Hospital worked towards supporting students with LD to reach their highest potential.

In particular, the McGill-Montreal Children's Hospital work was grounded in analyzing the needs, strengths, and issues of the whole child by taking into account the complex relationships between the child and family, as well as the interactions of the child within the classroom setting. Intervention plans were based on the following question: "How does the child learn best?" (Wiener & Siegel, 1992, p. 341). Through tailored-based academic support interventions at the McGill-Montreal Children's Hospital, children with LD were engaged with games, music, and playing cards designed to be both interesting and fun. Specialists at the centre believed in hands-on practice, insisting that staff members and interns gained "direct experience teaching children with learning disabilities" so that staff members were able to fully experience the difficulties exhibited by the child within their academic and home settings (Wiener & Siegel, 1992, p. 341).

Another milestone in the history of LD in Canada was the establishment of the Ontario Association for Children with Learning Disabilities (ACLD) in 1963, by four Ontarian parents: Doreen Kronick, Harry Wineberg, Robert Shannon, and Alan Howarth ((Wiener & Siegel, 1992). These parents founded and helped develop a provincial support network, advising other parents to have their children tested and followed by the McGill-Montreal Children's Hospital. By 1967, branches of ACLD were created in most Canadian provinces, and the national Canadian ACLD was formally incorporated in 1971. In 1981, the ACLD changed its name to the Association for Children and Adults with Learning Disabilities, and in 1986, they formally re-branded themselves as the Learning Disabilities Association of Canada (LDAC). One of the major contributions of the ACLD was to develop a definition for LD in 1981. Since 1981, the definition of LD continued to evolve. Today, the LDAC (2015, para 1–2) defines LD as follows:

> Learning Disabilities refer to a number of disorders which may affect the acquisition, organization, retention, understanding or use of verbal or nonverbal information. These disorders affect learning in individuals who otherwise demonstrate at least average abilities essential for thinking and/or reasoning. As such, learning disabilities are distinct from global intellectual deficiency. Learning disabilities result from impairments in one or more processes related to perceiving, thinking, remembering or learning. These include, but are not limited to: language processing; phonological processing; visual spatial processing; processing speed; memory and attention; and executive functions (e.g. planning and decision-making).

Additionally, the LDAC explains that LD varies in severity and may affect the "acquisition and use" of "oral language (e.g., listening, speaking, understanding); reading (e.g., decoding, phonetic knowledge, word recognition, comprehension); written language (e.g., spelling and written expression); and mathematics (e.g., computation, problem solving)." (LDAC, 2015, para 3). Moreover, the LDAC emphasizes that LD is biological in nature and is due to "to genetic and/or neurobiological factors or injury that alters brain functioning in a manner which affects one or more processes related to learning" (LDAC, 2015, para 6).

In Canada, approximately half (7 out of 13) of the provinces and territories — 4 provinces (i.e., Alberta, British Columbia, Ontario, and Saskatchewan) and 3 territories (i.e., Northwest Territories, Nova Scotia, and Yukon) — have partly endorsed or supported the LDAC's definition of LD (D'Intino, 2017). However, inconsistencies also exist across provinces in the ways that they have conceptualized the LD construct and offered accommodations to students with LD (D'Intino, 2017; Kozey & Siegel, 2008, Stegemann, 2016).

Saskatchewan, for example, defines LD as: "an individual's underachievement in reading, writing, and/or mathematics despite the presence of average to above average intelligence, appropriate instruction, regular school attendance, and favourable environmental factors" (Saskatchewan Learning, 2004, p. 10; D'Intino, 2017). On the other hand, Ontario defines LD as: "one of a number of neurodevelopmental disorders that persistently and significantly has an impact on the ability to learn and use academic or other skills" (Ontario, 2014, p. 1; D'Intino, 2017). While Saskatchewan's definition puts emphasis on environmental factors (e.g., instruction) in its definition of LD, Ontario focuses mostly on neurodevelopmental disorders to define LD.

Some provinces (i.e., Manitoba, Newfoundland–Labrador, Prince Edwards Island, and Quebec) do not use the term "learning disability," while other provinces and territories (i.e., Alberta, British Columbia, Ontario, Saskatchewan, Northwest Territories, Nova Scotia, and Yukon) continue to do so (D'Intino, 2017; Kozey & Siegel, 2008). In Quebec, students with neurological impairments are classified as being at-risk, as having severe behavioural disorders, or as having handicaps (Kozey & Siegel, 2008). At-risk students— which include students with learning difficulties, delays, disorders, or disabilities—are diagnosed "by their lack of progress toward goals established by the school regarding their learning, social development and qualification" (Kozey & Siegel, 2008, p. 166).

Similar to Quebec, Manitoba circumvents the LD construct in its policy documents and relies on the inclusive model. The focus is on diverse students who need additional support in succeeding and identifies: "students with exceptional needs…[as]…those who require specialised services or programming when deemed necessary by the in-school team because of exceptional learning, social/emotional, behavioural, sensory, physical, cognitive/intellectual, communication, academic or special health care needs that affect their ability to meet learning outcomes" (Manitoba, 2006, p. 5; D'Intino, 2017).

Clearly, both the definitions and conceptualizations for the spectrum of disorders encompassing LD are inconsistent across provinces. Similarly, there is no consensus in identifying, diagnosing, and accommodating students with LD across Canadian provinces (D'Intino, 2017; Kozey & Siegel, 2008; D'Intino, 2017). From their analysis of special needs education policy and legislation across provinces; D'Intino (2017), and Kozey and Siegel (2008) denounce the fact that most Canadian provinces continue to employ approaches such as the IQ-

Achievement DM to identify LD, since the IQ-Achievement DM is not considered reliable in diagnosing LD as documented by Restori et al. (2009).

Most recently, D'Intino (2017) reported that 7 out of 10 provinces and territories (i.e., Alberta, British Columbia, Northwest Territories, Nunavut, Ontario, Saskatchewan, and Yukon) employ an intelligence-achievement discrepancy model in diagnosing LD. British Columbia openly references the intelligence-achievement discrepancy model, where: "students with LD may demonstrate a significant discrepancy between estimated learning potential and academic achievement, as measured by norm-referenced achievement instruments" (British Columbia Ministry of Education, 2006, p. 47; Kozey & Siegel, 2008). Conversely, a minority of Canadian provinces — New Brunswick, Manitoba, and Nova Scotia— have adopted the Response-to-Intervention (RtI) model, which is usually a three-tiered identification and intervention system that offers support to students who are struggling academically.

There is also significant variability in accommodating students' particular needs throughout the Canadian provinces. For example, after analyzing policy documents on special needs education across provinces, D'Intino (2017) concluded that only 6 out of 10 provinces (e.g., Alberta, Saskatchewan, Quebec, New Brunswick, Prince Edward Islands) explicitly mention providing readers for students with specific needs. Moreover, some provinces and territories—especially British Columbia and the Yukon territory—outline detailed sets of accommodations required for students with special needs, in contrast to other provinces (e.g., Quebec). British Columbia and the Yukon territory offer accommodations, such as reading adaptations (audio-texts, electronic texts, text-to-speech reader), use of computer with word prediction and spell checker for writing assignments, alternative forms of assessment (e.g., oral and visual), graphic organizers, extended time provided for testing and assignments, direct instruction of study skills, extensive pre-teaching materials, and lower level reading materials (British Columbia, 2011; D'Intino, 2017). In contrast to British Columbia, Quebec and Ontario do not specify the need for all of these accommodations, omitting graphic organizers, direct instruction of study skills, alternative forms of assessment, and lower level reading material from their policy documents (D'Intino, 2017).

The lack of a unified Canadian definition of LD and consistency in the types of accommodations offered across provinces is problematic. For instance, students recognized in having an LD in certain provinces and receiving particular accommodation for their needs might not benefit from similar provision in another province. As such, students moving from one province to another may not be necessarily receiving the supports that they require in order to succeed. I, therefore, call upon a unifying Canadian definition of LD, as well as consistency in the types of accommodations offered to students with LD for their collective welfare and well-being. Such an initiative will prevent students with LD from facing unnecessary issues and hardships in fighting for their rights to certain accommodations when they move from one province to another.

Barriers Experienced by Students with Learning Disabilities in Learning Science

In addition to barriers related to identification of their LD and accommodation provision, it has been documented that students with disabilities face other challenges in their pursuit of STEM education. An analysis of the literature (as depicted in the Table of Appendix A) indicates that elementary and high school students with disabilities—including those with LD—experience cognitive difficulties within inquiry-based science classrooms as compared to their typically achieving peers, especially in terms of retrieving prior knowledge, engaging in critical thinking and reasoning, generating hypotheses, making predictions, and applying constructed knowledge to new contexts (Mastropieri, Scruggs, Boon, & Carter-Butcher, 2001; Scruggs & Mastropieri, 1994; Scruggs, Mastropieri, Bakken, & Brigham 1993). Moreover, students with LD and behavioural issues experienced more difficulties with reading and the comprehension of science texts as compared to their typically achieving peers (Parmar, Deluca, & Janczak, 1994).

Scruggs & Mastropieri (1994) observed elementary students with LD (*n* = 14; 8 students with LD and 6 students with mild mental retardation) in two inquiry-based science classrooms over a period of two academic years. The purpose of this study was to develop an in-depth understanding of how elementary students with mild disabilities construct their knowledge in an inquiry-oriented classroom that focused on environmental science concepts. The researchers found that students with LD exhibited particular difficulties with activities involving the sorting and classifying of variables, and also with activities requiring them to make predictive inferences, all of which are crucial skills needed for inquiry-based approaches. For example, elementary students with LD had difficulties sorting and classifying four types of seeds – bean, corn, peas and sunflower – on the basis of shape, texture, and colour.

In another study, Mastropieri et al. (2001) compared the academic outcomes of elementary students (grades 1 to 6)—including those with and without high incidence disabilities[6] (*n* = 51, 48 students with learning disabilities, 2 students with mild mental retardation, and 1 student with autism)—on cognitive tasks related to students' prior knowledge of scientific concepts, their understanding of key science concepts, and on their demonstration of inquiry skills (e.g., making predictions and drawing inferences) in an inquiry-based activity involving density and buoyancy. Findings indicated no significant differences in academic scores between typically achieving students and students with disabilities with higher IQ. To be noted

[6] High incidence disabilities are the "most prevalent among children and youth with *disabilities* in U.S. schools". and include students with emotional and/or behavioral disorders (E/BD), learning *disabilities* (LD), and mild intellectual *disability* (MID) (Gage, Lierheimer, & Goran, 2012)

that the authors did not provide specific details regarding definitions of higher and lower IQs. The authors concluded that students with disabilities with higher IQ performed as well as their typically achieving students in this particular inquiry-based curriculum unit. However, the academic scores of students with lower IQ were significantly lower on all aspects of the inquiry-based tasks as compared with students with higher IQ, and their typically achieving students. However, to only report that students with different IQ scores performed differently on inquiry-based tasks, is inadequate for us fully comprehend the challenges that students with disabilities were encountering while performing these hands-on tasks.

Furthermore, the study could have benefited from a qualitative analysis of the ways in which these groups of students (i.e., typically achieving students vs. students with high incidence disabilities with higher IQ) differed in their performance of the above-mentioned tasks. Through individual interviews, an in-depth comprehension of students' learning difficulties could have emerged. By understanding students' respective difficulties in their own voices, intervention-based strategies could be designed so as to effectively address any challenges that students with LD encountered while learning scientific concepts.

While these two studies provided insights into the inquiry-based task challenges experienced by elementary science students with LD, it is also important to explore how (e.g., lack of differentiated instruction) and why (i.e., deficits in memory, processing) these students experienced these challenges in the first place. To these ends, future research might examine the relationships between the cognitive characteristics (e.g., processing speed, working memory) of science students with LD and their performance on inquiry-based tasks involving making predictions, testing hypotheses, and drawing inferences. In this way, targeted interventions could consequently address specific cognitive deficits that students with LD experience in the classroom.

For example, if processing deficits negatively affect students' performance on specific inquiry-based tasks (e.g., designing experiments to test predictions, organizing data, and analyzing patterns), then specific strategies could be developed to improve their academic performance. For instance, simplifying complex processing tasks into discrete steps might help students to interpret science content more effectively. Based on my exploration of available studies, research addressing the cognitive issues experienced by college science students with LD is almost non-existent, and needs to be explored. As noted in Chapter 1, most of the intervention-based research to support the learning and academic achievement of students with LD focuses on inquiry-based interventions and peer-based tutoring strategies at the elementary and high school levels (see Mastropieri et al., 2006; Mastropieri, Scruggs, & Graetz, 2003; McDuffie, Mastropieri, & Scruggs, 2009; Simpkins, Mastropieri, & Scruggs, 2009).

As depicted in the Table of Appendix A, students with disabilities in STEM also encounter numerous environmental and social issues which affect their success in science. Hedrick, Dizén, Collins, Evans, and Grayson (2010) surveyed undergraduate students with disabilities (including those with LD) and reported that these students perceived their campus environment to be less supportive of their needs, and more conducive to meeting the needs of their typically achieving peers. However, Hedrick et al. (2010) did not specify in which ways the campus environment failed to promote these students' academic success (e.g., lack of accommodations or facilities for integrating students with disabilities). In addition to surveying the students with disabilities, in-depth interviews with students with LD could have broadened our understanding of the facilities and accommodations these students felt might be more favourable to their academic development and success.

In Hedrick's and colleagues (2010) study, students with disabilities also shared that the campus lacked initiatives to cultivate positive relationships between students with disabilities and their peers, faculty members, and university staff. Similarly, college students with disabilities including those with LD surveyed within other studies also reported difficulties in building good relationships with their peers (da Silva Cardoso et al., 2016; Jenson, Petri, Duffy, & Truman, 2011). Students with disabilities including those with LD felt that their typically achieving peers "were sometimes uncomfortable being honest with them because of their disabilities" (Jenson et al., 2011, p. 277). However, the authors did not specify which issues typically achieving peers were reluctant to discuss with students with disabilities.

In da Silva Cardoso's and colleagues (2016) study, students with disabilities including those with LD acknowledged their difficulties in constructing meaningful working relationships with their typically achieving peers, as the latter perceived them as "lazy" and "not good enough" to be in STEM programs (p. 379). Moreover, students with disabilities shared that their typically achieving peers perceived their rights to accommodations as being unfair (da Silva Cardoso et al., 2016).

Most recently, Thurston, Shuman, Middendorf, and Johnson (2017) reviewed several studies conducted by their own research group and other researchers on the challenges encountered by postsecondary STEM students with disabilities including those with LD, and best practices for educating these students in the US. Thurston's and colleagues (2017) concluded that students with disabilities including those with LD were underprepared to succeed within postsecondary science programs because they lacked exposure to challenging STEM curricula in middle school and high school. When students with disabilities enrolled in STEM programs in colleges and universities, they lacked support from their instructors, who were unwilling or unable to offer them academic assistance. The authors also found that STEM college and university faculty possessed insufficient knowledge and skills to effectively accommodate students with disabilities including those with LD (da Silva Cardoso et al., 2016; Thurston et al., 2017). While some colleges and universities offered tutors to support for students with disabilities including those with LD in their learning, the tutors lacked both specialized knowledge about students with disabilities as well as research-based adapted teaching and learning strategies within the STEM disciplines.

In a recent review of literature focusing on research conducted in science education for students with learning and other disabilities (from 1991 to 2015), the authors concluded that a majority of studies focused on intervention-based strategies related to higher education teaching and learning rather than on the issues encountered by science teachers and students with disabilities (Vavougios, Verevi, Papalexopoulous, Verevi, & Panagopoulou, 2016). Overall, although research on issues encountered by college-level students with LD remains sparse to non-existent, it is clear that several cognitive issues (e.g., reading deficits) and social factors (e.g., STEM faculty's insufficient comprehension of disabilities) impede the integration and academic success of these diverse learners.

Barriers faced by Science Instructors in Teaching Students with Learning Disabilities

It is to be noted that studies which focused exclusively on teachers' views about students with physical impairments, developmental disabilities, or mental-health issues in STEM were excluded from my literature review, and my review included only studies which focused on students with LD. Furthermore, studies focusing exclusively on teachers' perspectives surrounding students with LD in STEM programs are sparse to non-existent. Most studies exploring science instructors' perspectives in teaching students with LD included other types of disabilities as well (i.e., including physical impairments, developmental disabilities, and/or mental-health issues).

Nested within the microsystems of science classrooms, college instructors play a critical role in supporting diverse learners in their pursuit of science education. Yet, science instructors continue to face significant barriers in comprehending and addressing the unique needs of students with disabilities, including those of students with LD (Scruggs, Brigham, & Mastropieri, 2013). According to my review of the literature (summarized in the Table of Appendix B), science teachers regularly encounter the following barriers in cultivating an inclusive classroom environment and supporting their students with disabilities, including those with LD: insufficient knowledge in regards to understanding and teaching students with disabilities; insufficient knowledge about applicable laws surrounding educating students with disabilities; insufficient training on making science accessible for students with learning disabilities; a lack of confidence in teaching students with disabilities; time constraints in lesson planning for students with disabilities; insufficient support from the administration and special needs teachers in academically supporting students with disabilities; and negative beliefs and attitudes towards students with disabilities (Carlisle & Chang, 1996; Kahn & Lewis, 2014; Love et al., 2014; Moin, Magiera, & Zigmond, 2008; Mumba, Banda, Chabalengula & Dolenc, 2015; Ngubane-Mokiwa & Khoza, 2016; Norman, Caseau, & Stefanich, 1998; Robinson, 2002; Spektor-Levy & Yifrach, 2017; Stefanich, Norman, & Egelston-Dodd, 1996).

In the following sections, I expand on and discuss four major barriers that were constantly reported across the relevant literature; these barriers include lack of knowledge and understanding in teaching students with disabilities, negative beliefs and attitudes towards students with disabilities, insufficient training on making science accessible for students with disabilities, and the lack of support from the administration in academically supporting students with disabilities (Carlisle & Chang, 1996; Kahn & Lewis, 2014; Love et al., 2014; Moin et al., 2008; Mumba et al., 2015; Ngubane-Mokiwa & Khoza, 2016; Norman et al., 1998; Robinson, 2002; Spektor-Levy & Yifrach, 2017; Stefanich et al., 1996).

Inadequate knowledge and skills

Most empirical studies suggest that elementary, secondary, and university science teachers do not possess adequate knowledge and skills to teach students with disabilities, which consequently impedes the learning process of their students (Kahn & Lewis, 2014; Love et al., 2014; Moin et al., 2008; Mumba et al., 2015; Ngubane-Mokiwa & Khoza, 2016; Norman et al., 2018; Spektor-Levy & Yifrach, 2017; Stefanich et al., 1998). Insufficient knowledge (a) in understanding the needs of students with disabilities (Spektor-Levy & Yifrach, 2017), (b) on the availability and types of teaching resources for students with disabilities including those with LD (Love et al., 2014; Ngubane-Mokiwa & Khoza, 2016), and (c) on effective specialized teaching strategies (Kahn & Lewis, 2014; Love et al., 2014; Moin et al., 2008; Mumba et al., 2015; Ngubane-Mokiwa & Khoza, 2016; Norman et al., 2018; Spektor-Levy & Yifrach, 2017; Stefanich et al., 1998) were identified as central barriers in teaching students with disabilities.

More than 85 % of high school science teachers claimed to be inadequately prepared to (a) design, select, and modify activities for students with disabilities including those with LD; and (b) modify assessment strategies (e.g., testing and assessment formats) for students with disabilities including those with LD (Norman et al., 1998; Stefanich et al., 1996). Using the same survey questionnaire, Kahn and Lewis (2014) replicated Norman's et al. (1998) and Stefanich's et al. (1996) study. Similarly, Kahn and Lewis (2014) found that the majority of surveyed science instructors (K-12) reported that they were not well-prepared (69 %) to design, select, and modify activities for their students with disabilities including those with LD.

An even higher percentage of high school science teachers (approximately 90 %) reported difficulties in adopting a diversity of metacognitive strategies (e.g., supporting students with disabilities to develop self-awareness, self-questioning, self-monitoring, and self-reinforcement techniques) to support the learning of their students with disabilities including those with LD (Norman et al., 1998; Stefanich et al., 1996). Consistent with Norman's et al. (1998) and Stefanich's et al. (1996) study, Kahn and Lewis (2014) reported that more than three-quarters (82 %) of surveyed science teachers felt they were ill prepared to incorporate metacognitive strategies in their teaching strategies. Spektor-Levy and Yifrach (2017) also found that middle school science teachers lacked the understanding and skills needed to choose and implement effective teaching strategies for students with LD, as well as to differentiate science curricula by using multiple teaching materials to meet the needs of diverse learners. These studies suggest that secondary science instructors still lack appropriate background knowledge of differentiated teaching strategies needed to assist their students with LD in learning science.

At the university level, Love et al. (2015) reported that science professors faced challenges in adapting their pace of instruction to suit the individual needs of their students with disabilities including those with LD. Another common issue among university science faculty was their difficulty in implementing multiple means of instruction (e.g., recorded lecture notes, videos, and more frequent use of graphics) (Love et al., 2015). Ngubane-Mokiwa and Khoza (2016) attributed STEM lecturers' barriers in supporting the inclusion of students with disabilities to their lack of knowledge of important learning theories (e.g., constructivism), which would enable them to better adapt their science classrooms for diverse learners. Moreover, STEM lecturers seem to be unaware of the types of technologies available and ways to integrate technologies to support the learning process for students with disabilities in their science classrooms.

Negative Beliefs

Researchers have noted that both elementary and secondary school science instructors sometimes hold prejudices about students' abilities based on students' cognitive deficits (Carlisle & Chang, 1996; Kahn & Lewis, 2014; Norman et al., 1998). In a study by Norman, Caseau, and Stefanich (1998), approximately 50 % of K-12 science teachers felt that students with disabilities including those with LD prevented them from teaching typically achieving students, while 55.9 % of science teachers acknowledged that they had used students' disability as an excuse to explain students' failure (Norman et al., 1998). Other researchers reported that science teachers underestimated the academic abilities of their science students with LD (Carlisle & Chang, 1996). For instance, in a longitudinal study spanning three years, Carlisle and Chang (1996) concluded that elementary science teachers "consistently rated their students with LD as having significantly less adequate learning capabilities" (p. 18) compared to their typically achieving peers, and continuously assessed these students as being less capable of high levels of achievement.

To overcome their negative beliefs about students with disabilities including those with LD, around 80 % of elementary and secondary level science teachers in Norman et al.'s (1998) study acknowledged their need for further training. Most recently, Kahn and Lewis (2014) also confirmed that a majority (75 %) of K-12 science teachers believed that they required additional training to mitigate their biases and emotional issues in teaching students with disabilities including those with LD. However, there is a paucity of training opportunities for science instructors in these areas as discussed in the section below.

Lack of training

Science instructors' lack of training and experience in teaching science to students with disabilities including those with LD has been consistently reported as a major barrier within the US and South Africa (Kahn & Lewis, 2014; Love et al., 2014; Moin et al., 2008; Mumba et al., 2015; Ngubane –Mokiwa & Khoza, 2016; Norman et al., 1998; Spektor-Levy & Yifrach, 2017). Alarmingly, all surveyed high school chemistry teachers in a recent US study claimed they had received no training in special education or inclusive teaching practices to meet the needs of their students with disabilities including those with LD (Mumba et al., 2015). Spektor-Levy and Yifrach (2017) reported that most science teachers had not been equipped with effective instructional strategies to be able to effectively construct inclusive science classrooms for their students with disabilities including those with LD.

Additionally, another study has raised concerns regarding a lack of training for co-teaching students with LD (Moin et al., 2008). As a result, conflicts and tensions are common between special education teachers and general education teachers in science classrooms (Moin et al., 2008). In their study, Moin et al. (2008) reported that special education teachers felt they were regularly pressured by general education teachers to employ traditional science teaching materials and felt unable to effectively differentiate science materials for their students with LD (Moin et al., 2008). In turn, general education teachers believed that special education teachers lacked sufficient knowledge of the science content, and would be unable to effectively adapt science curricula for students with LD (Moin et al., 2008). These findings suggest that teachers engaged in co-teaching may need additional training in order to be able to work collaboratively for the welfare of their students with LD.

As emphasized by Norman et al. (1998), to effectively teach students with disabilities including those with LD, elementary and secondary school instructors rely on training from university science educators. Yet, more than 75 % of university science educators are unprepared to support pre-service teachers in differentiating the science curriculum to make it more accessible for students with disabilities including those with LD (Norman et al., 1998). Approximately 80 % of university science educators confessed to feeling unprepared to support pre-service teachers in (a) designing, selecting, and modifying activities for students with disabilities; (b) modifying assessment; and (c) using metacognitive strategies to support the learning processes of students with disabilities including those with LD. As a result, Norman et al. (1998, p. 135) raise an important question: “If so many university educators feel inadequately prepared to address teaching science to students with disabilities with preservice teachers, where will the preservice teachers gain this important training?”

Echoing the findings from Norman’s et al. (1998) study, Kahn and Lewis (2014) reported that college and graduate teaching programs do not adequately cover important topics such as testing accommodations, individualized education programs, or co-teaching practices for students with disabilities including those with LD. Kahn and Lewis (2014) highlighted that 70 % of K–12 science teachers did not receive formal training geared towards teaching students with disabilities including those with LD in their educational programs. Most of these teachers relied “on the job” training to learn the skills to teach students with LD. These findings suggest the need to further examine teaching programs and infuse these programs with effective research-based practices in teaching science to students with disabilities including those with LD.

Within the university settings, most science faculty confessed to not being trained in making science accessible for their students with disabilities including those with LD (Love et al., 2014; Ngubane-Mokiwa & Khoza, 2016). Although most of the university science instructors expressed their needs for more training in accommodating their students with disabilities including those with LD , they voiced their uncertainties in accessing services (i.e., who to contact and what services are offered) that provide professional development in special needs and inclusive education (Love et al., 2014). These findings suggest that university administrators may need to take a more active role in creating guidelines and informing university instructors about available training opportunities in teaching students with LD.

Insufficient Teaching Supports

Science teachers often did not feel supported by their institutional administrations in their attempts to offer educational equity to students with disabilities including those with LD (Love et al., 2014; Moin et al., 2008; Norman et al., 1998; Spektor-Levy & Yifrach, 2017). As reported by Spektor-Levy and Yifrach (2017), high school science teachers believed that school administrators had little interest in science accessibility for students with LD. Approximately 68 % of high school science teachers reported that their administration (i.e., school principals, subject coordinators) did not support them in either managing inclusive science classrooms, or in adopting specialized teaching methods for students with LD (Spektor-Levy & Yifrach, 2017). Similarly, at the university level, STEM faculty deplored the lack of information about available resources from university administrations (i.e., services offered by the technology office, and institutional disability office) to assist them in effectively teaching students with disabilities including those with LD (Love et al., 2014).

Gaps and Future Directions for Research Studies in Science Education for Students with LD

According to my review of the literature, most of these studies seemed to have mainly relied on quantitative approaches (i.e., surveys) to investigate the difficulties in teaching and learning science with regards to students with LD. Hartley and Muhit (2003) argued that "the social aspects of disability have been ignored and under investigated" (p. 107). Therefore, future studies might consider drawing on qualitative approaches (e.g., interviews) to listen to the unheard voices of stakeholders (i.e., students with LD, STEM instructors) on social issues that impact their lives. As positioned by Banyard and Miller (1998), qualitative approaches invite us to fully document the diverse perspectives of social agents rather than focusing on a more generalized viewpoint, which is the aim of quantitative approaches.

For example, currently, quantitative studies indicate that science instructors experience difficulties in differentiating science instruction for students with LD. However, it is not clear whether science instructors encounter difficulties to implement differentiated teaching strategies for all students with LD or those with particular deficits (e.g., reading issues). We are also unaware whether science instructors encounter difficulties to teach all topics in biology, chemistry, and physics, or only certain specific topics which present more challenges to differentiate than others for science students with LD. By employing a qualitative approach, a deeper comprehension surrounding the lack of knowledge on differentiated teaching strategies could be obtained. As such, professional development programs can be geared towards supporting teachers in effectively teaching students with particular difficulties (e.g., reading or processing issues) in specific science topics (e.g., mitosis and meiosis).

By capturing the voices of participants through interviews, the diversity of their perspectives can be represented such that individual views are valued and their unique needs and issues are addressed (Banyard & Millar, 1998; Danforth, 2006; Crane, 2017). Specifically, qualitative studies give voice to silenced individuals and allow “people in the community to direct the research so that it reflects their perceptions and needs, and not just those of the researcher” (Hartley and Muhit, 2003, p. 107). Such is the aim of the thesis which is geared towards documenting the multiple perspectives of both science students with LD and their instructors at Mountain CEGEP.

With an increasing number of students with LD accessing postsecondary education, it has become even more crucial to create a platform for them to express their diverse needs. Simultaneously, it is critical that researchers learn from individuals with LD, who should be viewed as “complex and competent,” as they are engaged to discuss their issues in their own authentic voices (Baglieri, Valle, Connor, & Gallagher, 2011; Danforth, 2006; Crane, 2017). By closely listening to the voices of students with LD, new knowledge might emerge on issues that they face in accessing science, and ways to best support their retention and success in STEM fields. For example, none of the above reviewed articles indicated the science topics (e.g., genetics, microbiology, electricity and magnetism, etc.) in which science students with LD experience difficulties to learn. For my doctoral study, I aim to document the science topics in which students with LD struggle. As such, intervention-based strategies could be designed and implemented to address issues encountered in the specific topics identified by CEGEP science students as challenging.

Moreover, studies on science students with disabilities have mostly been conducted in the US. A comprehensive understanding of the issues encountered by science teachers and by students with LD in STEM programs remains to be demystified in Canada. To the best of my knowledge, no comprehensive studies have been conducted in Quebec's CEGEPs to explore the issues that science instructors and students with LD face in teaching and learning science respectively. Quebec's CEGEPs present a distinctive microsystem by offering students two-year pre-university programs, thereby supporting students to complete some undergraduate programs in 3 years within Quebec's universities as compared to the four-year undergraduate programs in other Canadian provinces. Overall, CEGEP programs, comparable to 12^{th} grade and first year of university in the rest of North America, have a unique science curriculum, which differs from other Canadian provinces. As such, while learning science in the context of CEGEP classrooms, students with LD might experience unique challenges which need to be explored. As mentioned earlier, because an increasing number of students with LD are gaining access to CEGEP classrooms (Beaumont & Lavallee, 2012; Bonneli, Ferland-Raymond, & Campeau, 2010; Ducharme & Montminy, 2012; Havel et al., 2017), our comprehension of issues experienced by this unique population needs to be deepened, and eventually addressed through effective practices to support their success and retention in STEM programs.

As previously discussed, this dissertation addresses some of the gaps articulated above by exploring science instructors' difficulties in teaching their students with LD, and issues encountered by students with LD in learning science within the CEGEP settings. By exploring the views of CEGEP science instructors, this thesis will provide a better understanding on whether Canadian instructors face similar or different issues as compared to their counterpart in the US and other parts of the whole. Moreover, this dissertation draws on multiple voices (i.e., special needs educator, science instructors, and science students with LD) to construct a comprehensive understanding of key barriers impacting science instruction and learning for science students with LD. By comparing and contrasting the perspectives of multiple stakeholders (i.e., special needs educator, science instructors, and science students with LD), this thesis aims to provide insights into the most critical barriers impacting the teaching and learning practices for science students with LD.

In the next chapter, I explore my own voice as a special needs educator and biology instructor on barriers that I have witnessed students with LD experience within CEGEP science programs. Equally important, I also express my views on difficulties that CEGEP science instructors face in teaching their students with LD.

Chapter 3 (Manuscript 1): An Autoethnographic Exploration of Disability Discourses: Transforming Science Education and Research for Students with Learning Disabilities

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Abstract

In this autoethnographic inquiry, I examine the dominant disability discourses (e.g., the medical and social models of disability) that inform practice and research in science education for individuals with disabilities. Specifically, guided by my experience as a practitioner-researcher, I use reflexive vignettes and photovoice to discuss and critique disability discourses that construct students with LD as disadvantaged learners. Drawing on empirical observations and interview data from instructors and students, and coupled with reflexive vignettes, and photovoice; I also discuss the difficulties that students with LD face in becoming successful science learners, and the issues CEGEP science instructors encounter in teaching these students. In sum, disability discourses, such as the medical model of disability, pathologize students with LD by focusing on their individual deficits and blaming them for their academic struggles and failure in science. Moreover, because of their disability labels, students feel that their instructors perceive them negatively and hold prejudiced views regarding their abilities. In contrast to the medical model, the social model of disability situates the problem solely within the students' environment (e.g., teaching strategies) and does not consider the individual's innate issues (e.g., cognitive deficits). From a social model perspective, CEGEP instructors experience challenges in differentiating science instruction for students with LD, impacting these students' engagement and learning in science. By navigating through these discourses, I found my voice as a practitioner-researcher in Bronfenbrenner's (2005) ecological model, which recognizes that an individual's barriers stem

not only from their characteristics but also from their complex, multi-layered environment. This article, embedded within a reflexive process, describes my journey of self-transformation as a practitioner-researcher while bringing educational change to the academic lives of my students with LD.

Keywords: *Barriers, CEGEP science instructors, Students with Learning Disabilities, Medical Model of Disability, Social Model of Disability, Bronfenbrenner's Ecological Model*

Introduction

> I cannot drop the feeling that this matters. It seems so important, what we are doing here for these people: to give them what they need most, to provide them what is most indispensable for their bare survival. This is what makes a difference in people's lives, and isn't that what it is all about: to make a difference? (Hemelsoet, 2014, p. 220)

In 2009, I began to work as a science and math special needs educator in the Office for Students with Disabilities (OSD) at a college in Montreal, Quebec. My tasks involved assessing the psychoeducational reports of students with special needs to provide them with the necessary accommodations (e.g., note-taker) to support their learning. I was also responsible for designing and conducting individualized remedial tutorials for students with learning disabilities (LD) to help them in learning science and math.

As the semesters went by, I found that the majority of students with LD were struggling or failing in science. Each semester, students with LD were dropping out of the science programs and embracing other fields of study (e.g., computer science). The disappointment and sadness were evident in their voices as they told me that science was no longer for them. As a biologist (with a Master's degree in Animal Science), I could fathom their sentiments of having their beloved science snatched away from them. Their dreams of becoming – medical doctors, veterinarians, or engineers – were crumbling.

I felt that these students deserve to be understood and supported to pursue their studies in science. I was determined to make a difference in their academic lives. As such, I kept asking: What academic struggles do students with LD face in learning college science? How can we[7] support these students in overcoming their struggles and in enjoying success in science? I began exploring the literature on students with disabilities in science education to comprehend their academic barriers. To my disappointment, studies researching barriers faced by students' with LD were very sparse in the science and special education literature. In fact, the term *learning disability* is rarely found in science education literature, as pointed out by Brigham, Scruggs, and Mastropieri (2011). These authors discussed that the *Handbook of Research on Science Education* by Abell and Lederman (2007), which is the "holy grail" in science education, "omits the term learning disability from the index describing over 1,300 pages of text devoted to science education" (p. 224).

Disappointed with the lack of research on students with LD in science, I embarked on my doctoral journey in 2011, determined to listen to voices of students with LD on obstacles that imped their learning in science. Being a 'critical' and 'interpretivist' researcher, I could not ignore that "a researcher's own individual mind-set, bias, skills, and knowledge become an intrinsic part of the research process" (Knight & Cross, 2012, p. 44). As I engaged in the research process, I realized that I was also "part of the world being studied" (Knight & Cross, 2012, p. 44) because I was constantly interacting directly with students with LD on a daily basis to understand their difficulties and support them academically. My practical experiences—as a

[7] I am referring to teachers, administrators, and special needs educators.

special needs educator and a biology teacher working with students with LD—were central and influential in adopting a particular disability discourse to inform my doctoral study. For example, embodied in my role as a special needs educator (from 2009–2014), I solely focused on specific disability types that these students exhibited when I provided them with their necessary accommodations. As such, I found myself positioned within the medical model of disability, which views learning disability as a brain-based pathology. This model attributes the academic failure of students with LD *mainly* to their disability, while ignoring other issues (e.g., classroom practices) that could potentially explain their academic struggles.

As I conformed to my role as a college biology teacher in 2015, I found myself listening to voices of students with LD and transforming my classroom practices to favour their academic success. No longer did I feel that their learning disability was the sole cause of their failure. As such, I found myself aligning with the social model of disability, which attributes the academic failure of students with LD to the lack of accommodation in educational institutions. Yet, stemming from my practice, I also witnessed the limitations of the social model of disability as discussed later in this manuscript. Noting the limitations of both models, I embarked on a journey to embrace a theoretical lens that offers a comprehensive and holistic understanding of the confounding issues experienced by students with LD. I found my voice in Bronfenbrenner's (2005) ecological model, which allowed me to make sense of a diversity of issues that students with LD face in learning science.

In this autoethnographic inquiry, I draw on my experiences as a practitioner-researcher to reconstruct my doctoral journey. Specifically, I explore the evolution of my research project as I, the practitioner-researcher, navigated across and experienced the diverse disability discourses, including the medical, social, and ecological models of disability. Through this tumultuous academic navigation, I have become an agent of change, transforming my teaching practice to favour an inclusive approach that focuses on diverse science learners through the adoption of Bronfenbrenner's (2005) ecological model. Specifically, the Bronfenbrenner's (2005) ecological model invited me to focus both on the within-individual needs of my students with LD during tutorials, and also to use multiple means of instruction, engagement, and assessments in my classroom to meet the academic needs of my diverse learners. By adopting Bronfenbrenner's (2005) ecological model as a research lens, I was able to make sense of both within-individual and environmental barriers encountered by students with LD in science classrooms.

Embodying Autoethnography: Connecting the Practitioner to the Researcher

Autoethnography is an "autobiographical genre of writing and research" that embeds "multiple layers of consciousness" by connecting the personal to the social, cultural, and political (Ellis, 2004, p. 37). As such, autoethnography offers a "unique window through which the external world is understood" (Stanley, 2015, p. 148). In this inquiry, I specifically focus on the analytical and evocative forms of autoethnography to reconstruct my lived experiences.

Analytical autoethnography invites me to position myself as a "complete member researcher" and "make myself visible explicitly in the text" by openly discussing my personal views and experiences regarding disability issues (Anderson, 2006; Weaver-Hightower, 2012, p. 463). In particular, I "textually acknowledge" and "reflexively assess" the ways in which I, the practitioner-researcher, have transformed my views, practices, and understanding of science students with LD in college settings (Anderson, 2006, p. 385). Analytical autoethnography also invites me to "use empirical data to gain insight into some broader set of social phenomena than those provided by the data themselves" (Anderson, 2006, p. 387). Similar to Weaver-Hightower (2012), I have drawn on interview data from science students with LD on academic barriers affecting their learning. Moreover, I have embedded arguments from the broader literature on disability discourses, special needs, and inclusive education.

As mentioned earlier, I also form part of the “world” that I am studying as I work closely with students with LD as a special needs educator and a teacher. As such, in this inquiry, I draw on evocative autoethnography to include my “sensory and emotional” experiences while reflecting on disability discourses and working with students with LD (Ellis, 2004, p. 46). I experienced grief and sadness when my students with LD shared their distress of being trapped within the medical model of disability. I also expressed joy when my students with LD overcame their difficulties and succeeded academically. I have used written texts, my reflection logs as a special need educator and my teaching dairies, to construct reflexive vignettes. Reflexive vignettes represent vivid portrayals of daily events that elicit strong and powerful emotions and understanding from the readers (Humphreys, 2005). Data in the form of photographs taken by students in my classrooms and during tutorials were used in “a process of emotional recall” that provided access to lived emotions and events that occurred at a particular point in time (Ellis, 1999, p. 675).

By using an autoethnographic lens, I reveal my vulnerable self and my intimate thoughts on the ways that disability discourses have shaped my experiences as a practitioner-researcher, and in turn affected my students with LD in their construction of their identities as learners.

The Medical Model of Disability: An Outsider's Perspective

> Learning disability is neurological, physical and cellular. Let us not forget this basic fact, for it is a truism, and it should be the rock upon which all else in this field is built (Cruickshank, 1971, p. 73)

Drawing on a medical perspective, the brain is the site for several activities (e.g., perception, memory, emotion, and ideation), which are termed as brain-based functions. As such, any deficits within those activities (e.g., memory) might affect normal brain-based functioning, and lead to brain-based disorders that negatively affect individuals' lives (Anastasiou & Kauffman, 2013). Through valid psychometric tests (e.g., Wechsler Intelligence Scale for Children (WISC)), areas of their strengths and weaknesses in cognitive process skills (e.g., measured as the verbal comprehension index, visual spatial index, fluid reasoning index, working memory index, and the processing speed index) can be identified (Wechsler, 2014). Research studies have attempted to establish a relationship between deficits in cognitive functioning (working memory, processing speed) and learning or academic achievement in math and reading (Alloway, 2009; Daneshamooz, Alamolhodaei & Darvishian, 2012; Siegel & Ryan, 1988; Swanson & Kim, 2007; Vellutino, Scanlon & Lyon, 2000; Zentall & Ferkis, 1993). Empirical studies have shown strong relationships between such cognitive difficulties (e.g., working memory[8]) and learning abilities (Alloway, 2009; Daneshamooz, Alamolhodaei, & Darvishian, 2012). For example, research has demonstrated that working memory capacity is positively correlated to academic scores in mathematics, and is also a strong predictor of learning outcomes in mathematics for children with LD (Alloway, 2009; Daneshamooz, Alamolhodaei, & Darvishian, 2012).

[8] Working memory is the ability to remember and use relevant information while being engaged in an activity. For example, students use their working memory as they recall steps of a math problem while simultaneously solving the math problem.

Most countries collectively draw on a medical framework and explain LD as brain-based disorders. For example, the ministries of education in most Canadian provinces (e.g., British Columbia, Alberta, Nova Scotia, and Ontario, amongst others) define LD as a "neurobiologically-based medical or disease condition, which is either caused by, associated with, or results in any number of cognitive processing deficits" that affect learning and well-being of individuals (D'Intino, 2017; Kozey & Siegel, 2008, p. 169). Similar to the above-mentioned provinces, the Learning Disabilities Association of Canada (2015) employed a medical framework to define LD as "impairments in one or more processes related to perceiving, thinking, remembering, or learning. These include, but are not limited to: language processing; phonological processing; visual spatial processing; processing speed; memory and attention; and executive functions (e.g., planning and decision-making)" (para 2).

These definitions ground learning disability in the medical model of disability/deficit model such that LD is understood as a "within-child disorder arising from neurological or psychological-process impairment" and that any academic difficulties experienced by the students are solely due to the consequences of their impairment (Algozzine & Sutherland, 1977; Chappell, Goodley, & Lawthom, 2001; Chrestensen & Baker, 2002, p. 74; Crane, 2017; D'amato, Crepeau-Hobson, Huang, & Geil, 2005; Pearson et al., 2016). Specifically, operationalizing LD from the medical model of disability relies on neuropsychological assessments to identify areas of deficits within the child and an intervention process to remediate the deficits within the child (Chrestensen & Baker, 2002; Crane, 2017; D'amato et al., 2005).

In science education, a sparse number of studies have drawn on the medical model of disability to explore difficulties that students with LD experience as compared to typically achieving peers (Mastropieri, Scruggs, Boon, & Carter, 2001; Scruggs & Mastropieri, 1994). For example, Scruggs & Mastropieri (1994) observed elementary students with LD (*n* = 14; 8 students with LD and 6 students with mild mental retardation) in two inquiry-based science classrooms over two academic years. The purpose of this study was to develop an in-depth understanding of how elementary students with mild disabilities construct their knowledge in an inquiry-oriented classroom that focused on environmental science concepts. Among various activities, students constructed their understanding of organisms and their environment by setting up terrariums to study responses of beetles to various environmental variables. These researchers found that students with LD exhibited particular difficulties in sorting, classifying and making predictions or inferences which are key aspects of inquiry-based approach. These studies (i.e., Mastropieri, Scruggs, Boon, & Carter, 2001; Scruggs & Mastropieri, 1994) have collectively demonstrated that students with LD experience significant cognitive difficulties in reading science texts, retrieving prior scientific knowledge, engaging in critical thinking and reasoning during science activities, generating hypotheses, making predictions during science experiments, and applying constructed scientific knowledge to new contexts.

As such, to support these students' academic achievement and retention in education, the ministries of education in various Canadian provinces warrant that students with suspected cognitive deficits undergo diagnosis by medical experts and be identified as having a learning disability to receive special accommodations by their educational institutions (D'Intino, 2017; Kozey & Siegel, 2008). Several accommodations are provided to students to support them in their learning, such as: extra time to complete assessments, computers for writing tests, note-takers or scribes, and writing exams in a room with reduced distractions (Larochette & Harrison, 2012). Offering accommodations and remedial support are also in line with the philosophy and practice of the medical model of disability (D'amato et al., 2005; Goodley, 2001). Specifically, accommodations are synonymous to "medical treatments" offered to the child to remediate his/her disorders. D'amato and colleagues (2005) argued that the treatments offered to students with LD produce mixed-results and do not always guarantee their academic success.

Medicalizing Disability: Oppression of Science Students with LD?

As highlighted by Guzman (2009), and Smith and Buchannan (2012), the office for students with disabilities (OSD) follows a medical model for the accommodation processes. As a special needs educator working in the OSD, I felt that the medical model of disability contributes significantly to the academic success and mental well-being of students with LD. Being labelled as having an LD support the students in being offered the accommodations to help them in their learning. However, my meeting with Zeal, a first-year college student with LD, changed my perspective such that I felt that the medical model of disability might also have a negative impact on students' mental well-being. As the following vignette demonstrates, being identified as having an LD and disclosing their accommodations, are sources of continuous stress and tension for these students.

Vignette 1: Why should you send them my accommodation letter?

Zeal, a first-year college student, met with me to set up his accommodations. Given that he experienced processing deficits, his psychologist recommended accommodations such as extra time for completing his assessments and a computer for test-taking. During our meeting, Zeal explained that he experienced difficulties taking notes while teachers explained concepts. He felt that the teachers explained concepts at an extremely fast pace and that he took too much time to process and write down the information. I felt a note-taker would be helpful to fill in the gaps of missing information in Zeal's notes. As we concluded our session, he looked happy and excited that he would receive the support he needed. I assured him that I would send his accommodation *letter to his teachers. After hearing that, Zeal looked upset and scared. He told me: "Why do they need to know about me? Why should you send them the accommodation letter? It will be high school all over again. They will blame me when I don't get it. They will say it's because of my disability. . . . I want to be treated like others. I want to get the support without them knowing that I am registered with the OSD and that I am abnormal." (Personal notes, special needs educator reflection log, Fall semester 2012)*

Like Zeal, many students whom I met during my career as a special needs educator, were uncomfortable that their teachers and other people might be aware of their issues and accommodations. My experience with such issues resonates with research findings, which showed that attributing the LD label to students makes them feel vulnerable (Lyons & Roulstone, 2016). Because they believe that they are "not intelligent" or "smart", students with LD tend to develop lower self-confidence and self-concept as compared to their peers without LD (Lyons & Roulstone, 2016). To make matters worse, terms such as *special needs*, *learning disability*, and *accommodations* have shown to invoke pity and sorrow from society, thus negatively affecting students' views of themselves and of their abilities (Lyons & Roulstone, 2016).

In order to foster positive attitudes among my students with LD, I explained to them the benefits of teachers knowing about their accommodations (e.g., teachers could offer tailored, one-on-one academic support to them during office hours). Still, they insisted that not all science teachers would view them positively. They shared that their science teachers in high school discouraged them from pursuing science. Similar to my students' experiences of being oppressed, Liz Crow, an artist-activist with a physical disability, shared her heartbreaking story of having her accommodations withdrawn by the university where she was a medical student. Consequently, she failed her exams and was kicked out of university:

> I was kicked out of uni[versity] for being a cripple. I was up front about what I needed when I started, but half way through the year they withdrew my provision so I couldn't take my exams, and therefore, failed on a technicality. I was a medical student and if you peel back the layers, there wasn't a fit between me and the course from the university's perspectives (Crow, 2009, para 10).

In my role as a special needs educator, I have also encountered some physics and math instructors who viewed students with LD negatively and refused to offer them accommodations (i.e., extra time on quizzes) recommended by the Office for Students with Disabilities. They also questioned the validity of their students' disabilities. For example, some teachers asked me: "Does that student really have anxiety? She is always smiling and looks very happy." At times, I felt very frustrated with the instructors who doubted the validity of the students' respective disabilities.

Research has also demonstrated that science educators have negative attitudes towards students with disabilities including those with LD (Carlisle & Chang, 1996; Norman, Caseau, & Stefanich, 1998; Thurston, Shuman, Moddendorf, & Johnson, 2017). For example, some science educators felt that "it is unrealistic to expect a blind student to be a chemist" (Norman et al., 1998, p. 137). Contrary to these educators' beliefs, "there are in fact many blind chemists" (Norman et al., 1998, p. 137), which indicates that our society has serious misconceptions about the abilities of individuals with disabilities. Such negative societal views about individuals with disabilities have been influenced by the medical model of disability, which has medicalized disabilities and illness such that individuals with disabilities have been portrayed as problematic by society (Oliver, 1990; Goodley, 2001). Simon Brisenden (1986), a philosopher and poet with a disability, explained that the medical model is to blame for portraying people with disabilities as weak, pathetic, and in need of constant sympathy from “normal” individuals. This model has presented individuals with disabilities as physically and intellectually dysfunctional and in need of constant medical supervision (Brisenden, 1986).

Individuals with disabilities and some researchers have argued that the medical model puts its entire emphasis on “within-child factors, stressing the impairment and underplaying, even ignoring, the environmental factors” (Lindsay, 2003, p. 5; D’amato et al., 2005). On the contrary, LD is a result of interaction between genetic and environmental factors (D’amato et al., 2005; Gilger & Kaplan, 2001). Specifically, learning disabilities might be due to “the result of situations rather than attributes of individuals across situations” (Roth & Barton, 2004, p. 133). Many individuals with disabilities also believe that it is equally important to consider contextual issues within society which contribute to their impairment. The academic performance of students with LD might be affected by contextual factors (e.g., teaching strategy) rather than cognitive deficits, as shown in classical studies conducted by McDermott (1993); and Roth and Barton (2004).

Roth and Barton (2004) explored how an authentic science activity related to a real-life problem (e.g., pollution impacts on a creek) affects science learning. These researchers observed that one of the participants (Davie), a 13-year-old student, had severe writing problems and ADHD, and was performing below average in math and science in regular classroom. However, with the authentic science learning approach, Davie emerged as a highly literate science student instead of a science failure diagnosed with LD. In addition, Davie was helping his typically achieving students with the inquiry-based activities at the creek. It is clear that Davie’s difficulty in learning science was not due to his disability, as was portrayed by the medical model of disability. Instead, Davie's problem was located in the science teaching approach employed by his teacher.

Such views resonate with the social model of disability, which postulates that LD is socially constructed and "caused by the inflexibility of the school system and by its inability to meet the diversity of children" (Terzi, 2005, p. 447). Below I describe and discuss the social model of disability, and explain how the social model of disability guided my teaching practice and discuss its limitations as a practical and research lens.

Understanding Disability from the Insider's Perspective: The Social Model of Disability

> It wasn't my body that was responsible for all my difficulties, it was external factors, the barriers constructed by the society in which I live. I was being dis-abled—my capabilities and opportunities were being restricted—by prejudice, discrimination, inaccessible environments, and inadequate support. (Crow, 1996, p. 2)

In June 2013, I came across an article by Liz Crow, who advocates for disability rights through her films and public performances. Her article, which resonates with the social model of disability, offered me the opportunity to make sense of how individuals with disabilities define and experience their disabilities.

Originated in the 1960s, the social model of disability explains that individual limitations or deficits as postulated by the medical model of disability are not the real problem; the core issue dwells in society's failure to address the needs of people with disabilities in its social structure (Chappell et al., 2001; Goodley, 2001; Oliver, 2009; Shakespeare & Watson, 1997; Terzi, 2005). As emphasized by Oliver (2009), "…the social model of disability insists that disablement has nothing to do with the body. It is a consequence of social oppression" (p. 23). This model embraces the philosophy that changes are required in society's practices to remove the barriers that discriminate against individuals with disabilities (Chappell et al., 2001; Goodley, 2001; Oliver, 2009; Shakespeare & Watson, 1997; Terzi, 2005). Specifically, by providing an inclusive and supportive environment free of prejudice and discrimination, individuals with disabilities are offered opportunities to fully participate in society (Chappell et al., 2001; Goodley, 2001; Oliver, 2009; Shakespeare & Watson, 1997; Terzi, 2005). By embarking on a journey of empowerment and resilience, embodied within the social model of disability, individuals with disabilities began to redefine disability research and practice through their collective voices via art-based performances, films, and writing.

Brisenden (1986) explained that “to understand disability as an experience, as a living thing, we need more than medical facts. . . . Our experiences must be expressed in our words and integrated in the consciousness of mainstream society” (p. 173–174). Similarly, Crane (2017) supports Brisenden’s (1986) argument and highlights the importance of drawing upon the voices of individuals with disabilities to listen and learn about their struggles and their needs. As Crane (2017) and Kiernan (1999) argued, the voices of students with disabilities have long been silenced in research endeavours and it is urgent to consider their perspectives as they are key stakeholders in their education.

As a practitioner-researcher attempting to improve science education for students with LD, I feel inspired by the words of Brisenden (1986) and those individuals with disabilities advocating for disability rights. I feel that voices of individuals with disabilities need to be valued and researched as they are strong, powerful, independent, and insightful individuals who construct and contribute meaningfully to society.

Based on my practical experience as a special needs educator, I am convinced that the views shared by individuals with disabilities are crucial to constructing a more equitable and fair society, and will lead to changes for their well-being and society as a whole. In the following vignette, I discuss the importance of paying close attention to the voices of science students with LD to design strategies that best support and empower them.

Vignette 2: Listening to the voices of students with LD.

I am very concerned about Wise's progress in learning biology. Wise was diagnosed with dyslexia and processing deficits. I have employed all the research-based learning strategies (e.g., graphic organizers, mnemonics, cue cards) that focus on improving academic performance of science students with LD but to no avail.

Today was week 7 of the remedial tutoring sessions that I conducted with Wise to support her in her learning in biology. I decided to use another approach. I asked her about her interests and she told me that she loves pictures and is passionate about drawing and doodling. Thinking on my feet, I downloaded a couple of black and white pictures on mitosis. I magnified the pictures using the paint application so that the organelles and different stages in mitosis would be more apparent. She seemed mesmerized by the size of the pictures. At that moment, I knew that I had managed to capture her attention. She was very engaged during the tutorials and commented on the shape and positioning of the organelles. She even took out her coloured pencils and coloured the organelles. By the end of the session, she had grasped a good chunk of the material. Before she left, she said: "I cannot believe it's over, I didn't see the time go by. I was having so much fun with you. And I think I understand bio now." (Personal notes from special needs educator report log, Fall semester, 2013)

Through my work with Wise, and the hundreds of students with whom I have worked throughout my career as a special needs educator, I have come to realize that each student is unique in their disability, personality, and interests. This should not be surprising as although human beings share similarities, their genetic codes are unique, making them interestingly diverse. Therefore, how can we expect that a single strategy (e.g., the inquiry-based approach) will benefit all students? From my experience, listening to students with LD and drawing on their interests and needs are key components to designing strategies that best address their unique struggles. For example, listening to Wise’s voice on her interests and capitalizing on her strengths as an art-lover paved the way for me to implement a learning strategy that not only engaged her, but contributed to her success in biology. In turn, Wise felt empowered because she understood the concepts of mitosis. As emphasized by Maestri-Banks and Pope (2011), individuals feel empowered when they are supported in reaching a specific goal; in this case, Wise was not only enjoying biology, but also performing well on her tests, which was her end goal.

Yet, based on my experience and conversations with my students with LD, not all students are empowered to succeed in their respective science courses. Most of them confessed to me that their instructors had difficulties explaining to them science concepts. Instead of using multiple teaching approaches, the science instructors tend to use similar explanations.

Informing my Teaching Practice through the Social Model of Disability

When I started teaching biology in January 2015, I was determined to create an inclusive learning environment for all my students, one that was not only free of discrimination and prejudice, but also allowed all students—irrespective of their abilities, gender, cultural background, social circumstances, and career aspirations—to fully participate in my class (Achieve Inc., 2013). It was crucial for me that my students feel safe to engage in learning instead of feeling segregated and stigmatized (Baurhoo & Asghar, 2014). Moreover, my teaching approach capitalizes on the cognitive, cultural, and social strengths of diverse learners rather than focusing on their cognitive deficits (Baurhoo & Asghar, 2014).

I adopt a universal design to my teaching approach that embeds multiple ways of representing taught concepts, engaging students during instruction, and assessing students to support their cognitive development (Rose, Harbour, Johnston, Daley, & Abarbanell, 2006). Instead of only presenting information orally and through PowerPoint lectures, I work towards co-constructing biological knowledge with my students, which involves conducting small experiments in the classrooms, drawing out taught concepts, watching videos on specific biological concepts, interpreting biological figures and diagrams, problem-solving with authentic biology-related cases, and learning collaboratively with their peers. For assessments, I provide opportunities for my students to demonstrate their knowledge of taught concepts orally through presentations, drawing concept maps, building models, and taking traditional quizzes and exams. In this way, I tap into the strengths of all my students and offer them multiple and diverse opportunities to learn instead of using a “one size fits all” approach.

For example, to teach cell biology, I used multiple ways to present the cellular structure and functions. In addition to an interactive lecture that students and I co-construct, students are given opportunities to use art-based materials (e.g., pom-poms, construction paper, playdough) to construct a cell and depict the diverse organelles that regulate the cellular functions (see Figure 1). The photographs, in Figure 1, bring up vivid memories of my students, who showed unprecedented excitement when they realized that they could build models.

In every class, I could observe the enjoyment and eagerness on my students’ faces when I brought out the art supplies so that they could bring biology to life. This idea stemmed from my experience with students like Wise, who taught me that students with LD can be successful learners if their interests and passions are embedded within the teaching and learning strategies. My students also participated in constructing concept maps and completing summary sheets about cellular functions and structure. Not only did these diverse strategies provide alternative representations of the cellular structure and function, they offered multiple ways to engage and assess students. While some students shared with me that the concept maps best helped them learn biology, others explained that they understood the concepts better by constructing biological models using art materials. What matters most to me is that I successfully listen to the unique voices of my diverse students so that I can effectively meet their unique needs.

Figure 1. Two different models of the cell I co-constructed with my students in a biology class

Limitations of the Social Model of Disability

After a few semesters, I noticed that some of my students with special needs (LD, anxiety, and depression) were still struggling in learning biological concepts. In spite of drawing on the social model of disability to favour an inclusive learning environment, some of my students with special needs were barely passing. With much disappointment and despair, my reflections led me to believe that drawing on this model to inform my teaching practice is insufficient to provide a fair and equitable education to my biology students with LD.

Various researchers and disability activists have also argued that the social model of disability is incomplete, as it denies impairment (Anastasiou & Kauffman, 2013; Crow, 1996; Oliver, 2009). Impairment, as defined by the Disabled People's International, “is the functional limitation within the individual caused by physical, mental, or sensory impairment” (Oliver, 1998, p. 1447). In denying impairment, the social model of disability is “failing to acknowledge the subjective reality of many disabled people’s daily lives” (Crow, 1996, p. 12). Specifically, by underpinning disability within a sociological lens, the social model of disability neglects to take into account the within-individual attributes of the individual. The social model denies the biological selves of individuals with disabilities and claims that they do not form part of the disability (Anastasiou & Kauffman, 2013). Consequently, from a social model lens, the person with disabilities is viewed as an incomplete individual, who is “biologically naked and only subjected to social values and roles” (Anastasiou & Kauffman, 2013, p. 445).

Because these cognitive impairments form part of students’ life and experiences, they need to be valued, understood, and addressed along with social issues. By denying these cognitive impairments, the social model of disability does not provide opportunities for individuals to fully express themselves. Sometimes, difficulties experienced by students with LD cannot be addressed solely by altering the environmental or social structure. For example, I have multiple students who experience anxiety in addition to their LD, and they need support from a medical expert to deal with their anxiety. In some cases, to succeed academically, they might need medication, in addition to an inclusive environment suited to meet their needs.

Based on my professional experience and the current disability discourses, I recognize that students with LD are whole individuals with intricate biological, psychological, and social attributes. As a doctoral student exploring academic barriers faced by science students with LD, I have come to understand that it is imperative to give students with LD the opportunities to not only discuss the social barriers that affect them, but also the biological and psychological problems that they encounter.

Bronfenbrenner's Ecological Model: Transforming Science Education and Research

I have explored the possibility of employing a disability lens that takes into account the complexity of barriers—encompassing the biological, psychological, and social factors—that students with disabilities encounter in learning science. After a thorough search of the literature, I found my voice in Bronfenbrenner's (1976, 1986, 1994, 2005) ecological model as a framework that informs both my practice and my doctoral research study. Bronfenbrenner (2005) posited that individuals' development processes (e.g., biological, psychological, social, emotional, and cognitive) are shaped by the intricate, bidirectional interactions between their within-individual attributes (e.g., self-confidence, resilience, motivation) and the multi-layered environment in which individuals develop. I strongly believe that Bronfenbrenner's ecological model offers a meaningful lens to develop an in-depth and comprehensive understanding of the barriers impacting the lives of individuals with disabilities.

Unlike the medical model of disability, which narrowly defines within-individual characteristics on the basis of impairment, Bronfenbrenner's (2005) ecological model offers a more comprehensive view of within-individual attributes. Specifically, this model invites us to view individual characteristics not only from an impairment perspective as emphasized by the medical model of disability, but also from a position of power. For example, while focusing on within-individual characteristics of students with LD, Bronfenbrenner's ecological model permits us to make sense of their positive qualities such as resilience and determination to succeed. Simultaneously, Bronfenbrenner's ecological model invites us to construct a deeper understanding of diverse ecological barriers located within a complex and multidimensional ecological system, as opposed to the social model of disability, which outlines few barriers (e.g., environmental, social, and attitudinal).

Science Teaching and Learning for Students with LD: An Ecological Perspective

As a college biology teacher aiming to provide a just and inclusive science education for all my students, I have found that Bronfenbrenner's (2005) ecological model provides an exciting and innovative lens through which I can make sense of my students' learning problems as stemming from different structures (classroom, home, family, and others). As illustrated in the vignette below, I drew on Bronfenbrenner's ecological model to develop a comprehensive understanding of the diverse issues impacting students' with LD academic achievement and success in my biology classroom.

Vignette 3: Where is the barrier: In the individual, the environment, or both?

Amber, a student with LD, had been failing most of the quizzes and tests in my class. Yet, Amber had a strong determination to succeed. She came to see me often to go over quizzes and tests. To support Amber in successfully learning biology, I suggested that she take free remedial tutoring with me. But, first, it was crucial for me to identify the potential set of barriers affecting her learning process. Drawing on Bronfenbrenner's (2005) ecological model, I built a schema to map all the possible barriers that could impact Amber's learning. To fulfill this task, I kept an open mind and asked many questions: What barriers are impeding Amber's learning process? Is it the classroom? My teaching style? Disability-related? Within Amber's home environment? I spoke with her to figure out the exact types of barriers that have impeded her academic success in biology.

To further understand these barriers, I carefully observed her during the tutorial sessions. I noticed her difficulties in remembering biological terminology and vocabulary. When we discussed the PowerPoint presentations from previous classes, she could not recall that we had gone over these concepts in class. I also observed that Amber learnt by verbally reciting the slides. She explained to me that she did not feel comfortable writing notes and shared that the learning specialist at the college supported her strategy of learning verbally.

Still, I suggested that she write notes, as it might help her understand and recall the concepts. During our remedial tutorials, I integrated a note-taking strategy amongst other strategies (drawing, building models). We would first discuss biological concepts by drawing and building models. Then, she would orally explain to me the concepts in her own words or by drawing or using models. As she explained the concepts, I would write out short notes for her. Each session, I suggested that she write the notes, but she always declined. After a month, she started writing her own notes (**see Figure 2**)*. At the end of the semester, Amber's comprehension of biology improved sufficiently. She passed the biology course with a 61%. However, she still performed at a much lower academic level than the class average (73%). (Personal teacher diary, Fall semester, 2015*)

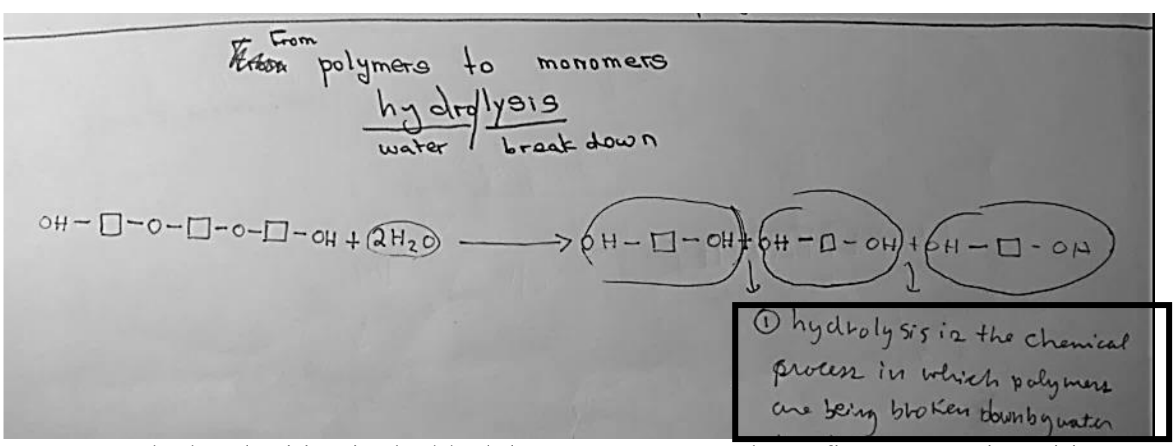

Figure 2. The handwriting in the black box represents Amber's first attempt in writing biology notes

Drawing on Bronfenbrenner's (2005) ecological model, I positioned Amber at the heart of the ecological system (see Figure 3 below). I recognized that Amber's learning process in biology was being shaped by a myriad of complex interactions that took place between: (a) her personal characteristics, encompassing her biological, psychological, social, emotional attributes; and (b) her environment (classroom, college, home). According to Bronfenbrenner (2005), the environment is complex and webbed in a set of four nested subsystems—microsystem, mesosystem, exosystem and macrosystem. As illustrated in the vignette, to support Amber's learning, it was crucial that I identify the potential barriers that were hindering her learning process within her ecological system. I attempted to map the potential barriers experienced by Amber within the four subsystems.

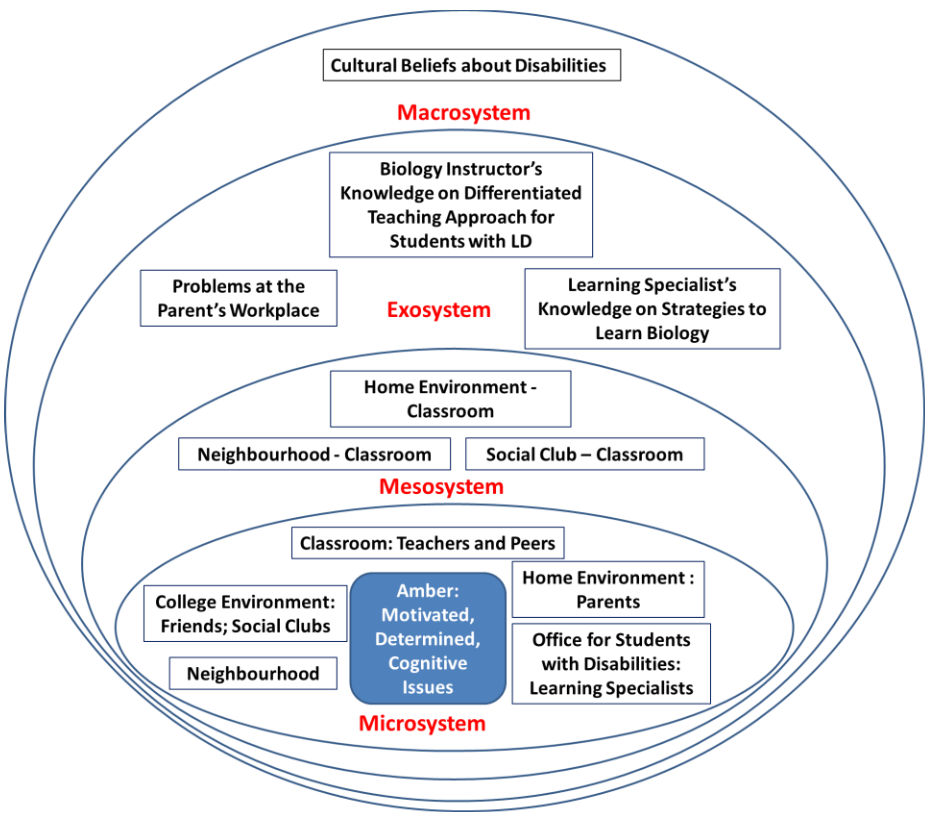

Figure 3. Amber's ecological system: Within-individual and contextual factors impacting learning

The microsystem represents the immediate environment in which Amber is physically present and directly interacts with others (teacher, peers, and parents) (Bronfenbrenner, 2005). For a student, the immediate surroundings might be made up of science classrooms, family, peer groups, and school clubs. In this context, Amber continuously interacts and builds relationship with others (me as her biology instructor, parents, friends, etc.). These direct relationships (e.g., individual–peer relationship) might positively or negatively impact her learning process. For example, it is well-documented that students with LD are not always accepted by their peers, who make them feel de-valued and withdraw from peer-to-peer interactions (da Silva Cardoso et al., 2016; Cambra & Silvestre, 2003; Erten, 2011; Hong, 2015; Garrison-Wade, 2012; Marshak et al., 2010; Strnadová, Hájková, & Květoňová, 2015). In my biology classroom, peer-assisted learning is central to my practice. Therefore, if the relationship between Amber and her typically achieving peers is unfavourable during peer-related activities, it is likely that her academic performance would be affected.

In the same vein, I analyzed potential barriers impeding Amber's learning within the mesosystem. The mesosystem is defined by the linkages and processes taking place between two or more microsystems in which the individual is physically active (Bronfenbrenner, 2005). In particular, interactions in one microsystem (e.g., an individual's home) might influence behaviour in another microsystem (e.g., an individual's school) (Bronfenbrenner, 2005; Eamon, 2002; Strayhorn, 2010). For example, the microsystem constituting family support (i.e., parents check student's homework and limit access to watching TV) may positively impact academic achievement in math classrooms (i.e., another microsystem) for African American high school students (Strayhorn, 2010). I identified a few connections between different microsystems that might negatively affect Amber's learning process in biology (see Figure 3). For example, Amber might lack support from her parents (one microsystem), which could negatively impact Amber's learning process in the biology classroom (another microsystem). In line with my views, various empirical studies have demonstrated that high school and postsecondary students with supportive parents perform better academically as compared to those with unsupportive parents (Gonzales, Mari, Cauce, Friedman, & Mason, 1996; Gutman, Sameroff, & Eccles, 2002).

The exosystem is defined as "the linkages and processes taking place between two or more settings, at least one of which does not contain the developing person, but in which events occur that indirectly influence processes within the immediate setting in which the developing person lives"(Bronfenbrenner, 1994, p. 40). Bronfenbrenner (2005) posits that exosystems such as parents' workplace, and a teacher's personal life and experiences, do not directly involve the developing individual, but can indirectly impact the development of a school-aged child. Bronfenbrenner (2005) exemplifies the exosystem by discussing that mothers who were forced to quit their jobs and take care of their babies were found to more likely mistreat their progenies. In this example, the changes that previously took place in the mothers' professional lives constituted an exosystemic barrier affecting the well-being of their developing children.

Similarly, while working with Amber, I drew on my own life experiences to support Amber's learning process in biology. For example, to explore and implement effective instructional strategies that could contribute to Amber's success in biology, I drew on my prior knowledge gained from previously taking courses in special needs education at the university. However, the knowledge that I constructed in the university setting was not particularly conducive in helping Amber to succeed in my course. Moreover, I also sought advice from my most experienced colleagues to gain new insights on ways to best support Amber's learning. My prior knowledge gained at the university setting on differentiated teaching strategies for science students with LD, and subsequent interactions with my colleagues, englobed a unique professional setting that "does not contain the developing person", namely Amber (Bronfenbrenner, 1994, p. 40). Yet, my prior experiences and events that occurred in my professional sphere "indirectly influence processes within the immediate setting in which the developing person lives" (Bronfenbrenner, 1994, p. 40). Specifically, before the beginning of the one-on-one tutorials that I offered to Amber, my inadequate knowledge of effective strategies to meet Amber's unique learning style within the classroom setting constituted an exosystemic barrier that affected Amber's academic performance in biology. Moreover, the strategies (e.g., using a universal design for teaching approach) that my colleagues suggested to me were already implemented in my classroom and did not contribute to favour Amber's scholarship in biology.

Initially I focused on the *potential* barriers impacting Amber's learning and had yet to understand the *realistic* issues that Amber was experiencing. I engaged Amber in a discussion on the *potential* problems that I identified above and depicted in Figure 3. From these conversations, it seemed that she was experiencing two major issues in learning biology. First, her learning strategy (located at a within-individual level) was negatively impacting her understanding of biological concepts and academic performance in biology. Second, Amber was also facing barriers from the exosystemic level which constituted the learning specialist. During my meeting with the learning specialist, she confessed that she was trained in psychology at the university setting, but she had no background in science education and was unaware of strategies to support students with LD in science. In turn, her experiences and knowledge gained from the university setting, in which Amber was physically absent, "indirectly influence processes within the immediate setting in which the developing person lives" (Bronfenbrenner, 1994, p. 40) such that her lack of familiarity in science teaching and learning for students with LD was partly affecting

Amber's ability to adopt effective studying strategies to favour her understanding of biology. Moreover, she explained that she was merely reinforcing Amber's choice to not write class notes as a means to motivate her and improve her self-confidence. As explained in the vignette, by offering Amber one-on-one tutorials and focusing on her academic needs, I was able to support her effectively by employing multiple strategies.

By employing Bronfenbrenner's ecological model as a practical lens, I was able to depict a holistic, but accurate and clear picture of different aspects of Amber's life as a student. When I showed the diagram in Figure 3 to Amber, she smiled and engaged in an animated conversation with me regarding her supportive friends, dedicated parents, and the nutrition club at the college. Her face lit up when she saw that I described her as motivated and determined. She kept thanking me for recognizing that she has potential. Unbeknownst to me at that time, my relationship with Amber would grow and flourish. She seemed to trust me and attempted strategies that I proposed. In my experience, Bronfenbrenner's ecological model is a unifying framework that brings into play positive ways to favour students' learning and self-worth.

Towards Transforming Disability Research in Science Education: The Ecological Model of Disability

As previously discussed, Bronfenbrenner's ecological model was revolutionary in transforming my teaching practice to comprehend barriers experienced by students' with LD, and meet their particular academic needs. While working closely with students with LD, it became even more evident that the issues they experienced encompassed a multitude of within-individual and contextual factors, which are embedded within a multi-layered web of complexity. As evident in Amber's case, Bronfenbrenner's ecological model permitted me to map all the possible barriers that a student with LD might experience in a learning situation.

With this in mind, I drew on Bronfenbrenner's ecological model as a lens to inform my doctoral study, and I was able to capture voices of students' with LD and unveil the complex, interwoven barriers that imped their learning processes in science.

Unfortunately, to the best of my knowledge, no study has drawn on the ecological model to discuss within-individual and contextual barriers impacting students' with LD learning and academic achievement in science education. By drawing on the ecological model, I made sense of within-individual issues, contextual issues, and the intersection of within-individual and contextual issues affecting students' pursuit of scholarship in science. Moreover, the ecological model has allowed me to move away from traditional approaches used in research inquiries that explore a limited range of factors located at the within-individual or contextual levels instead of attempting to explore barriers across ecological systems (Bronfenbrenner, 2005).

As I near the end of my doctoral journey, I feel that I am no longer enslaved by the medical model of disability, which compelled me to construct my understanding of disability from a cognitive deficit perspective. Neither am I entirely positioned within the social model of disability, which prevented me from making sense of students' issues from a cognitive deficit perspective. Bronfenbrenner's (2005) ecological lens has inspired me to construct my understanding of issues from a comprehensive perspective, allowing me to make sense of Amber's and other students' issues from multiple systems, transform my teaching practice, and contribute effectively to the academic success of my students with LD.

Conclusion

In this autoethnographic inquiry, I unveiled the delicate process of attempting to position myself within a disability discourse to inform my doctoral research study, with the objective of transforming and improving science education for students with LD. I found myself at the heart of constant stress and tension as I navigated opposing discourses: the medical and social models of disability. Drawing from my dual identities as a practitioner-researcher, I engaged in a reflexive process on the potential application of the social and medical models in informing barriers experienced by students with LD.

My journey was laden with countless difficulties, as I was tempted to employ the powerful and highly revered medical model of disability. On the other hand, I was also tempted to employ the social model of disability as it is gaining popularity in the disability research literature. Yet, in this autoethnographic inquiry, I have come to challenge both the medical and the social model of disability as inadequate and incomplete in informing a deep and comprehensive understanding of issues experienced by students with LD. Moreover, these frameworks are not in line with my objectives of transforming and improving science education through the identification of authentic barriers impacting students' with LD learning.

After struggling to position myself within a discourse that could inform my doctoral research study, the ecological model became my voice. My experiences as a practitioner were the determining factor in deciding to draw on the ecological model to inform my doctoral thesis. As evident in my practice and research with students like Amber, the ecological model provides a more holistic, in-depth understanding of both within-individual and contextual barriers that students with LD face in their daily struggles in science learning. During my doctoral work, the ecological lens permitted me to listen to the unheard and silenced voices of students with LD.

While no two doctoral journeys are alike, I am certain that other doctoral students embodied within the practitioner-researcher identities, might also be experiencing dilemmas in framing their doctoral study and positioning themselves within a specific discourse. I hope that this autoethnographic inquiry empowers and inspires other doctoral students and researchers to find their voices within discourses that favour social change and improve academic lives of minority students, while taking a stance against traditional, powerful, and popular discourses.

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Bridging Chapter 3 (Manuscript 1) and Chapter 4 (Manuscript 2)

In chapter three, I explored my perspectives as a special needs educator and as a biology instructor by highlighting the issues experienced by science students with LD within a CEGEP setting. Additionally, I described my observations in regards to the difficulties faced by science instructors in teaching their students with LD. Based on my observations and conversations with students with LD, I found that these students often expressed the fear of being negatively perceived by their teachers and peers due to their LD diagnoses. Indeed, in my role as a special needs educator, I personally experienced certain math instructors questioning the validity of their students' LD diagnoses, often to the point that these instructors refused to offer students necessary accommodations as mandated by the Office for Students with Disabilities (OSD). Some students with LD shared with me that their instructors misunderstood their learning needs and were subsequently unable to explain science concepts to them in ways that they would be able to comprehend. Science instructors tended to use only one teaching approach instead of using multiple strategies (e.g., visual, tactile) that could potentially have made science learning more accessible to them. Similarly, many instructors confessed to me that they were unaware of appropriate instructional strategies which would be able to meet the unique needs of students with LD. In my role as a CEGEP biology instructor, I also struggled with designing and implementing effective instructional strategies for my students with LD, and my students highlighted their own difficulties in developing and using effective learning strategies in science; this may partly explain their struggles in performing well in their science courses.

Overall, in line with Bronfenbrenner's ecological model, Chapter 3 highlights that the barriers experienced by science students with LD and their instructors are multifaceted and encompass both within-individual (e.g., teachers' beliefs about learning disabilities), and contextual barriers (e.g., lack of effective teaching strategies). As emphasized by Baglieri, Valle, Connor, and Gallagher (2011) and Danforth (2006), the multiple perspectives of social agents namely researchers, practitioners, students, and/or families need to be taken into consideration when exploring disability related issues. Drawing on perspectives from a variety of stakeholders (i.e., researchers, practitioners, students, and/or families) allows for a comprehensive understanding and mitigation of disability related problems (Baglieri et al., 2011). To these ends, Chapter 3 explored my views surrounding my role as a special needs educator and biology instructor using the tenets of Bronfenbrenner's ecological model as a research framework, while Chapter 4 explored various science instructors' views in working with students with LD by examining their beliefs and experiences.

As discussed throughout Chapter 3, science instructors are located within the microsystem of Bronfenbrenner's ecological model and are therefore instrumental in supporting the learning and academic success of students with LD. Developing a comprehensive understanding of the issues they face in teaching students with LD can help bring about changes to their teaching practices through effective professional development programs. Chapter 4 asks the following research questions: What types of barriers do college science instructors believe they experience in teaching and supporting their students with LD? What challenges do science teachers feel that they face in providing academic assistance to their students with LD outside of the classroom setting and during office hours? Drawing on semi-structured interviews, Chapter 4 provides an analysis of the voices of 18 CEGEP science instructors on first-order (i.e., external/environmental) and second-order (i.e., internal/within-individual) barriers faced while working with students with LD.

Chapter 4 (Manuscript 2): "*I can't tell you what the learning difficulty is*": Barriers experienced by CEGEP science instructors in teaching and supporting students with learning disabilities

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Abstract

The ultimate task of supporting the learning, academic success, and inclusion of students with learning disabilities (LD) in science classrooms falls predominantly in the hands of the instructors. As such, science teachers are mandated to adopt and develop instructional strategies to meet the diverse academic needs of students with LD. However, not all instructors are appropriately equipped and skilled at differentiating instruction and supporting the inclusion of diverse learners in their classrooms. This qualitative study explores the perspectives of 18 CEGEP science instructors on challenges experienced in teaching and academically supporting their students with LD. To capture their struggles in teaching science to students with LD, 18 CEGEP science instructors (n = 7 in the biology department; n = 6 in the chemistry department; and n = 5 in the physics department) participated in semi-structured interviews. The barriers that emerged from the study were grouped into three overarching themes: Theme 1: instructors' insufficient knowledge and skills in teaching and supporting students with LD; Theme 2: insufficient support in working with students with LD; and Theme 3: instructors' difficulty in establishing relationships with students with LD. These findings emphasize the importance of supporting science instructors in enacting differentiated inclusive practices for students with LD through effective professional development and training programs.

Keywords: *Barriers, CEGEP science instructors, Instructional Practices, Students with Learning Disabilities*

Context and Review of Literature

In Canada, increasing numbers of students with learning disabilities (LD) are enrolling in postsecondary institutions (Gagné & Tremblay, 2011; Hansen, 2013). Compared to their typically achieving peers, Canadian students with LD experience significantly lower levels of educational attainment and are more likely to drop out of postsecondary institutions (Bizier, Till, & Nicholls, 2015). Specifically, Science, Technology, Engineering, and Mathematics (STEM) disciplines seem particularly challenging for these students, oftentimes resulting in them choosing to either switch from STEM majors to non-STEM fields, or drop out of college altogether (Chen, 2013; Sithole et al., 2017). Furthermore, compared to typically achieving STEM students, students with hidden disabilities (e.g., learning disabilities, emotional and behavioural disorders, attention-deficit/hyperactivity disorder) encounter numerous obstacles in science and are more likely to drop out of postsecondary STEM programs (Dunn, Rabren, Taylor, & Dotson, 2012). Consequently, these students are underrepresented in STEM fields.

Even though some students with disabilities[9] were able to persist and complete their STEM programs, they were more likely to be unemployed or out of the workforce compared to their typically achieving peers in the US (Thurston, Shuman, Moddendorf, & Johnson, 2017). In the context of this paper and as documented by various researchers (Abu-Hamour, 2013; Baker, Boland, & Nowik, 2012; Costea-Bărluţiu & Rusu, 2015; Love et al., 2015; Murray, Sniatecki, Perry, & Snell, 2015; Vickers, 2010; Zhang et al., 2010), students with disabilities include those who have LD, developmental disabilities, physical disabilities, and mental health issues.

[9] Students with disabilities have been described by researchers as those having learning disabilities, developmental disabilities, physical disabilities, and mental health issues.

Unfortunately, efforts to engage and support students with disabilities in science fields are sparse in postsecondary academic settings. As such, these students may not have access to productive STEM career pathways.

To accommodate and support the inclusion of students with disabilities including those with LD in higher education (HE), Canadian postsecondary institutions have enacted policies and legislations drawn from provincial laws (Erten, 2011). These legal frameworks and legislation, such as the *Act to secure Handicapped Persons in the Exercise of their Rights with a View to Achieving Social*, *School and Workplace Integration* (2011), the *Commission des droits de la personne et des droits de la jeunesse* (2018), and the *Quebec Charter of Human Rights and Freedoms* – emphasize both the legal and social obligations of Quebec's CEGEPs (i.e., colleges) to accommodate students with disabilities (Raymond, 2012; Havel, Raymond, & Dagenais, 2017). In particular, the *Quebec Charter of Human Rights and Freedom* sets forth the legal foundations that recognize the academic needs of students with disabilities and their rights to equal treatment (section 10), privacy (section 5), and confidentiality (section 9) (Beaumont & Lavallée, 2012). Such legislations protect students with disabilities from discrimination by ensuring reasonable accommodation, and prevent colleges from presupposing students' failures on the basis of their disabilities (Bouchard & Leblanc, 2016). In spite of these legal frameworks and legislation in place, students with disabilities continue to face challenges in STEM programs due to a lack of appropriate accommodations and inadequate inclusive practices in science programs (Dunn et al., 2012; Hedrick et al., 2010; Garrison-Wade, 2012; Gregg et al., 2016; Thurston et al., 2017). Moreover, in middle and high schools, these students are commonly offered less challenging science and math curricula (Garrison-Wade, 2012; Thurston et al., 2017) because of the misperception by their instructors that they are less capable of succeeding in science (Dunn et al., 2012).

As explained by Dunn and colleagues (2012), it is vital for teachers to consider the unique challenges experienced by students with disabilities and to employ appropriate strategies to support their engagement and learning in STEM programs. Research suggests that most secondary and postsecondary science educators are not fully equipped to enact inclusive teaching practices that foster the academic progress of students with disabilities (Kahn & Lewis, 2014; Baker, Boland, & Nowik, 2012; Dunn et al., 2012; Thurston et al., 2017; Mumba, Banda, Chabalengula, & Dolenc, 2015; Norman, Caseau, & Stefanich, 1998; Scruggs, Brigham, & Mastropieri, 2013). In particular, students with disabilities in STEM programs felt that faculty at postsecondary institutions generally lacked knowledge about disabilities and were therefore unable to effectively support their learning needs by employing multiple means of instruction and offering appropriate accommodations to facilitate their learning and academic progress (Dunn et al., 2012; Thurston et al., 2017). However, these instructors are mandated to make STEM learning accessible for students with disabilities. To better support the instructors in employing inclusive practices for students with LD, we first need to understand the different types of barriers that postsecondary STEM instructors currently experience in teaching and supporting students with LD.

To the best of my knowledge, research on the specific barriers experienced by postsecondary instructors in teaching and supporting students with LD within the science program is particularly scarce. Therefore, in this article, I provide a general literature review on the struggles experienced by postsecondary instructors in teaching students with disabilities across different academic disciplines. It is to be noted that most studies have focused on students with disabilities which consist of students who have learning disabilities, developmental disabilities, physical disabilities, and also mental health issues. Studies that focused solely on physical disabilities or developmental disabilities have not been included in the review. My review of the literature revealed four central barriers that prevent college and university faculty from effectively teaching students with disabilities. These barriers include: instructors' insufficient knowledge and experience of disability-related issues; lack of understanding of disability laws and policies; confidentiality and disclosure restrictions on disabilities; and finally, the absence of training and professional development (PD) opportunities.

Various studies report that college and university faculty lack the knowledge and experience to offer accommodations to students with disabilities (Abu-Hamour, 2013; Baker, Boland, & Nowik 2012; Costea-Bărluţiu & Rusu, 2015; Love et al., 2015; Murray, Sniatecki, Perry, & Snell, 2015; Vickers, 2010; Zhang et al., 2010). A majority of surveyed faculty members felt unprepared and had limited experience to effectively teach students with disabilities (i.e., LD, developmental disabilities, physical disabilities, and mental health issues) in their classrooms (Baker et al., 2012; Love et al., 2015). For example, in a study that explored science faculty attitudes towards students with disabilities, Love et al. (2015) found that college and university professors were rarely equipped with pedagogical knowledge and classroom management skills to work with students with disabilities. In terms of differentiating instruction for students with disabilities, West, Novak, & Mueller (2016) discussed that, in the US, many college instructors did not enact inclusive strategies (e.g., using multiple means of representing taught concepts) when teaching students with disabilities. However, when comparing faculty practices in differentiating instruction across different countries, Lombardi, Vukovic, and Sala-Bars (2015) reported that Canadian instructors, compared to those in the US and Spain, were less likely to adopt inclusive practices. These inclusive practices include using multiple means of assessing students, extending the deadline dates for assignments, and offering flexible response options on exams (e.g., oral vs. written assessments).

Similarly, special accommodations (e.g., offering makeup tests) for students with disabilities constitute conflicting barriers for college instructors in Quebec (Bouchard & Leblanc, 2016). Under the Quebec college instructors' union collective agreement, instructors are under no obligation to prepare specialized class notes and make-up tests for students with disabilities (Bouchard & Leblanc, 2016). Enacting such accommodations for students with disabilities adds to the instructors' workload and to make matters worse, instructors are not compensated for the extra work required (Bouchard & Leblanc, 2016).

Another key issue is faculty's lack of knowledge on disability laws, policies, and procedures for students with disabilities. For instance, in the US, postsecondary professors have expressed uncertainty on the application of the *Americans with Disabilities Act* (ADA) to teach and support students with disabilities (Murray et al., 2008; Sniatecki et al., 2015). Similar trends were observed in Romania and Jordan. In Romania, faculty members in HE were not familiar with disability-related laws and policies which mandated them to differentiate the curriculum for students with disabilities (Costea-Bărluţiu & Rusu, 2015). In Jordan, a majority of university faculty were unaware of national laws governing the right and access to education for students with disabilities (Abu-Hamour, 2013).

A major barrier experienced by faculty in HE was confidentiality restrictions that prevented them from being informed about the nature of their students' disabilities (Bouchard & Leblanc, 2016; Love et al., 2015, Vickers, 2010). Because instructors are rarely given information on their students' specific disabilities, they struggle to understand their students' special needs. Bouchard and Leblanc (2016) stated that "if the professor is unaware of the disability's effect on interpersonal relations and communication, this could give rise to a tense situation between the student and the teacher" (p. 33). While the office for students with disabilities is mandated to maintain confidentiality on students' disabilities, university professors argued that they have "legitimate educational interests" in understanding their students' respective disabilities and accommodating them to the best of their abilities (Vickers, 2010, p. 10).

The lack of training and PD programs also emerged across the literature as a barrier which negatively affected faculty members' teaching practices in HE (Abu-Hamour, 2013; Baker et al., 2012; Becker & Palladino, 2016; Behling & Linder, 2017; Zhang et al., 2010). In both Jordan and the US, faculty members stressed the need for training and PD opportunities to make sense of the academic needs of students with disabilities, and to enact reasonable accommodations to support their students' learning and academic achievement (Abu-Hamour, 2013; Baker et al., 2012; Becker & Palladino, 2016).

The aforementioned studies offer some insight into the barriers that faculty members face with their students with disabilities in various countries. However, studies examining difficulties faced by science instructors in working with their students with learning disabilities in HE are limited (Love et al., 2015) and this issue requires further exploration for several reasons. STEM fields present unique challenges for students with disabilities. According to Love et al. (2015), students with disabilities experience multiple issues with development of critical thinking and reasoning skills, which make science learning increasingly challenging (Love et al., 2015). Similarly, students with disabilities in grades 4, 8, and 12 scored significantly lower grades than their typically achieving peers on science achievement tests in the US (National Center for

Education Statistics, 2015). It is reasonable to assume that Canadian students with disabilities including those with LD also experience a lower level of achievement in science as compared to their typically achieving peers.

The task of favouring the inclusion of students with LD falls predominantly in the hands of science instructors (Scruggs et al., 2013). Therefore, to support the inclusion, learning, and retention of students with LD in science programs, barriers faced by postsecondary science instructors in teaching students with LD need to be understood and addressed. As such, the objective of this study was to develop a comprehensive understanding of the challenges faced by Canadian college science instructors in teaching and academically supporting students with LD. The following research questions guided this study: *What types of barriers do college science instructors believe that they experience in teaching and supporting their students with LD? What challenges do science teachers feel they face while providing academic assistance to their students with LD outside of the classroom settings?*

This study adds to the literature by drawing on qualitative approaches such as semi-structured interviews, unlike previous studies (e.g., Abu-Hamour, 2013; Costea-Bărluţiu & Rusu, 2015; Sniatecki et al., 2015; Zhang et al., 2010) which employed quantitative approaches (e.g., surveys with closed-ended questions) to explore instructors' views on disability-related issues. Semi-structured interviews were employed to engage 18 college science instructors in an open and in-depth discussion, and capture diverse perspectives on teaching students with LD in science. My study sheds light on key areas where science faculty members require PD to improve their pedagogical approaches with their students with LD. Moreover, postsecondary institutions can draw on this study's findings to develop strategies that address key issues which surfaced during my conversations with the science instructors.

Theoretical Framework: Brickner's First-Order and Second-Order Barriers

In order to construct a meaningful understanding of the struggles faced by college science instructors, I drew on Brickner's (1995) and Ertmer's (1999) framework to analyze the first-order and second-order barriers experienced by these teachers. First-order barriers are external to teachers and stem mostly from the environment (e.g., lack of professional development opportunities offered by the college), whereas second-order barriers are internal to teachers and include teachers' epistemological and pedagogical beliefs on teaching and pedagogical practices (Ertmer, 1999).

In science education, Ertmer's (1999) framework analyzing first-order and second-order barriers has been used extensively to explore challenges encountered by science teachers in integrating inquiry-based practices and technological tools in their classrooms (Coley, Warner, Stair, Flowers, & Croom, 2015; Donna & Miller, 2013; Donnelly, O'Reilly, & McGarr, 2013; Fitzgerald, 2013; Lee, Feldman, & Beatty, 2012; Webb, Bunch, & Wallace, 2015). However, to my knowledge, no previous studies investigated the first-order and second-order barriers experienced by science teachers with their students with LD. In what follows, I elaborate on the salient features of first-order and second-order barriers in the context of inquiry-based approaches and technology implementation in science classrooms. Thereafter, I explain the rationale for using Ertmer's (1999) framework to identify and discuss first-order and second-order barriers in this study.

First-order barriers, such as lack of financial resources, insufficient equipment, time constraints, and inadequate teaching and learning resources, prevent teachers from employing inquiry-based approaches and technology to support students' engagement and learning in inclusive science classrooms (Donna & Miller, 2013; Fitzgerald, 2013). Both Fitzgerald (2013) and Donna and Miller (2013) identified students' behaviour and aptitudes as important first-order barriers influencing science teachers' practices in classrooms. For example, elementary science teachers in Fitzgerald's (2013) study, explained that "children run riot with all materials: it just gets out of hand," making it difficult for teachers to engage students in inquiry-based approach (p. 22).

Several second-order barriers were also identified in Donna and Miller's (2013) study which focused on teachers' pedagogical beliefs about the benefits of technology on students' learning in science classrooms. As emphasized in science education policies (e.g., National Science Education Standards), technology integration in science classrooms enables students to mimic scientists and work collaboratively inside and outside the classroom setting for inquiry purposes (e.g., discussing data collected during experiments). However, their findings showed that teachers experienced second-order barriers such as: (a) negative beliefs on the implementation of technological tools in science classrooms, and (b) lack of knowledge regarding the benefits of technology in inquiry-based classroom settings.

Ertmer's (1999) framework enabled us to categorize barriers emerging from the conversations with instructors as first-order (e.g., lack of support from school administration) or second-order (e.g., individuals' beliefs and knowledge). Highlighting the distinction between first-order and second-order barriers was crucial to this study because first-order barriers are beyond teachers' control as they are located at other levels of the education system (e.g., administrative, departmental). By employing Ertmer's (1999) framework, I identified and examined the multiple levels at which the first-order barriers occurred. Researchers have argued that second-order barriers are difficult to mitigate as they represent "long-held beliefs, attitudes, and conceptualizations that represent important aspects of individual sense-making" (Alleman, Holly, & Costello, 2013, p. 2). Because of this argument, the central objective of this study was to identify and examine the second-order barriers that affected teachers' instructional practices geared towards academically supporting students with LD. By differentiating between the first-order and second-order barriers, I am able to suggest ways in which these barriers can be addressed.

Methodology

Drawing on a social-constructivist-interpretivist framework (Creswell, 2013), this study seeks to understand the complex and varied perspectives of college science instructors. Within this framework, researchers view "reality and meaning making as socially constructed" through the lived experiences and interactions between the researchers and the participants (Creswell, 2013; Tubey, Rotich, & Bengat, 2015, p. 225; Tuli, 2010). This was the case in the present study wherein I engaged individual science instructors in sharing and co-constructing their multiple views in teaching students with LD through conversational interviews. Positioned within the social-constructivist-interpretivist paradigm, I recognize that my own experiences as a special needs educator working in the Office for Students with Disabilities (OSD) at the college where the study took place partly shaped the interpretation of the meaning co-constructed with the participants. I also draw on the first-order and second-order barriers framework as a lens to interpret and develop deeper insights into the shared difficulties voiced by the participants.

Setting and participants

Science faculty members at an English CEGEP in Quebec, Canada, were invited to participate in the study. CEGEPs are colleges that provide two-year pre-university programs, three-year career and technical programs to students who have completed Grade 11 in high school (Jackson, 2013). Invitations were sent by email to a total of 47 college instructors teaching various science courses at the English college: Mountain CEGEP (pseudonym). The criteria for participation included experience in teaching at the college level for more than five years with one or more students with LD in their course. Out of the 47 science instructors, 18 volunteered to share their experience in teaching students with LD. Science instructors in the biology (*n* = 7; 5 females and 2 males), chemistry (*n* = 6; 2 females and 4 males), and physics (*n* = 5; 1 female and 4 males) departments participated in the study, as shown in Table 1. All these instructors possessed either a master's or doctoral degree in a science discipline.

Table 1. Profiles of college science instructors participating in the study

Pseudonym	**Gender**	**Content Area**	**Teaching Experience (years)**	**Education**
Adam	Male	Biology	32	M.Sc.
Angela	Female		11	M.Sc., B.Ed.
Barry	Male		8	M.Sc.
Daisy	Female		12	Ph.D.
Megan	Female		25	M.Sc.
Stefani	Female		10	Ph.D.
Vanessa	Female		12	M.Sc.
Antony	Male	Chemistry	10	Ph.D.
Fiona	Female		15	Ph.D.
Hans	Male		8	Ph.D.
Pamela	Female		12	Ph.D.
Robert	Male		24	Ph.D., M.Ed.
Vincent	Male		7	Ph.D., M.Ed.

David	Male		20	M.Sc., B.Ed.
Kyle	Male		7	Ph.D.
Mary	Female	Physics	10	M.Sc., Cert. Ed.
Paul	Male		8	Ph.D.
Zack	Male		15	M.Sc.

These participants and I shared a working relationship for several years prior to the study taking place. I worked as a special needs educator in the Office for Students with Disabilities (OSD) at Mountain CEGEP, assisting in the integration of students with disabilities at the CEGEP. In this role, I was involved in assessing students' psychoeducational reports, providing them with reasonable accommodations, informing the faculty about the students' accommodations, and offering remedial tutoring and learning strategies to science and math students with LD. I also worked in close collaboration with the science faculty to advocate on students' difficulties on their behalf.

Prior to collecting data, ethical approval to conduct this study was granted by McGill's university ethics committee as well as the Mountain CEGEP's research ethics board. Consent was obtained from each instructor to participate in the study. To keep the identities of the instructors anonymous, they were given pseudonyms, as shown in Table 1.

Data collection techniques: Semi-structured Interviews

Data collection occurred through semi-structured interviews which lasted between 45 minutes to 2 hours. Semi-structured interviews contribute to an in-depth understanding of "the lived experience of other people and the meaning they make of that experience" (Seidman, 2006, p. 9). Moreover, semi-structured interviews offer access to teachers' ideas, thoughts, memories, and stories, which are essential in capturing their lived experiences (Buck, Cook, Quigley, Eastwood, & Lucas, 2009), which was the aim of this study.

The interview questions (Appendix D) were designed by drawing on my professional experience, informal discussions with students with disabilities and science instructors, as well as by employing Ertmer's (1999) framework (i.e., first-order and second-order barriers). For example, an interview question designed to elicit the participants' views on first-order barriers included: Do you feel that you have enough support from the college to work with students with LD? An example of an interview question related to second-order barriers included: What difficulties have you personally encountered while teaching students with LD?

Data analysis

To analyse and interpret qualitative data, researchers begin with the coding process (Blair, 2015). For the coding process, I adopted an integrative approach using both data-driven/inductive and theory-driven coding techniques which are well documented in the literature (Fereday & Muir-Cochrane, 2006; Yukhymenko, Brown, Lawless, Brodowinska, & Mullin, 2014). I began data analysis by employing inductive coding to conceptualize the ideas that were important to the participants (Chamberlain, 2012; Gibbs 2007). Because inductive coding is "goal-free", I did not code with respect to the research questions and theoretical framework (i.e., first-order and second-order barriers) (Yukhymenko et al., 2014, p. 97). This allowed us to capture the instructors' ways of thinking, concerns, and strategies, and identify all meaningful units in the data. By coding inductively, I was able to capture the innovative strategies employed by some of the instructors to overcome certain barriers. These strategies, which have emerged due to inductive coding, are explored in the discussion section of this paper.

During the inductive coding process, I conducted "close readings of text" (Thomas, 2006, p. 4). The interview transcripts were read multiple times to allow understanding to emerge. Codes were attributed to sentences and paragraphs in the interview transcripts and salient concepts were identified (Hewitt-Taylor, 2001). This coding approach concurs with the constant comparative analysis approach wherein "the analyst chunks the data into smaller segments, and then attaches a descriptor, or 'code,' for each segment" (Leech & Onwuegbuzie, 2008, p. 594). For example, two salient codes - "[1]*don't know what their learning disability is*," and *no information on accommodation strategies*[2] - emerged from the following excerpt: "*We don't know what their particular learning disability is*[1]*. We don't have any information about how we individually should be adapting to their needs*[2]" (David, physics instructor).

Following inductive coding, I coded the data for the second time in relation to the research questions and objectives to identify the multiple barriers that the participants experienced in teaching students with LD. Next, I proceeded to a theory-driven coding process. The 18 interview transcripts were further analyzed and relevant sentences and paragraphs were coded for the third time based on the theoretical framework (i.e., first-order and second-order barriers). The framework offered a meaningful lens to identify the external and internal barriers impacting instructors' experience with their students with LD.

Throughout the three-stage coding process, I constantly compared and grouped similar codes into larger categories. For example, the following related codes - *not given information on disability (first-order barrier)*; *"don't know the disability type" (first-order barrier)*; *"kept in the dark about students with LD" (first-order barrier)*; *"wish to know more about students' disabilities" (first-order barrier)* – were first compared and contrasted, then finally brought together to construct the category: *lack of information on students' disabilities*. The next step in this interpretive process comprised generating themes from the categories. For example, the related categories focusing on (1) *lack of information on students' disabilities*, and (2) *lack of prior training* were combined to create an overarching theme: *insufficient support to work with students with LD*.

In this study, the constant comparative analysis method has been modified and used outside of grounded theory (e.g., Boeije, 2008; Fram, 2013; Leech & Onwuegbuzie, 2008; Mason et al., 2015). As explained by Fram (2013), the constant comparative analysis method outside of grounded theory is useful to "maintain the emic perspective (participant's view as insider) and how theoretical frameworks can maintain the etic perspective (outsider/ distant concepts) throughout the analysis" (p. 13). Similarly, in this study, I focused on the participants' emic views on their respective barriers. But, by also employing Ertmer's (1999) framework (i.e., first-order, and second-order barriers), I was able to establish relationships between instructors' internal difficulties and environmental barriers in teaching students with LD. Altogether, in this study, the constant comparative analysis outside of grounded theory was useful to "identify, create, and see the relationships among parts of the data when constructing a theme" (Leech & Onwuegbuzie, 2008, p. 594).

Trustworthiness of Findings

The trustworthiness of the study's findings is demonstrated in terms of credibility and transferability (Lincoln & Guba, 1985). Credibility was partly established by my "prolonged engagement" with the setting and participants in my position as a special needs educator at Mountain CEGEP (Lincoln & Guba, 1985, p. 303). Embedded within the college's culture, I was an insider supporting college instructors in working with students with disabilities. As such, I was able to construct working relationships with the participants, enabling them to speak freely, knowing that their "confidences will not be used against them" (Lincoln & Guba, 1985, p. 303). Member checks were conducted by inviting each participant to share their perspectives on the interpretation of data (Lincoln & Guba, 1985; Merriam, 2009). Additionally, two independent researchers were invited to discuss and critically examine the interpretation of the themes. The independent researchers also engaged in a review process to trace some of the findings back to the raw data in the interview transcripts (Lincoln & Guba, 1985). To enable other researchers and practitioners to transfer this study's findings to other settings, I offer a comprehensive description of the research context and participants (Lincoln & Guba, 1985).

Findings

Three overarching themes were identified: *Theme 1: Instructors' insufficient knowledge and skills in teaching students with LD*; *Theme 2: Insufficient support in working with students with LD,* and *Theme 3: Difficulty in establishing relationships with students with LD*. In this section, I begin by describing *Theme 1: Instructors' insufficient knowledge and skills in teaching students with LD*. *Theme 1* is a second-order barrier depicting the limited knowledge and skills of science instructors to understand their students' special needs and make science accessible for them. The participants' insufficient pedagogical knowledge and skills are intricately connected to a set of first-order barriers. The first-order barrier constitutes *Theme 2: Insufficient support to work with students with LD.* Without information on students' specific disabilities, the participants felt unequipped and unprepared to academically support them in learning science. Similarly, the participants felt that training and PD opportunities were lacking or ineffective in understanding and supporting students with LD. Another set of first-order barrier includes: *Theme 3: Difficulty in establishing relationships with students with LD,* which depicts the instructors' challenges in establishing working relationships with their students with LD, who were reluctance in sharing their issues and seeking academic support. Overall, the first-order barriers include the following: a lack of information on students' disabilities; instructors' lack of prior training and professional development (PD) opportunities; students' reluctance to share their disabilities and corresponding academic needs; students' reluctance to seek academic support; and students' difficult and anxiety-ridden behaviours.

Theme 1: Instructors' Insufficient Knowledge and Skills in Teaching Students with LD

Nine out of eighteen participants felt that they lacked sufficient knowledge and skills to teach science to students with LD. Within this theme, two categories emerged: teachers' lack of knowledge in identifying academic difficulties of students with LD, and teachers' difficulty in differentiating science instruction to make it accessible for these learners. For example, the participants shared their difficulties in identifying the types of academic challenges (e.g., solving science problems) that students with LD faced in science classrooms. In their view, a learning disability (LD) was perceived as being a complex construct resulting in students facing a range of unidentified academic problems that were difficult to address. Zack, who teaches physics, explained that there are:

> *a lot of difficulties [experienced by students with LD] you don't know about.... It's [learning disability] not like a broken arm where you can see the cast; these are students that are struggling internally and you don't often know how to best help them.*

As demonstrated in the above quote, Zack's lack of insight on his students' specific disability-related challenges makes it difficult for him to effectively support them.

David, a physics instructor, also explained his challenges in identifying the exact factors affecting the academic success of students with LD. Specifically, David expressed his confusion in identifying whether students failed because they had a LD, a low aptitude for learning physics (i.e., an individual difficulty), or due to a lack of academic support from teachers (i.e., an environmental issue):

> *I would say [it] is challenging if there is sometimes a confusion of learning disability with lack of aptitude. Any time we think that a student has low aptitude for a subject, it could be that we're misunderstanding them and they may just have a learning disability…. That's the biggest conflict: trying to figure out, feeling comfortable to see someone fail and say, "It's okay," because this just isn't their thing rather than they've failed because somehow, we weren't able to overcome the difficulties they were facing.*

Unlike David who was conflicted in differentiating between students' lack of aptitude or disability, Paul, another physics instructor, associated students' learning difficulties with their cognitive disabilities. However, he was unable to identify the specific cognitive issues - difficulties in activating prior knowledge, a math deficit, difficulties in problem solving, or deficits in the conceptual understanding of physics - that impaired the learning process of his students with LD:

> *I say I'm not sensitive enough perhaps, or my senses aren't attuned enough to pick up noticeable differences in where they're having difficulties…. Yeah, so where is your [student's with LD's] block in working through this problem? You know, is there a conceptual block, is it a math block, is it activating other bits of knowledge?*

A lack of knowledge in employing teaching strategies specific for students with LD also emerged as a barrier for the participants. For example, Daisy, a biology instructor, explained that she lacked knowledge on teaching practices that are suited to address learning issues encountered by students with dyslexia: "*I don't know if there are strategies in terms of dealing with dyslexia in particular in being able to process information.*" On the other hand, Vanessa, another biology instructor, seemed aware that there are different strategies to teach students with dyslexia. While she capitalized her efforts to use multiple means of instruction, Vanessa is uncertain on how to adapt the biology curriculum for students with dyslexia. She shared her difficulties in accessing specific instructional strategies tailored for these students:

> *I know that there're different techniques and training. Like for example, there're lots of ways of dealing with dyslexia. I don't know them all. And where I present material or a special little five-question practice thing for them in a different manner, then perhaps whatever the topic would come easier or clearer. But because I don't know what to look up or what to look for in terms of teaching tools, I don't know where to approach them. All we can do is rehash the material again, and add some creative touches.*

Theme 2: Insufficient Support in Working with Students with LD

As noted earlier, participants' insufficient knowledge and skills to identify and address the academic difficulties faced by students with LD were closely related to several first-order barriers (e.g., lack of information on students' disabilities, training and PD). These first-order barriers are discussed below.

Lack of information on students' disabilities. One of the most challenging aspects of teaching students with LD was attributed to the lack of information on the students' disabilities. Twelve out of eighteen teachers observed that the OSD offered no information on the students' diagnosis but only stated the need for accommodation. Without a meaningful understanding of their students' issues, these instructors experienced difficulties in academically supporting them. For example, Robert, a chemistry instructor, explained that not knowing about the students' disabilities prevented him from adjusting his teaching to accommodate their special needs:

Teachers are not told what the disability is. I don't think it helps. I think I'd like to know what the issue is; I think it would be good to know. So if I knew what the issue was, I can make my own adjustments but if I don't know what the issues are, then it becomes more problematic.

Another chemistry instructor, Fiona, also struggled with not knowing about her students' specific LD and expressed a need for more information on her students' specific disabilities. Unlike Robert, Fiona seemed to have a clear view on the ways that she could use this information to enact differentiated teaching approaches. For example, Fiona noted that she would offer her students with LD supplementary exercises in chemistry to support their learning:

They don't specify [the LD], they just tell you they need extra time and that's it…. I wish I would know more [about their LD]. I don't think I would treat them any differently in a general setting. But I think I might try to help them with extra exercises or maybe when they come see me for help, try to help them a little bit differently. But yeah, I would like that information.

Similarly, Angela, who teaches biology, explained that not being given information on students' LD constitutes a "*weakness*" of the system. Like Fiona, Angela felt that she could accommodate her students with LD provided that she was equipped with the knowledge about her students' specific difficulties, needs, and the strategies tailored to address her students' struggles in learning biology:

It's very hard to say because I'm not privy to the information of what type of learning disability they have. I think it's a weakness. I think the system should tell me. I need a description of what things can be done to help this particular student do better.… I'd like

> *to more about their learning difficulties. I'm interested in learning difficulties. I could probably accommodate most learning difficulties*.

Kyle, who teaches physics, also explained that with a lack of information on students' respective disabilities, it is difficult to support them in learning physics. Additionally, he felt that the OSD cannot expect him to fully accommodate the students with LD given that he is not empowered with the knowledge regarding his students' disabilities, and tools to make physics accessible to them:

> *I don't know what the disability is. So if I had that information I might be able to try and help them out…. Don't expect me to address it if you won't tell me. Because that's my argument, don't tell me I have to be accommodating, I mean I will for the respective tests and stuff. But don't tell me that I can help this person learn if you're telling me, hey there somebody behind the screen that needs help you guess how to help them. What am I supposed to do? I don't know.*

Prior training and professional development opportunities. Coupled with the lack of information from the OSD on their students' specific disabilities and subsequent strategies to differentiate science instruction for these learners, six out of the eighteen instructors felt that a lack of prior training and ineffective PD also contributed to their lack of knowledge and skills to differentiate instruction for their students with LD. To teach science or any other courses in Quebec's colleges, a teaching diploma or degree is not mandated. Therefore, many college instructors lack a formal background in general and special needs education and are not familiar with differentiated teaching approaches for students with LD. For example, Hans, a chemistry instructor, observed that his colleagues, including himself, do not possess degrees or diplomas in education and teaching. As such, Hans felt that they are "*teaching on the fly*" without effectively identifying differentiated strategies and responding to students with LD's academic needs:

> *A lot of us teaching don't have any formal [educational] background with special needs students. To say we're learning – teaching on the fly, is true… a lot of the time I feel like we're sort of proceeding blind when it comes to students with learning disabilities. I find it very hard to tell what strategies are working for students with learning disabilities.*

To compensate for their lack of knowledge on students with LD, the instructors attended conferences and workshops. Yet, Robert, a chemistry instructor, felt that in spite of attending conferences, he still struggled to understand the ways in which students' LD impact their learning:

> *Even though I've gone to many learning conferences, I don't know that much about specific learning disabilities and maybe in general how their learning disabilities interfere with their learning…. it's very hard on the ground level to know what those impediments are.*

Two out of these six instructors had formal education training, having completed an undergraduate degree in education which led to a teaching certification for high school science. Yet, in spite of their training in education, these instructors felt that their teaching diplomas/degrees failed to equip them with the necessary tools to differentiate science instruction and learning for students with LD. For example, Angela is the only instructor in the biology department to have completed a teacher training program. Although she has more pedagogical knowledge than her colleagues do, she still faced challenges in identifying the specific academic difficulties that her students with LD experienced in biology:

> *I have limited knowledge of [LD]—and I have an educational background. That means I have much more background than most of my colleagues on this [educating students with LD]. And still, I could not tell you—from the time I spend with a student [with LD]—I can't tell you what the learning difficulty* is.

David, a physics instructor, mentioned that the teacher certification program in education emphasized the importance of meeting the needs of students with LD, but did not provide details about the nature of those needs. As a result, similar to Angela, David also experienced difficulties in comprehending his students with LD's special needs:

> *I was trained as a high school teacher, which means I went through the McGill Faculty of Education and when I went through that professional training, what I heard over the course of the year was, "We must meet the needs of special needs students." But I got very little specific information about what those needs were.*

Theme 3: Difficulty in Establishing Relationships with Students with LD

As observed by 14 out of 18 science instructors, students with LD tend to exhibit certain negative attitudes and difficult behaviours including: reluctance to share information about their LD and seek academic support from their teachers; a persistent lack of engagement with science; and difficult and anxiety-ridden behaviours. Consequently, the science instructors struggled to establish good rapports with their students with LD and construct productive teacher-student working relationships that supported their science education.

Some students' reluctance to share their LD and academic needs posed considerable challenges for the participants, who struggled to understand and respond to their students' specific difficulties. Mary, a physics instructor, recalled several situations where she asked students to share their LD diagnosis, as they were continuously failing her class tests. As Mary explained, she was unable to help these students because they were unwilling to share their learning issues with her:

> *I would deplore the fact that they [students with LD] are unwilling to share what their learning disability is. It makes my job more difficult. If I don't know what their problem is, then I can't think of a way to help them…. I have had a few students where the situation got so bad that I had to ask them point blank, you have to tell me … because you're failing this class miserably and I can't help you.*

Similarly, Stefani, a biology instructor, also encountered challenges in getting her students to share their respective academic issues. Although she encouraged her students with LD to share their needs with her privately, she noted that they rarely came during office hours. Stefani explained that "*a little bit of extra communication*" from these students could inform her teaching practice:

> *I encourage them to come. They don't come very often….sometimes a little bit of extra communication from them would help in terms of what their needs are or what I could improve upon to help them…. I'm sure there are some things that I could be doing that would help. So I think just for me, I would prefer to know what they need than to not know and again, I'm not sure whether I always do know what they actually need.*

Echoing the views of physics and biology instructors, some chemistry teachers also invited students with LD to seek individualized academic support during their office hours, but their endeavours were unsuccessful. In particular, Pamela, a chemistry instructor, noted that her students with LD were reluctant to "*come for help*" in spite of being less "*academically inclined*" and experiencing difficulties in the classroom setting. She pleaded with her students to come and discuss their issues with her, specifically regarding tests, but her attempts were unsuccessful:

> *The students don't seem to come for help. They are less academically inclined, it's not working for them [in] the academic setting… I tell them they must all come after each test and speak with me. Of course they don't, but I say I really, really want you to talk about your test even if you're happy about it or sad about it.*

The lack of engagement of some students with LD in learning science was another emerging barrier experienced by the participants. Megan, a biology instructor, shared that with most of her students with LD, "*there's no engagement*." She constantly faced challenges in encouraging and motivating her students with LD to learn biology. However, she felt that her students with LD embraced "*the disability as an excuse for not performing*" in biology. Megan recalled a situation where one of her students with LD was not engaged in her lab:

> *[It is a challenge] getting them to do a little bit more work and not transfer their disability as an excuse for not performing, like the student we had last year. In the lab she'd just sit there and stare. There was no engagement in what I was talking about, she was in a dream land…*

Adam, another biology instructor, also recalled several experiences with one of his biology students with LD, who did not review or prepare for their individualized remedial sessions. As such, he felt that the remedial tutorials were less productive than they should have been because the student was "*kind of lost*" during the session:

> *On a couple of occasions, she [the student with LD] hadn't clearly reviewed, and because of her learning disability, she was kind of lost if she hadn't looked at it recently. And so she had great difficulty explaining some of these difficult concepts…. I think that [session] was less productive.*

Another barrier that emerged was instructors' difficulty in teaching and supporting students who displayed difficult and anxiety-ridden behaviours. Vincent, a chemistry instructor, recalled that one of his students with attention deficit hyperactivity disorder (ADHD) displayed ineffective behaviours while collaborating with his typically achieving peers in an active classroom setting. Regardless of the diversity of activities that Vincent proposed as options, the student was either disengaged or acted out during peer-led instruction. Vincent's reference to a "*challenging instance*" revealed his difficulty in handling the student's behaviour:

> *The minute I put him [the student with ADHD] in a social situation [group activity], he would actually bring down his group because he was either highly opinionated and he'd be very vocal about it [the given activity] or hyper about it.… If his group trusted him to do something, he wouldn't do it because he just wasn't there, so that was a challenging instance.*

Barry, a biology instructor, discussed his difficulties in teaching students with anxiety. He described the challenge of getting the students to focus on the content and not on their personal worries, and defined himself as a counsellor rather than a teacher when it came to teaching students with anxiety:

> *My challenges are with those who have anxiety, it's just managing their anxiety, getting them to try to focus on the course material and not their own anxiety. Not their previous struggles, not their worries about not being able to pass the class…..half the time you're just trying to manage their expectations and being more of a counsellor than a teacher.*

Discussion and Implications

This study explores college science instructors' views on their struggles in teaching students with LD by drawing on the interpretive framework of first and second order barriers, developed by Brickner (1995) and Ertmer (1999). The framework is particularly helpful in critically differentiating between the first-order (e.g., lack of information on students' disabilities) and second-order barriers (e.g., teachers' lack of knowledge and skills in teaching students with LD). This research demonstrates that the majority of barriers impacting science instructors' practices are first-order in nature, and external to the teachers. Of particular importance, this inquiry illuminates the first-order barriers impeding college instructors' practices, which stem from both within (e.g., the OSD) and outside (e.g., external PD opportunities) of the college.

Findings from this study also reveal that second-order barriers experienced by science teachers are interconnected to multiple first-order barriers. In particular, instructors' insufficient knowledge (a second-order barrier) in understanding and responding to the academic difficulties of students with LD is intricately connected to a set of first-order barriers that encompasses: (a) no information from the OSD on the nature of students' disabilities; (b) students' reluctance to share their learning difficulties and seek teachers' support; and (c) the inadequacy and inefficacy of PD opportunities in educating teachers on students with LD's academic difficulties, and in employing differentiated strategies to overcome their students' difficulties.

Our analysis shows that science instructors' insufficient knowledge and skills are central barriers to designing and implementing tailored instructional strategies and support mechanisms that successfully impart science knowledge to students with diverse types of LD. In the same vein, other research studies suggest that science teachers, particularly in elementary and high school settings, struggle in designing, selecting, and modifying activities for students with disabilities (Kahn & Lewis, 2014; Mumba et al., 2015; Norman et al., 1998). Similarly, university instructors in STEM disciplines also face challenges in differentiating instruction for students with disabilities (Love et al., 2015). Love and colleagues (2015) found that university STEM instructors felt that "learning disabilities and certain forms of autism were among the most difficult disabilities to recognize and accommodate for" (p. 35). These university instructors had difficulties adapting their curriculum for students with disabilities due to a lack of financial resources to obtain appropriate instructional materials (e.g., 3-D print models) (Love et al., 2015).

Our study indicates that instructors' lack of knowledge and skills in differentiating science instruction for students with LD can be partially attributed to their lack of training in education. Likewise, science instructors who had no training in teaching students with disabilities did not possess sufficient knowledge and skills to implement effective instructional practices for these students, and some also held negative beliefs regarding these students' cognitive and academic abilities (Mumba et al., 2015; Norman et al., 1998). However, contrary to the findings by Norman et al. (1998), in this inquiry, teachers' inability to use differentiated strategies was not related to stereotypical beliefs such as the notion that students with LD inherently possess a low aptitude for science. In fact, this study demonstrates science teachers' eagerness and willingness to develop and adopt multiple techniques and scaffolds geared towards improving the engagement and academic achievement of their students with LD. While some teachers in this study noted that they lacked professional training, others shared that they had received formal training (e.g., a teaching degree) and attended PD workshops. Yet, unlike previous studies (e.g., Kahn & Lewis, 2014; Mumba et al., 2015; Norman et al., 1998), these teachers felt that such PD programs failed to consider and address critical issues that were fundamental to teaching students with LD in science. In particular, participants in this study felt unsupported during their formal training to design and implement instructional practices that could improve the learning and academic achievement of students with LD in science. These findings are in line with the study of Sharma, Forlin and Loreman (2008), who reported that Canadian teachers were neither offered courses pertaining to inclusive education nor opportunities to work with individuals with disabilities during their practicum, as compared to teachers in Australia, Hong-Kong and Singapore. Additionally, science education professors lacked the knowledge and skills to appropriately train instructors to develop appropriate teaching practices to work with science students with disabilities (Norman et al., 1998).

Compared to existing research (e.g., Kahn & Lewis, 2014; Mumba et al., 2015; Norman et al., 1998), this inquiry adds a new dimension to the literature on teaching science to students with LD. Specifically, this study's findings add to the current literature by demonstrating that several factors, in addition to training and PD programs, contribute to teachers' lack of knowledge in comprehending and employing individually-tailored interventions for students with LD in science. As previously discussed, this study shows that a lack of information on students' LD from the OSD, and students' reluctance to inform their teachers about their LD, negatively affect teachers' instructional practices. Although the participants were aware that the OSD is mandated to maintain the confidentiality of their students' respective disabilities, they still felt the need to be informed about the nature of their students' LD. In line with these findings, another study reported that university professors were concerned when "the student's disability is kept secret from the instructor and is not noted in the accommodations paperwork" (Vickers, 2010, p. 10). Moreover, Love and colleagues (2015) also reported that university instructors in STEM felt that it "was difficult to identify and help students with learning disabilities due to confidentiality" issues (p. 32).

While the OSD personnel is legally bound to ensure that students' learning disabilities are kept confidential and not shared without their permission, it is equally crucial to advise them that their disabilities should not be treated as a taboo and kept hidden (Marshak, Van Wieren, Ferrell, Swiss, & Dugan, 2010). Instead, these students should be supported by the OSD in their path towards self-knowledge, self-acceptance, and self-advocacy of their LD (Kimball, Wells, Ostiguy, Manly, & Lauterbach, 2016). It is, therefore, essential that the OSD personnel emphasizes to these students that their teachers might be willing to further accommodate their academic needs, should they choose to disclose their disabilities. Moreover, research has shown that when students disclosed their LD to their professors, students with LD found their professors to be highly supportive in comprehending their situation and offering special accommodations (e.g., extensions on assignments) (Kranke, Jackson, Taylor, Anderson-Fye, & Floersch, 2013). As such, the OSD can guide students who wish to disclose their LD to their instructors by helping them "to explain, in layperson's terms, what their disability entails, how it interferes with functioning in an academic environment, and how certain accommodations are necessary" (Marshak et al., 2010, p. 159). In this way, teachers would gain additional information on the different types of LD experienced by their students, which might serve to equip them with a sound knowledge of these students' areas of difficulties and needs, and thus facilitate their learning process.

Although the main focus of this research was to gather college science instructors' views on barriers in teaching students with LD, some coping mechanisms adopted by the participants in response to these issues are worth articulating. In particular, some instructors highlighted the necessity of being sensitive, caring, and respectful of the students' pathway in the respective science courses, especially with those who are reluctant to discuss their disabilities and academic difficulties. They stated the importance of not bearing preconceived or negative judgements on these students' abilities to perform well in science. Other resourceful teachers were successful in building trusting relationships with their students with LD by constructing and implementing creative approaches (e.g., giving assignments that require students to meet with them individually; offering free candy in their office). These participants emphasized that such differentiated techniques portrayed them as approachable and depicted their willingness to fully support students with LD in their pursuit of science. In line with these teachers' self-reported strategies, Orr and Hammig (2009) also observed that "instructor empathy and approachability are characteristics that appear to hold particular value to students with LD" (p. 192). Moreover, instructors who were caring and demonstrated their understanding of the challenges experienced by students with LD, were more likely to be approached by these students for additional academic help (Mytkowicz & Goss, 2012).

Similarly, Hartman-Hall and Haaga (2002) observed that students with LD showed greater willingness to seek help from instructors who showed a positive reaction towards offering accommodations. Based on these studies, it seems that the strategies proposed by these instructors might prove helpful in encouraging students with LD to build a good rapport with them, and eventually share their diagnosis, and seek individualized remedial support during office hours. However, further research is warranted to explore the effectiveness of these self-reported strategies in supporting both teachers and students in constructing strong and meaningful relationships, and enabling students with LD to become more confident and motivated to approach their teachers when experiencing academic difficulties.

This study has important implications for the training and PD for college science teachers in developing a comprehensive understanding of the academic difficulties experienced by students with LD, and in implementing diverse instructional practices conducive to successful learning. As discussed by the participants in this inquiry, previous training in university settings and PD programs at the college settings failed to provide teachers with adequate opportunities to understand the characteristics of students with LD or their academic difficulties in science classrooms. As such, training and PD programs need to be geared towards increasing instructors' understanding of the spectrum of LD they might encounter in science classrooms, and the difficulties that students with LD encounter in learning science. For example, science instructors need to be informed that students with LD exhibit major difficulties in reading science textbooks, retrieving prior knowledge, making observations, generating hypotheses, solving mathematical problems, and applying newly constructed science knowledge to new situations as compared to their typically achieving peers (Mastropieri & Scruggs, 1994; Mastropieri, Scruggs, Boon, & Carter, 2001; Mastropieri, Scruggs, & Butcher, 1997).

Moreover, these PD sessions should focus on improving teachers' awareness of the psychosocial and emotional issues (e.g., low self-concept, low self-efficacy and depression) that students with LD experience as compared to typically achieving students (Hampton & Mason, 2003; Lackaye & Margalit, 2006; May & Stone, 2010; Pijl & Frostad, 2010). Clearly, due to the intricately complex interactions between cognitive and psychosocial barriers, science may not be easily accessible to students with LD as compared to those without LD. By learning about the characteristics of students with LD and the associated psychosocial and emotional issues through PD opportunities, college science instructors who previously struggled to understand the reasons underlying the students with LD's difficult attitudes and behaviours, low performance or failure might improve their understanding of students with LD's characteristics. Moreover, as emphasized by several researchers, PD opportunities should be enacted to aid instructors in developing empathetic relationships with their diverse learners (Harris, 2015; Peck, Maude, & Brotherson, 2015). As previously discussed, teachers who display care and commitment to inclusive practices are more likely to foster positive attitudes in the classroom and develop sensitivity towards their students (Harris, 2015). Yet, there are very few PD models that are "useful for training and preparing teachers to cultivate empathy as a professional disposition" (Warren, 2014, p. 395). As such, it is imperative that future research studies explore PD models that support college science educators in cultivating empathy and constructing caring and trusting relationships with their students with LD.

As also discussed by Schumm and Vaughn (1995), PD programs that "provide teachers with a menu of strategies described superficially or presented through simulation is not likely to impact instructional practice" (p. 350). Specifically, mentioning the strategies and giving verbal examples of the benefits of the strategies are inadequate to ensure the necessary changes in teachers' practices that actively favour the academic growth of their students with LD. Based on their extensive research on PD programs for teachers working with students with disabilities, Schumm and Vaughn (1995) highlighted the importance of crafting PD training programs that draw on real-life and authentic orchestration of teaching strategies for individuals with disabilities in inclusive classrooms. As such, during PD, college science instructors should be offered opportunities to experience hands-on activities in teaching students with LD in authentic science classrooms. For example, in the "in-class mentoring professional development" model, the mentor-teacher is present in an actual classroom to demonstrate effective strategies that teachers can employ when individuals with disabilities are experiencing difficulties in learning (Foreman, Arthur-Kelly, Bennett, Neilands, & Colyvas, 2014). Such a PD approach, grounded in modelling, allows college science instructors to obtain hands-on experience in employing diverse strategies that favour the academic achievement of their students with LD.

Another PD approach – "Lesson study for accessible science" – has been explored to support science and special needs teachers in enacting inclusive instructional practices for students with LD in middle school (Mutch-Jones, Puttick, & Minner, 2012). In "Lesson study for accessible science," a science and special educator work in collaboration by teaching each other their science lesson. In turn, the science teacher or special educator embeds the role of the student and makes sense of each other's science lesson as learners (Mutch-Jones, Puttick, & Minner, 2012). Then, after presenting their lessons, they critically analyze the content, teaching approach, emerging confusions surrounding the lesson (Mutch-Jones, Puttick, & Minner, 2012). As such, they work together to improve the lesson and make it accessible to diverse learners by focusing on the needs of students with LD, and taking into account on how students' disabilities might manifest in each lesson (Mutch-Jones, Puttick, & Minner, 2012) . The "Lesson study for accessible science" is grounded in collaborative professional development such that both the science teacher and special educator engage in critical reflection on their lessons and teaching practice (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Mutch-Jones, Puttick, & Minner, 2012). The "Lesson study for accessible science" approach showed promising results such that teachers were able to critically reflect on their practice and adapt their teaching by generating more accommodations and meeting the needs of all students in their inclusive science classrooms (Mutch-Jones, Puttick, & Minner, 2012). However, the instructors did not increase their knowledge of science content or learning disabilities while participating in the "Lesson study for accessible science" PD program (Mutch-Jones, Puttick, & Minner, 2012). This PD program could be adapted for college science instructors by engaging them to discuss their lesson plans with their colleagues in their departments. The instructors can learn from each other and consequently construct inclusive science classrooms for their learners with LD.

Overall, continuous research efforts should be invested towards exploring different PD formats and approaches that are best suited to enhance teachers' knowledge and skills towards supporting students with LD in college science classrooms, because such studies are clearly sparse in the literature of science, inclusive, and special needs education.

Conclusion

This study contributes to the literature by shedding light on the complex and intricate relationships between first-order and second-order barriers, which impact science teachers' practices for students with LD. Compared to previous studies (Kahn & Lewis, 2014; Mumba et al., 2015), this study captures teachers' voices through in-depth, semi-structured interviews, and recognizes that several first-order barriers (e.g., lack of information on students' cognitive deficits) contribute to science college instructors' insufficient knowledge and skills in supporting students with LD.

Contrary to the findings of Norman et al. (1998), this study shifts the blame from science teachers, who are often portrayed as uncaring and holding prejudicial views regarding their students with LD, to the lack of effective PD programs in supporting science instructors to meet the academic needs of their students with LD. Thus, it is crucial that postsecondary faculty in STEM disciplines are adequately prepared and equipped to identify, understand and respond to the academic needs of students with LD. Merely providing documentation to faculty instructors on accommodations for students with LD is insufficient. It is vital that postsecondary institutions hire an adequate number of well-trained staff to provide the appropriate resources to effectively support instructors through PD programs. Future research should explore support mechanisms for instructors to favour the engagement and learning of students with LD in science. Because findings from this study may not represent the views of all college science instructors on barriers experienced with their students with LD; more research – grounded in both the qualitative and quantitative paradigms – is warranted internationally to explore instructors' challenges with these students.

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Bridging Chapters 3 (Manuscript 1), 4 (Manuscript 2), and 5 (Manuscripts 3)

Chapter 3 draws on my observations as a special needs educator and as a CEGEP biology instructor to articulate some of the principal teaching and learning issues experienced by college science students with LD. Based on my observations and conversations with students with LD, they expressed their sentiments of being negatively judged by their peers and teachers as being academically inferior due to their diagnoses of LD. Other key issues that emerged in Chapter 3 included both students' and instructors' views that their science instructors lacked diverse instructional strategies to appropriately meet their learning needs. In Chapter 4, I explored CEGEP science instructors' perspectives on their difficulties in teaching and academically supporting their students with LD through semi-structured interviews. Summarizing chapter 4's findings, the main issues encountered by science instructors included instructors' insufficient knowledge and skills in teaching and supporting students with LD, the lack of appropriate supports for instructors in working with students with LD, and instructors' reported difficulties in establishing relationships with students with LD. Building upon the findings from Chapter 3 on science instructors' lack of knowledge and skills to effectively teach their students with LD, in Chapter 4, I argued that effective professional development programs need to be established for CEGEP instructors which would enable them to improve their knowledge of the needs of students with LD, and equip them with appropriate pedagogical techniques to better meet the academic needs of diverse learners.

As argued by Baglieri et al. (2011), and Danforth (2006), seeking a plurality of voices is key to deepening our comprehension of issues affecting teaching and learning practices for students with LD. Crane (2017) calls for researchers to invite individuals with disabilities to "tell their story" and to "show others what they need and want and what barriers they experience" (p.

26). To these ends, Chapter 5 seeks to understand the perspectives of students with LD surrounding their difficulties in accessing science education within CEGEP settings. Chapter 5 focuses on the following questions: What types of barriers do college students feel they encounter in learning science? In what ways do they think these barriers affect their academic achievement and success in college science programs? In exploring these research questions, Chapter 5 employs qualitative approaches—namely semi-structured interviews and photovoice—to capture the unheard voices of CEGEP science students with LD. In summary, Chapter 5 adopts a similar strategy as Chapter 3 and Chapter 4 in seeking the multiple perspectives of major stakeholders so as to improve researchers' understanding of disability-related issues surrounding teaching and learning practices within CEGEP level science programs.

Chapter 5 (Manuscript 3): *"I sit there and feel empty and alone"*: Voices of CEGEP Students with Learning Disabilities on Academic Barriers in Learning Science

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Abstract

Compared to their typically achieving peers, Canadian students with disabilities are more likely to experience academic difficulties, drop out of postsecondary institutions, and face unemployment. Alarmingly, in Science, Technology, Engineering and Mathematics (STEM) disciplines, students with learning disabilities (LD) achieve significantly lower grades than their typically achieving peers across elementary, secondary, and postsecondary settings. Because students with LD lag behind in STEM academic achievements as compared to their typically achieving peers, this qualitative study was designed to explore a myriad of issues that impede learning and the academic success of Quebec college science students with LD. Data from 11 students with LD were collected through semi-structured interviews and journals. In addition, 5 out of the 11 students participated in a photovoice project in which they photographed artefacts and spaces that represented barriers they encountered while learning science. The participants identified the following barriers: difficulty in learning science due to their respective disabilities; perceptions of being academically disadvantaged in comparison to their peers; the use of surface learning strategies; overly fast pace of instruction; undifferentiated teaching approaches; and lack of consistency and structure in teaching approaches. Based on these findings, this study offers valuable insights into designing effective interventions that could better address the academic needs of college students with LD, and facilitate their inclusion and retention in science programs.

Keywords: *Barriers, CEGEP students with learning disabilities, learning and teaching practices*

Context and Research Problem

I don't have the brain and ability to be in science. I have tried and done my very best . . . . I think it's best that I switch to the social sciences. I just wanted you to know because you're my advisor and I'm sorry to disappoint you. I know you put a lot of efforts in tutoring me but it's just my brain – I'm so different from the others. I don't get it. I'm not fast enough and I'm falling behind. Science is no longer for me….I don't know anymore.

The excerpt above captures the internal dilemmas and struggles that college students with learning disabilities (LD) encounter in their Science, Technology, Engineering, and Mathematics (STEM) programs. As discussed in Chapters 1 and 2, LD is understood as involving "impairments in one or more processes related to perceiving, thinking, remembering, or learning. These include, but are not limited to: language processing; phonological processing; visual spatial processing; processing speed; memory and attention; and executive functions (e.g., planning and decision-making)" (Learning Disabilities Association of Canada, 2015, para 2). On numerous occasions, many of my students with LD have voiced concerns about their inability to meet the college's STEM program expectations and subsequently opted out of science programs to pursue non-STEM programs. In line with my experience, Dunn, Rabren, Taylor, and Dotson (2012) and Martin, Stumbo, Martin, Collins and Madison (2011) highlight that students with hidden disabilities (i.e., learning disabilities, emotional and behavioural disorders, attention-deficit/hyperactivity disorder) encounter numerous obstacles in learning science, are more likely to drop-out, and are underrepresented in the postsecondary STEM fields.

In general, postsecondary STEM programs present unique challenges for all students, including those with LD (Chen, 2013; Street et al., 2012). STEM programs are complex with dense science concepts and a high amount of new vocabulary to be mastered within a short period of time (i.e., within a semester). For example, in a typical biology course at the CEGEP level, students have only a semester to learn concepts in various biology fields (i.e., anatomy/physiology, biotechnology, genetics). The lab component of STEM programs demands that students are engaged in critical thinking and reasoning while they conduct experiments with high end technological tools (e.g., Polymerase Chain Reaction, ELISA, amongst others).

Not surprisingly with such intensive science courses, around 50 % of undergraduate students in STEM programs drop-out and switch to non-STEM programs in the US (Chen, 2013). In Canada, a significant decline in the PISA science scores of high school students occurred between 2006 [M = 534, SD = 2] and 2012 [M = 525, SD = 1.9] (OECD, 2015). Moreover, a decrease in the proportion of Canadian students graduating (21.2 %) from STEM disciplines was also observed (Conference Board of Canada, 2013; DeCoito, 2016). Due to the lower number of STEM graduates emerging from science, math, computer science, and engineering disciplines, a grade of “C” was awarded to Canada, which was ranked 12th out of 16 countries (Conference Board of Canada, 2013; DeCoito, 2016).

While pursuing STEM programs poses major issues for all students, students with LD encounter particular challenges in learning science. As highlighted by Gregg, Galyardt, Wolfe, Moon, and Todd (2017), students’ perseverance and success in STEM areas depend on environmental variables namely the presence of a strong support system to help them acquire adequate learning skills to succeed in science. Yet, students with disabilities often lack academic supports and learning strategies to successfully persist in the sciences (Dunn et al., 2012; Gregg et al., 2016; Hedrick, Dizén, Collins, Evans, & Grayson, 2010; Thurston, Shuman, Moddendorf, & Johnson, 2017). Indeed, the historical exclusion of students with disabilities from postsecondary STEM education has been attributed to inadequate practices of inclusion and to a lack of appropriate accommodations within science programs in the US (Dunn et al., 2012; Hedrick et al., 2010; Gregg et al., 2016; Thurston et al., 2017).

Similarly, in Canada, the *Canadian Human Rights Commission* (2017) surveyed individuals with disabilities aged 15 or older and reported that these individuals are "facing barriers while trying to access their education" (p. 3) such that they lack "the institutional support, the accommodation, the funding, and the programs and infrastructure required to access and benefit from the same quality of education as their fellow students" (Canadian Human Rights Commission, 2017, p. 1). For example, Canadians with disabilities reported that accommodations to write exams under "necessary conditions" (i.e., extra time and quiet room) were often not respected (Canadian Human Rights Commission, 2017, p. 4). Moreover, due to a lack of funding, postsecondary educational institutions hired fewer numbers of teaching assistants making it challenging for postsecondary instructors to accommodate the needs of their students with LD in larger classrooms (Canadian Human Rights Commission, 2017).

Altogether, as compared to their typically achieving students, STEM students with disabilities expressed that their postsecondary institutions were "less committed to support[ing]… them socially, assist[ing]… them in coping with non-academic responsibilities, and generally promot[ing]… their engagement in supportive relationships (e.g., peers, faculty members)" (Hedrick et al., 2010, p. 133).

Additionally, students with disabilities were not prepared for the postsecondary science programs given that they were offered a less challenging science and math curricula in their special needs classes in middle and high schools (Garrison-Wade, 2012; Thurston et al., 2017). Students in Garrison-Wade's study used words such as "watered-down, dumb math, too easy, and slide through classes" to describe their learning experiences in high school (Garrison-Wade, 2012, p. 11). Not surprisingly, students with disabilities struggle in postsecondary science programs and are more likely to drop out as compared to their typically achieving peers.

In addition to their unsatisfactory learning experiences within the classroom environment, studies have suggested that students with LD also experienced difficulties while taking tests and exams at the postsecondary level (Heiman & Precel, 2003; Jenson, Petri, Day, & Truman, & Duffy, 2011; Whitaker, Lowe, & Lee, 2007;). In their classical study, Heiman and Precel (2003) compared 191 college students with LD vs. 190 students without disabilities on their ability to function during exams; the authors found that students with LD had more difficulties concentrating during exams, were concerned about running out of time, and experienced more stress, nervousness, frustration, and helplessness as compared to their typically achieving peers. Similarly, another study reported that college students with disabilities (i.e., LD, ADHD, autism, and physical impairments) were stressed and anxious in courses such as chemistry and algebra that required abstract thinking, and advanced understanding (Jenson et al., 2011).

The challenges highlighted above (e.g., lack of academic supports, insufficient accommodations, and higher levels of stress and anxiety) might explain the significantly lower academic performance of science students with disabilities (i.e., identified as those having an individualized education plan) on the National Assessment of Educational Progress (NAEP) science scales[10], as compared to their typically achieving peers across 4th, 8th , and 12th grade levels in the US (US Department of Education, 2015). For example, students with disabilities in the 12th grade performed at a significantly lower academic level on the NAEP science scale with a mean score of 120, as compared to their typically achieving peers whose mean score was 153

[10] The NAEP represents a measure of trends in academic achievement of elementary and secondary students in the US. The NAEP science scale ranges from 0 to 300, and is subdivided into three tiers of academic performance: basic, proficient and advanced. For example, grade 12 science students with mean scores of 146 – 177 are categorized in the basic level, while those with mean scores of 178 – 209 are categorized as proficient in science.

(US Department of Education, 2015). At the postsecondary level, a higher percentage (i.e., 50 %) of students with LD scored a grade of C+ or lower in general chemistry as compared to 40 % of typically achieving students who received a similar grade (Street et al., 2012), which indicates that students with LD tend to struggle more in science and perform at a lower academic level than their typically achieving peers.

Due to the obstacles encountered in their educational programs, Canadian students with LD experienced significantly "overall lower levels of educational attainment[11] than those who did not have a disability" and were more likely to drop out of postsecondary institutions as compared to their typically achieving peers (Bizier, Till, & Nicholls, 2015, p. 7). Moreover, individuals with disabilities were less likely to have completed their postsecondary qualifications as compared to those without disabilities (35.6% versus 61.1%) (Bizier, Till, & Nicholls, 2015). Similarly, Hong, Herbert, & Petrin (2011) found students with disabilities (including physical disabilities, LD, developmental disabilities, and mental health diagnoses) had significantly lower college completion rates in comparison to their peers without disabilities. Alarmingly, although some students with disabilities (including physical disabilities, LD, developmental disabilities, and mental health diagnoses) completed their postsecondary STEM programs, these students were more likely to be unemployed or out of the workforce as compared to their typically achieving peers (Thurston et al., 2017).

Because of the multiple issues encountered by postsecondary students with LD in accessing science education, they are often confined to the margin of the STEM education system as compared to their typically achieving peers. The margin-center metaphor, coined by

[11] Within the context of their study, Bizier et al. (2015) defined educational attainment as the successful completion of high school diploma programs as well as postsecondary programs, including trades certificates, college diplomas, university certificates below bachelor level, and university degrees (Bizier, Till, & Nicholls, 2015).

the feminist theorist bell hooks[12] (1984), evokes the struggles and hardships of African American individuals oppressed within a society constructed by predominately White social agents. This metaphor might be applied to make sense of the experiences of students with disabilities within STEM programs, as explained later in this section. Living in a social sphere dominated and powered by White individuals, hooks (1984) made sense of her African American self as positioned within the margin:

> To be in the margin is to be part of the whole but outside the main body. As black Americans living in a small Kentucky town, the railroad tracks were a daily reminder of our marginality. Across those tracks were paved streets, stores we could not enter, restaurants we could not eat in, and people we could not look directly in the face . . . we could enter that world, but we could not live there. We had always to return to the margin, to cross the tracks to shacks and abandoned houses on the edge of town. There were laws to ensure our return. Not to return was to risk being punished. Living as we did—on the edge—we developed a particular way of seeing reality. We looked both from the outside in and from the inside out. We focused our attention on the center as well as the margin. (hooks, 1984, p. ix)

'The margin' refers to those spaces occupied by non-traditional groups (including women, racially/ethnically underrepresented students, and women of color) who have been excluded from mainstream educational spaces, which are defined as being 'the center'(Ong, Smith, & Ko, 2018). In her classical study on the marginalization of homeless and underprivileged students in science, Barton (1998) drew on the margin and center dichotomy to outline issues which sidelined students to the margin of science classrooms. These issues included: limited access to

[12] bell hooks uses the unconventional lowercasing of her name to depict that the most important in her works is: the "substance of books, not who I am." (Williams, 2006)

school materials and spaces to study, tensions between school and home life, difficulties in situating themselves within the science curriculum, and institutional policies. These students continuously faced stereotyped ideologies, constructed by those who were in higher positions of power from ‘the center’ (e.g., white male scientists), on issues such as schooling and learning.

In the same vein, in another study, Rahm (2007) discussed the experiences of African-American youth whose socio-economic status placed them on the margin. The author found that these African-American students had less access to media science and little access to science outside of school, while their white American peers had more access to Western science through enriched after school science programs (Rahm, 2007). Most recently, Ong, Smith, and Ko (2018) noted that the spaces within ‘the center’ are often unwelcoming to women of color in STEM education. African-American female students/women, in particular, expressed feelings of being excluded and isolated in predominantly white institutions as they were viewed as “intellectually incompetent” in STEM fields (Ong, Smith, & Ko, 2018, p. 30).

The present study seeks to understand how students with LD construct their position along the margin-center continuum and outlines some of the learning issues that these students may experience within their science classroom communities. In other words, the margin-center metaphor guides this investigation to inform our understanding on how students with LD in science articulate their views of ‘the center’ which is dominated by teachers and typically achieving students while they engage in science learning. In particular, exploring the learning barriers experienced by postsecondary science students with LD is highly warranted because of their higher drop-out rates from science programs, overall lower academic performance and unemployment issues as compared to typically achieving students.

Moreover, research on the complex barriers encountered by postsecondary students with disabilities in STEM is limited (Lee, 2014, Thompson-Ebanks, 2014) and the literature capturing the inner voices of students with LD in their daily struggles to learn science is clearly lacking, especially in Canada. At the same time, existing studies on the struggles of individuals with disabilities within STEM fields focus primarily on the experiences of students with physical disabilities (e.g., Dunn, Rabren, Taylor, & Dotson, 2012; Hedrick et al., 2010; Gregg et al., 2016; Thurston et al., 2017). As highlighted by Fullarton and Duquette (2016), postsecondary institutions in Canada have attempted to remove the physical barriers for students with disabilities, but the unique challenges and experiences of students with LD have been largely overlooked by researchers. It is crucial to explore and dismantle the barriers that students with LD are facing to facilitate their scholarship in science programs.

Therefore, the objective of the present qualitative study is to develop a comprehensive understanding of the barriers affecting the learning and academic success of science CEGEP students with LD. Through semi-structured interviews and photovoice projects, I captured the voices of CEGEP students with LD on their difficulties in learning science. To this end, the following research questions guided my inquiry: *What types of barriers do college students feel they encounter in learning science? In what ways do they think these barriers affect their academic achievement and success in college science programs?* Enabling students with LD to openly discuss their challenges is essential to understanding how their learning disabilities affect their engagement in the sciences, and the specific strategies which can be implemented to better support them in their pursuit of science.

Theoretical Framework: Bronfenbrenner's Ecological Model

To conceptualize the multiple barriers experienced by science students with LD, I drew on Bronfenbrenner's (1979, 1986, 1994, 2005) ecological model. Bronfenbrenner's (1979, 1986, 1994, 2005) ecological model posits that both within-individual characteristics (e.g., self-concept) and the environment (e.g., teachers' and peers' attitudes, teaching strategies) are key elements in shaping effective learning environments and facilitating students' academic achievement (Martyn, Terwijn, Kek, & Huijser, 2014; Rohrbeck, Fantuzzo, Ginsburg-Block, & Miller, 2003; Strayhorn, 2009).

In line with Bronfenbrenner's ecological model, the present study also recognizes that every individual is positioned within a complex socio-cultural sphere nested within four subsystems—the microsystem, mesosystem, exosystem and macrosystem– which impact the individual's development, beliefs, and experiences. The microsystem is defined as the:

> …pattern of activities, social roles, and interpersonal relations experienced by the developing person in a given face-to-face setting with particular physical, social, and symbolic features that invite, permit, or inhibit engagement in sustained, progressively more complex interaction with, and activity in, the immediate environment… (Bronfenbrenner, 2005, p. XVII)

In the context of the present study, the microsystem is defined as the immediate environment (i.e., science classrooms) in which students with LD construct their roles as science learners when they engage in learning activities with their peers and teachers. Following the microsystem, the next ecological environment is the mesosystem (i.e., a system of microsystems) which is defined as "the relations among two or more settings in which the developing person becomes an active participant" (Bronfenbrenner, 2005, p. 46). The student's home life (e.g., conflicts with parents), for example—which constitutes a microsystem—can affect his or her personal development, consequently affecting his or her learning experiences within the science classroom. In turn, the exosystem has been defined as "a setting that does not itself contain a developing person but in which events occur that affect the setting containing the developing person" (Bronfenbrenner, 2005, p. 46). For example, students do not form part of the school administration where decisions are made on test formats (multiple choice questions, essay types). Yet, these test formats could potentially affect students' academic performance and grades.

The outermost ecological environment is represented by the macrosystem, which embeds the "overarching patterns of stability, at the level of the subculture or culture as a whole, in forms of social organization and associated belief systems and lifestyles" (Bronfenbrenner, 2005, p. 47).

By employing Bronfenbrenner's ecological framework for this study, we are invited to take into account the multiple individual and contextual barriers that negatively impact the learning experiences of college science students with LD. Bronfenbrenner's ecological model allows for a more comprehensive analysis and understanding of the multiple issues experienced by students with LD in learning science as compared to traditional models of disability (i.e., the medical and social models of disability).

Unlike Bronfenbrenner's ecological model, the medical model of disability only considers within-individual barriers (e.g., cognitive deficits) and neglects the role that contextual barriers play in negatively affecting students' academic achievement (Gokool-Baurhoo, 2017; Saxton, 2018; Wasserman & Campbell, 2017). In contrast, the social model of disability stands in opposition to the medical model of disability, as it instead locates the difficulties experienced by individuals with disabilities within the context of societal determinants (e.g., discriminatory attitudes, inflexible societal structures, teachers' stereotyped views about students with LD.) (Gokool-Baurhoo, 2017; Saxton, 2018; Wasserman & Campbell, 2017). However, the social model of disability fails to take into account the within-individual deficits which need to be considered in effectively assessing the difficulties of individuals with LD. Both the medical and social models of disability have inherent limitations; while the medical model of disability only takes into account cognitive impairments, the social model of disability focuses solely on social factors as barriers.

If we study cognitive and social factors as separate elements without considering the interplay between them, our comprehension of academic barriers for students with LD in science will be limited. Applying Bronfenbrenner's (2005) ecological model allows us to develop a deeper knowledge of the intricate ways in which within-individual and contextual barriers interact to affect students' learning of science, and allows the present study to analyse both within-individual and social barriers with equal importance.

Review of Literature

Drawing on Bronfenbrenner's (2005) ecological model as a lens, I explored the existing literature focusing on the specific challenges encountered by students with disabilities in postsecondary institutions (i.e., colleges and universities). Studies focusing solely on the struggles of science students with LD are limited. Therefore, a broad exploration of the literature was undertaken by analyzing difficulties experienced by students with disabilities across diverse disciplines in higher education.

Taking into account within-individual factors and personal characteristics, science students with LD encounter difficulties related to the nature of their disabilities, lack of understanding of their own disabilities and accommodation services available to them, feelings of inadequacy and stress, and fear of stigma, especially when they compared themselves to their typically achieving peers (da Silva Cardoso et al., 2016; Fullarton & Duquette, 2016; Hong, 2015; Kendall, 2016; Marshak, Van Wieren, Ferrell, Swiss, & Dugan, 2010; Mullins & Preyde, 2013; Stampoltzis, Tsitsou, Plesti, & Kalouri, 2015; Thompson-Ebanks, 2014).

For example, in their study on within-individual barriers affecting college students' experiences, Thompson-Ebanks (2014) reported that students with disabilities described their attention problems, memory difficulties, and unpredictable moods as important factors in their decisions to withdraw from college. In another study, students with disabilities (i.e., dyslexia, attention deficit hyperactivity disorder (ADHD), and other mental-health issues) described their disabilities as "always interacting" with their academic lives and negatively affecting their academic performance (Mullins & Preyde, 2013, p. 151). Other researchers have found that students with disabilities (i.e., learning disabilities, mental-health issues, and medical conditions) also experienced feelings of embarrassment and inadequacy which made them less likely to seek support from faculty, staff, and peers (Hong, 2015; Thompson-Ebanks, 2014).

In describing themselves, students with disabilities (i.e., learning disabilities, mental-health issues, medical conditions, developmental disabilities) used several terms including "stupid", "invalid", "not normal", "what's wrong with me", and "incapable of better judgement". These terms clearly demonstrated their lack of self-confidence surrounding their postsecondary academic performance (da Silva Cardoso et al., 2016; Hong, 2015, p. 218). Their feelings of inadequacy and low self-confidence worsened when their typically achieving peers performed better than them on exams (Fullarton & Duquette, 2016). Specifically, Hong (2015) found that students with disabilities were inclined to become more irritated and disheartened when their academic performance was lower than their typically achieving peers, since their peers seemed to obtain better grades with less academic effort.

The negative perceptions of typically achieving peers towards students with disabilities represented barriers to their inclusion in postsecondary classrooms (da Silva Cardoso et al., 2016; Erten, 2011; Garrison-Wade, 2012; Hong, 2015; Marshak et al., 2010; Strnadová, Hájková, & Květoňová, 2015). A high majority of students with disabilities experienced emotional distress when their typically achieving peers stated to them that they used their disabilities as an excuse to get accommodations and special treatment (Hong, 2015; Marshak, 2010; Strnadová et al., 2015). Other students with disabilities resented their typically achieving peers for lacking sensitivity and for misunderstanding their needs (Erten, 2011; Hong, 2015). For example, some students with disabilities expressed that their typically achieving peers were embarrassed of socializing with them in public due to their disabilities (Hong, 2015). Because they were sometimes viewed differently by their peers, students with disabilities felt stigmatized and alienated from college life.

Other contextual factors affecting the inclusion and academic success of students with disabilities (i.e., learning disabilities, developmental disabilities, mental-health issues, and medical conditions) included: professors' insufficient understanding and knowledge concerning the nature of students' disabilities; instructors' reluctance to differentiate their teaching practice; and to offer accommodations to students with disabilities (i.e., learning disabilities, developmental disabilities, mental-health issues, medical conditions) (da Silva Cardoso, Fullarton & Duquette, 2016; Hong, 2015; Kendall, 2016; Marshak, Van Wieren, Ferrell, Swiss, & Dugan, 2010; Mullins & Preyde, 2013; Stampoltzis, Tsitsou, Plesti, & Kalouri, 2015; Thompson-Ebanks, 2014). In their study of students' experiences at a university, Marshak et al.

(2010) reported that students with disabilities (i.e., learning disabilities, attention deficit disorder (ADD), physical disabilities, mental-health issues, and medical conditions) felt that faculty members did not "fully believe" that the students had a disability (p. 158). Similar to Marshak's et al. (2010) study, Mullins and Preyde's (2013) study highlighted the skepticism exhibited by university professors surrounding the validity of their students' invisible disabilities (i.e., those with LD). In fact, some professors insisted on viewing official documentation related to students' diagnoses (Mullins & Preyde). Such situations heightened students' with LD emotional distress, and led them to feel "less legitimate" than those who experienced physical disabilities (Mullins & Preyde, 2013, p. 157).

Some students also felt that their teachers were indifferent to their needs, and lacked awareness, understanding, and knowledge about students with disabilities (Erten, 2011; Hong, 2015; Kendall, 2016; Strnadová, Hájková & Květoňová, 2015). In terms of teachers' lack of concern about their needs, students explained that they had to continuously remind their professors about their specific disabilities and about providing appropriate accommodations to them (Kendall, 2016). In one study, students with disabilities had sent emails to their professors about their disabilities and accommodations, but their professors failed to respond to their emails (Hong, 2015). In yet another study, students reported that professors lacked a deep and comprehensive understanding of the impact of different types of disabilities on students' learning and daily lives (Erten, 2011). Some professors in the study seemed not to understand that students with comorbid diagnoses encountered challenges in "sitting for three-hour lectures" (Erten, 2011, p. 107). In another study investigating issues experienced by students with disabilities in STEM postsecondary programs, students felt that they were being perceived as being “dumb” by their professors, and that STEM subjects were for the “elitist” (da Silva Cardoso et al., 2016, p. 381).

Another set of contextual factors – insufficient accommodation - impacted the academic success of students with disabilities (Erten, 2011; Hong, 2015; Kendall, 2016; Marshak, Van Wieren, Ferrell, Swiss, & Dugan, 2010; McGregor et al., 2016; Mullins & Preyde, 2013; Strnadová, Hájková & Květoňová, 2015). As indicated by Kendall (2016), some students with disabilities described the pace of instruction as being too fast, and they were subsequently unable to take notes during lectures. Other students with disabilities, who also had attention problems, had difficulty in maintaining focus on both the concepts taught during lectures, while trying to take notes at same time. Furthermore, when revising for tests and exams, students with dyslexia experienced difficulties in reading and interpreting their own notes taken during class (Strnadová, Hájková & Květoňová, 2015). While students with disabilities in these studies requested special accommodations from their professors to receive class notes prior to the lectures, these notes were not made available to them (Kendall, 2016; Marshak, Van Wieren, Ferrell, Swiss, & Dugan, 2010; Strnadová, Hájková & Květoňová, 2015). Professors are not mandated to offer accommodations such as providing class notes before lectures. According to the students with disabilities, professors felt that offering notes before lectures would result in a low attendance rate (Kendall, 2016). Other professors believed that their “lecture notes are copyrighted” and students should not have access to these notes before class (Marshak, Van Wieren, Ferrell, Swiss, & Dugan, 2010, p. 158). Another reason provided by professors for not equipping students with lecture notes prior to classes was that providing notes in advance would be unfair to typically achieving students (Strnadová, Hájková & Květoňová, 2015).

A further issue surrounding inadequate accommodation which surfaced within the literature was professors' unwillingness to employ different types of assessments in evaluating their diverse learners (Fuller et al., 2004; Kendall, 2016; McGregor et al., 2016; Redpath et al., 2013). Students with LD have indicated that they experienced more difficulties with certain types of assessments (e.g., written) than their typically achieving peers (McGregor et al., 2016). Among difficulties reported in Fuller et al.'s (2004) study, 34 % of students with disabilities shared that they had difficulties with written assignments, while in Redpath's et al. (2013) study, 30 % of students with disabilities revealed that they felt high-stakes exams were barriers to their academic performance. While interviewing students with disabilities (i.e., learning disabilities, medical conditions, and physical disabilities), Kendall (2016) noted that those with dyslexia seemed to struggle on written assignments because of their difficulties with spelling and grammar. These students suggested that testing their understanding of the material could be assessed using oral evaluation, since this form of assessment would better capitalize on their verbal strengths. Unfortunately, as reported by students with disabilities, very few professors are willing to modify their assessments by offering alternative testing methods (Kendall, 2016).

Although some students with disabilities reported that accommodation provisions (e.g., extended time, quiet room) were helpful for their academic success, others found that accessing accommodations was barrier-laden (Al-Hmouz, 2014; Bolt, Decker, Lloyd, & Morlock, 2011; Erten, 2011; Fullarton & Duquette, 2016; Marshak et al., 2010; Mullins & Preyde, 2013). For example, Marshak et al. (2010) reported that students with disabilities (i.e., learning disabilities, ADD, physical disabilities, mental-health issues, and medical conditions) faced barriers when accessing testing accommodation services on their campus. Taking their tests outside of their classrooms proved to be problematic for students with disabilities as they did not benefit from the help (i.e., giving hints to students on certain questions) offered by the professors within the classroom settings (Marshak et al., 2010).

Students with disabilities also highlighted that note-taking services presented barriers for them because these services often involved classroom peer note-takers (Marshak et al., 2010). Indeed, students with disabilities reported that the notes from note-takers did not have important elements, and/or were not provided on time (Marshak et al., 2010). In more drastic cases, the note-takers failed entirely to provide class notes to the students with disabilities (Marshak et al., 2010).

These above-discussed studies offer insights on the difficulties faced by postsecondary students with multiple types of disabilities in different facets of their academic life. Most of these studies relied on quantitative methods (i.e., surveys) to explore the difficulties experienced by students with disabilities in postsecondary institutions. The present study seeks to create opportunities for students with LD to disclose the intricate complexities surrounding the barriers which impact their learning, perseverance, and retention within science programs. Specifically, the present study adds to the literature by employing a qualitative approach (i.e., semi-structured interviews and photovoice methods) to listen to and document the authentic voices of students with LD on their challenges within science programs at the CEGEP level.

Methodology

This qualitative study is epistemologically grounded in a social constructivist - interpretivist paradigm such that I make sense of "the world as constructed, interpreted, and experienced by people in their interactions with each other and with wider social systems" (Tuli, 2010, p. 100; Tubey, Rotich, & Bengat, 2015, p. 224). As such, I drew on semi-structured interviews to interact with students with LD, and understand their complex, multiple, and varied perspectives on their experiences in learning science. In this study, I also viewed the participants as “writers of their own history” by making “meanings of their own realities” (Tubey, Rotich, & Bengat, 2015, p. 225). To this end, the participants took part in a photovoice project, where they photographed artefacts and spaces, representing barriers while learning science. These photographs represent the participants’ constructed realities on their most distinctive struggles that hindered their engagement with, and learning in science.

Context and Setting

This study was undertaken at a Canadian CEGEP (Collège d'enseignement général et professionnel), Mountain CEGEP (pseudonym), located in Montreal, Quebec. With a total of 48 public CEGEPs (43 are French language CEGEPs and 5 are English-language CEGEPs), Quebec’s CEGEPs network offer two types of programs after grade 11: a variety of three-year technical studies programs that lead to a professional career in different fields, and a two-year pre-university program to prepare students for university education (Fédérations des Cégeps, 2014). The three-year technical study programs that are grounded in applied science include biological and agricultural technologies, health care (e.g., nursing programs), animal health technology, engineering technologies, dental hygiene, respiratory technologies, amongst others. Students in the technical programs are exposed to multiple core science courses which are not limited to introductory chemistry, physics, anatomy and physiology.

The two-year pre-university science program, which is comparable to Grade 12 and the first year of university in the rest of North America, includes a diversity of core science courses focusing on biology, chemistry, and physics in addition to mathematics and general education courses. Students in the two-year pre-university science programs are required to choose and opt for multiple biology courses namely: general biology, anatomy and physiology, human genetics, amongst others. Embedded in a competency-based learning approach, CEGEP educational systems focus on developing students' critical and creative thinking by engaging them in problem solving, encouraging them to apply scientific knowledge to real-life situations, and communicate using scientific language.

Participants

Mountain CEGEP has a total population of 6000 students between 18 and 22 years of age. Students with LD – diagnosed by medical professionals, psychologists, neurologists – were invited to participate in this study. The participants who voluntarily agreed to take part in this study were enrolled in a three-year technical program (i.e., nursing) or a two-year pre-university science program. They were registered with the Office for Students with Disabilities (OSD) to receive the appropriate accommodations (e.g., extended time, computers, scribes, specialized remedial tutoring) with the hope that these support mechanisms would help them succeed in their respective programs. As a special needs educator at Mountain CEGEP, I was in charge of analyzing the psychoeducational and neurological reports, and letters from psychologists to offer the required accommodations as recommended by the psychologists. Additionally, I designed and conducted individualized remedial activities in science and math with the students with LD to support them in learning in science.

The participants were science students from two cohorts (2011– 2013 and 2012 – 2014) at Mountain CEGEP who experienced multiple and diverse learning disabilities occurring comorbidly with Attention Deficit Disorder (ADD)/Attention Deficit Hyperactivity Disorder (ADHD), anxiety, amongst other issues. I contacted all the 18 students from these two cohorts and invited them to participate in this study. Out of the 18 prospective participants, 11 students with LD voluntarily decided to participate in the study. The 7 participants who declined to participate in the research study explained that they were busy and were not able to fully engage in the interviews and photovoice projects. Out of the 11 participants, 5 students participated in the photovoice projects while the others explained that the photovoice projects would be intensive and time consuming for them. The profile (e.g., gender, age, programs, and types of LD) of each participant is outlined in Table 1.

Table 1. Profiles of science students with LD participating in the study

Pseudonyms	**Gender**	**Age**	**Program of study/year**	**Disabilities Types**	**Other Difficulties**
Bianca	Female	20	Pre-University Science Program – Year 1	LD otherwise unspecified	ADHD inattentive type, Oppositional defiant disorders, Anxiety and depression
Clara	Female	20	Pre-University Science Program - Year 1	LD, Dysorthographia	ADD, anxiety
Deborah	Female	20	Technical Program (Dental Hygiene) – Year 2	LD otherwise unspecified	Anxiety
Eva	Female	20	Pre-University Science Program – Year 1	LD otherwise unspecified	ADHD, anxiety
Jake	Male	20	Pre-University Science Program – Year 1	LD otherwise unspecified	ADHD, Panic attacks
Megan	Female	19	Pre-University Science Program – Year 1	LD otherwise unspecified	ADHD
Olivia	Female	19	Pre-University Science Program	LD otherwise unspecified	ADD inattentive type

Penny	Female	20	Technical Program (Nursing) – Year 2	LD, Auditory processing disorders, language disabilities	Hearing problems
Ricky	Male	19	Pre-University Science Program – Year 1	LD in reading and written expression	
Victoria	Female	20	Technical Program (Nursing) – Year 2	LD in reading and written expression; LD in mathematics; Non-verbal LD	

Salient Types of Disabilities Exhibited by the Students

Six students (5 females and 1 male) namely Bianca, Deborah, Eva, Jake, Megan, and Olivia, were classified as having an LD not otherwise specified. According to Morin (2014), "learning disability NOT otherwise specified" (LD-NOS) is attributed to individuals having issues that cannot fit into learning issues that relate to reading, writing, and math. LD-NOS appears in the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV) but not in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-V), which focuses on specific learning disorders with impairment in reading, written expression, and mathematics (Morin, 2014).

One female student, Clara, was diagnosed with dysorthographia, which is a "term referring to a specific learning disability (SLD) associated with poor performance in spelling" (Chia, 2009, p. 76). Dysorthographia also "refers to the difficulty of writing words correctly according to the rules of a language, i.e., the difficulty of spelling, which, in fact, is the case with disorders in reading and writing" (Kuure, Kuure, Sandbäck, Yliherva, 1992, p. 191). The most common characteristics of dysorthographia are "omissions, substitutions, and inversion of grapheme[13]" (Alves, Casella, & Ferraro, 2016, p. 124). Clara's psycho-educational report indicated that she had issues in recalling sentences and severe delays in understanding spoken paragraphs with deficits in her working memory. Furthermore, she had significant difficulties in manipulating phonemes into words (i.e., phonological segmentation (1st percentile) was impaired).

Three students (Ricky, Victoria, and Holly) were diagnosed with LD in reading and written expression. The *Diagnostic and Statistical Manual of Mental Disorders* (DSM-V) (2013) described impairment in reading as difficulties in "word reading accuracy, reading rate or fluency, and reading comprehension" (p. 67). According to Marinova-Todd, Siegel, and Mazabel (2013), all children with reading problems have deficits in phonological processing, working memory and short-term memory, and syntactic awareness. In Ricky's psycho-educational evaluation, it was clearly stated that he had difficulty with vocabulary retrieval and had reading comprehension deficits. Ricky experienced difficulties with his phonological memory.

In the case of Holly, the psychologist highlighted that she had issues with her working memory and phonological awareness which predicted problems in reading. The *Diagnostic and Statistical Manual of Mental Disorders* (DSM-V) (2013) documents impairment in reading expression as having difficulties in "spelling accuracy; grammar and punctuation accuracy; clarity or organization of written expression" (p. 67). For example, in Holly's psycho-educational report, the psychologist pointed out that Holly was "weak" in her writing samples, punctuation, and editing. Specifically, the psychologist described Holly's sentences as awkward with omissions of words and letters. Overall, she had errors in her writing.

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[13] Graphemes can be individual letters and groups of letters that represent phonemes or sounds. For example, the word 'leaf' is a 2 letter grapheme such that 'ea' represents the sound /ee/.

In addition to LD in reading and written language, both Victoria and Holly also experienced LD in mathematics. The *Diagnostic and Statistical Manual of Mental Disorders* (DSM-V) (2013) describes impairment in mathematics as issues with “number sense; memorization of arithmetic facts, accurate or fluent calculation, and accurate math reasoning” (p. 67). For example, Holly was described to have issues with arithmetic such that she experienced difficulties with mental computations.

Ethical Considerations

Prior to collecting data, ethical approval to conduct this study was granted by McGill’s ethics’ committee and the college’s research ethics board where the study took place. Consent was obtained from each student to participate in the study. During the project, there were no conflicts of interests between the students and the author. This is because the author was not teaching them at that time and was not responsible for assessing the students or allocating grades that directly affected their academic achievement.

Data Generation

To explore the views and experiences of college students with LD about difficulties in learning science, they were invited to participate in semi-structured interviews, which lasted between 1 – 2 hours. The detailed process of the semi-structured interviews is described in the next section titled semi-structured interviews. Following the semi-structured interviews, all the students were invited to participate in the photovoice project which is described in the next section. The duration of the photovoice project undertaken by 5 out of the 11 students was four months. The three sources of data stemming from the photovoice project included: photographs, photovoice journals, and photovoice semi-structured interviews (30 – 45 mins). In Figure 1, I outlined the process of data collection.

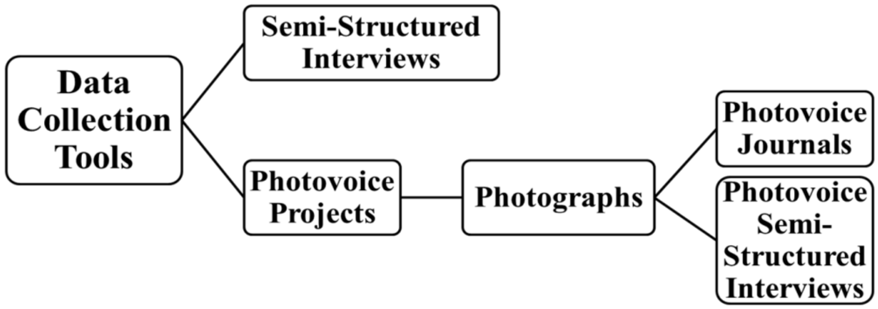

Figure 1. Multiple sources of data to explore students' views of barriers in science learning

Semi-structured interviews. The semi-structured interviews were designed to illuminate the participants' perspectives, emotions, and experiences on difficulties in learning science. The interview questions were constructed on the basis of the (a) research questions of the study; (b) the review of the limited literature on barriers experienced by students with LD in learning science; and (c) the first author's experiences in working with students with LD in learning science. The interview guide employed to explore views of science students with LD at Mountain CEGEP is found in Appendix B.

Photovoice. Pioneered by Wang and Burris (1997), the photovoice methodology is understood as "a process by which people can identify, represent and enhance their community through a specific technique" (p. 369). The photovoice methodology is grounded in Freire's critical consciousness which enable members of a community to express their social experiences and become conscious of the issues that influence their lives (Wang & Burris, 1997). Influenced by feminist perspectives, the photovoice approach recognizes that all individuals irrespective of their biological, social and psychological differences have insights and knowledge to share about their communities. Moreover, from a feminist perspective, issues affecting a particular community should come from community members and not from outsiders who are likely to lack insights about the community (Wang & Burris, 1997). Such is the case in this study whereby students with LD are insiders and have unique insights on their difficulties in learning science.

Mitchell, Weber, and Pithouse (2009, p. 121-122) further explains that "through the lens of a simple point and shoot camera," participants mold into researchers to "produce their own images, making visible their voice around a particular social issue that affects them directly." Therefore, by relying on photography as the main source of data, the photovoice methodology is "a means of accessing other people's worlds and making those worlds accessible to others" (Booth & Booth, 2003, p. 431). Specifically, photovoice "aims to capture the reality of people's lives and make these realities accessible to others using photographic images" (Povee, Bishop, & Roberts, 2014, p. 895). By representing their barriers through photography, students with LD are offered opportunities "to express themselves in new and imaginative ways" (Mcintyre, 2003, p. 52) and become conscious of the barriers that affect them *most* in learning science (Mcintyre, 2003, Wang & Burris, 1997). Given that the photovoice methodology removes "some of the language barriers faced by people with learning disabilities…" (Germain, 2004, p. 170); I argue that such an approach allows science students with LD to unreservedly express their views, feelings, and emotions on their respective learning challenges.

As also discussed by Lico and Luttrell (2011), photovoice is a method of inquiry that "puts cameras in the hands of people who have been misrepresented and who have been left out of policy decision making about matters that concern their daily lives" (p. 670). Moreover, Mitchell, de Lange, and Nguyen (2016, p. 244) discussed that photovoice is a "research tool" that "privileges the voices of those most marginalized (typically girls and women), and serves as a tool for self-representation and reflexivity." Such is the case with individuals with disabilities, who have been historically stigmatized, marginalized, and excluded in sharing their views and in decision-making processes regarding their challenges and needs (Booth & Booth, 2003; Carnahan, 2006; Jurkowski & Paul-Ward, 2007). Therefore, photovoice, as a participatory action research tool, opens doors for the untold, hidden, and silenced views and stories of students with LD to emerge in photographs of artefacts and spaces that represent barriers for them as science learners.

Prior to the start of the photovoice project, the 5 participants were offered training and guidelines by the author regarding the ethical and moral implications of photographing spaces and artefacts. The participants were educated about the ethics, power, and the responsibilities of using a camera - especially on the importance of seeking permission from the institutions and people before photographing private spaces and artefacts (Jurkowski & Paul-Ward, 2007; Jurkowski, 2008; Mitchell, 2011; Wang & Burris, 1997). For instance, as discussed by Mitchell (2011), participants need to consider alternatives to guard the anonymity of photo subjects. Some of the strategies to preserve the anonymity of photo subjects include: taking photos at a greater distance, or capturing photos representing body parts (e.g., arms, hands) (Mitchell, 2011). Mitchell (2011, p. 21) also explains that ethical issues can be partly addressed when participants engage in "working at a more symbolic or abstract level" by taking photographs of artefacts.

Data collection and analysis approaches for photovoice differ significantly across various studies with different populations such as individuals with HIV, disabilities, care givers amongst others (Hergenrather, Rhodes, Cowan, Bardhoshi & Pula, 2009). The photovoice data collection and analysis approach for this study is consistent with researchers who have worked with similar populations (i.e., individuals with disabilities) (e.g. Booth & Booth, 2003; Carnahan, 2006; Jurkowski & Paul-Ward, 2007; Jurkowski, 2008; Thompson & colleagues, 2008). Specifically, the photovoice project was divided into three phases. During the first phase of the photovoice project, students were invited to take photographs of artefacts and spaces that represented the barriers they experienced in engaging and learning science during the fall 2015 semester. To guide the process of photography, participants were requested to focus on the overarching question: “What *major* problems and issues are you experiencing in learning science (biology, chemistry, and physics) this semester?” Taking into account the students’ availabilities, course loads, and schedules; each participant was asked to take at least 3 photographs that depicted their *most significant* struggles throughout the semester.

After photographing the artefacts and space, students engaged in a reflexive process by writing journals to record their immediate thoughts, emotions and experiences (Guce, 2017; Hiemstra, 2001) on their obstacles as science learners. Journal writing offered a venue for the participants to “capture contexts and internal experiences” on their challenges in learning science, which could not be expressed verbally (Guce, 2017; Iida, Shrout, Laurenceau, & Bolger, 2012, p. 282). To support the participants in the journal writing process, they were requested to focus on three guiding questions: (a) What inspired you to take this particular photograph? (b) what barriers does this photograph represent in science learning? and (c) what strategies did you use to overcome the problems that you represented in the photographs? These guiding questions helped the students to focus on illuminating the barriers that affect their learning.

Following the process of journal writing, each student also participated in the process of photo-elicitation, which involved the analysis of the photographs during an individualized semi-structured interview (15 – 30 minutes) with me. Instead of a focus group interview or group discussion, an individualized semi-structured interview was selected as some of the participants were not comfortable to showcase and discuss their photographs with others. The approach to employing semi-structured interviews in photo-elicitation is consistent with Hebblethwaite and Curley (2015); and Ebrahimpour, Esmaeili, and Varaei (2018). During photo-elicitation, the participants “lay out the photographs they have taken on the conference table, review each one, and think what the photographs meant to them…" (McIntyre (2003, p. 53). Specifically, the students discussed the significance of the photographs and chose one photograph that represented their most challenging barrier throughout the semester (Aldridge, 2007). Such an approach enabled the participants to engage in a reflexive process on the barriers that mostly impacted their learning of science concepts.

Data Analysis

To analyse and interpret data, this study drew on the constant comparative analysis approach outside of grounded theory (e.g., Boeije, 2008; Fram, 2013; Leech & Onwuegbuzie, 2008; Mason et al., 2015). The constant comparative analysis approach can be employed to analyse multiple sources of data such as interviews and journals (Jacelon & Imperio, 2005; Leech & Onwuegbuzie, 2008). Moreover, data (e.g., photographs, interviews) stemming from photovoice projects has also been analyzed by the constant comparative analysis approach (Hebblethwaite & Curley, 2015; Ebrahimpour, Esmaeili, & Varaei, 2018).

I began data analysis by adopting an open or inductive coding approach which enabled me to make sense of the participants' perspectives and concerns in learning science at Mountain CEGEP. The analysis process involved "close readings of text" such that each interview transcript and journal were read multiple times to allow me to "build concepts from data" (Chamberlain, 2012; Gibbs 2007, p. 45; Thomas, 2006, p. 4; Yukhymenko et al., 2014). Specifically, the central ideas and views of the participants were conceptualized by attributing codes to sentences and paragraphs (Hewitt-Taylor, 2001). This coding approach is similar to the constant comparative analysis method wherein "the analyst chunks the data into smaller segments, and then attaches a descriptor, or 'code,' for each segment" (Leech & Onwuegbuzie, 2008, p. 594). For example, the codes – "make me feel different", "affects me", "not always on my mind", "bothers me", "keep it inside" - stem from the following excerpt: [1]*I mean, it[LD] does make me feel different from others, but like I said,* [2]*I don't know why it affects me so much. I feel like it shouldn't, so I don't know what it … when I talk about it.* [3]*It's not something that I think about all the time, like oh, I'm so different.* [4]*It's not always on my mind, but when I have to talk about it, it kind of bothers me. I just keep it inside.* (Olivia)

Following open-coding, I coded the data a second time in light of the research questions and objectives to identify difficulties that students with LD encountered in learning science. Then, the refined codes were compared and contrasted to identify similarities and emerging patterns across the interview transcripts and journals (Boeije, 2002). Specifically, I organized and grouped "similarly coded data into categories or 'families' because they share some characteristics…" (Saldaňa, 2009, p. 8). For example, the following codes – "*I tend to not pay attention to certain little details*"; "*I have trouble focusing*"; "*I will still always end up being distracted…*"; "*I can get easily distracted by anything, just noises around me*"; "*I have trouble concentrating*" – indicated that students with LD experienced difficulties in focusing and paying attention. As such, these codes were organized and grouped into the category titled "focus and attention."

In Appendix D, I present the codes and categories that depict the challenges encountered by students with LD in their journeys as science students. During this process of examining and comparing data, asking questions, and constructing meaning; I also employed analytical memos, displays, matrices, concept maps, and diagrams (Boeije, 2002; Corbin, Strauss & Strauss, 2015) to compare and contrast the emerging codes, categories and themes.

The codes and categories were further analyzed and grouped together to develop broader themes. Specifically, I drew on the constant comparative analysis method to "identify, create, and see the relationships among parts of the data when constructing a theme" (Leech & Onwuegbuzie, 2008, p. 594). For example, the following categories – rapid pace of instruction, lack of structure in science classrooms, teaching strategies – were grouped together to form the theme: Teaching practices. The emerging themes from the interviews and journals were further compared by constructing cross-case matrices and concept maps (Maxwell, 2012). This process allowed the exploration of the interrelationships across various themes that were constructed from the data.

Trustworthiness of Findings

To enhance rigor and trustworthiness of the findings, multiple strategies related to credibility and transferability were employed (Lincoln & Guba, 1985; Merriam, 2009). Credibility was established by my prolonged engagement with the participants such that I was responsible for their special needs dossier and offering them remedial tutorials and interventions in science and math courses. By working closely with the participants, I was able to build a relationship with them and they candidly shared their issues knowing that their "confidences will not be used against them" with their teachers (Lincoln & Guba, 1985, p. 303). To ensure credibility of the findings, the multiple sources of data (i.e., semi-structured interviews, photographs, and journals) were triangulated and corroborated to explore consistencies and contradictions in students' perspectives on their difficulties in learning science. Furthermore, I conducted member checks by individually inviting each participant to share their perspectives on the data analysis and the themes generated from the study (Lincoln & Guba, 1985; Merriam, 2009). To seek multiple interpretations, two independent researchers were invited to critically analyze and discuss the interpretations of data until a consensus was reached on the themes. In qualitative studies, it is important that findings can be transferred to other contexts and settings.

Findings and Analysis

In this section, I present the findings regarding barriers that college science students with LD encountered in learning science. These findings stemmed from the collective analysis of the semi-structured interviews, photographs, photovoice journals and photovoice interviews. As detailed below, the analysis of findings demonstrated that these students experienced multiple, complex, and interrelated barriers in learning science. Specifically, the analysis of various data sources revealed that most of the students voiced out that their diagnosed disabilities affected their engagement and learning in science. The students also compared their academic achievement to their typically achieving peers and perceived that they were at a disadvantage based on their respective disabilities. Additionally, this study's findings also revealed that students with LD lacked effective learning strategies in science. The participants also explained that the teaching approaches adopted by their science teachers did not meet their learning needs. Altogether, six cross-case themes stemmed from this study which included: (a) learning difficulties in science, (b) students' perceptions of being academically disadvantaged as compared to their peers; (c) surface learning strategies, (d) fast pace of instruction, (e) undifferentiated teaching approaches, and (f) lack of consistency and structure in teaching approaches. These main themes are described below.

Theme 1: Learning Difficulties in Science

All the participants attributed their difficulties in learning science to their specific learning disabilities. They shared several difficulties in learning science: difficulty in focusing and paying attention; memory issues; and difficulties with reading, vocabulary acquisition, and comprehension of science text. In what follows, the impact of these learning difficulties is discussed.

Difficulty in focusing and paying attention. The majority of students' narratives (7 out of 11) highlighted the extent to which their respective disabilities restricted their abilities to focus and pay attention during lectures, study sessions, and exams. "Zoning out" during lectures was a common issue for all the seven participants with LD who have also been diagnosed with AD/HD. In particular, Megan associated her tendency to "zone out" to her "brain" and how it works. In her words, she explained: *"[My brain] works that way and it's like boom: I'm back to reality and I didn't even realize that I zoned out*." The participants' difficulty in focusing on particular academic tasks had a serious impact on their learning process. In the excerpt below, Megan described that her inability to focus in class led her to miss out on key information during lectures, which prevented her from understanding the taught concepts:

> *I start thinking about other things. I feel distracted and I feel like, I don't know. Sometimes I just don't even notice. I just start thinking about something else and then I realize that I should be paying attention in class and that I missed a bunch of stuff the teacher said and there's nothing I can do about it*. (Source: Semi-structured interviews)

Owing to her difficulty in paying attention to particular details, Eva explained that she was only able to construct a surface understanding of taught biology concepts:

> *I tend to not pay attention to certain little details. For example, especially in bio, you know, I understand the whole concept of mitosis, meiosis, but I'll forget, like, you know, what particular part goes there? Where are the spindle fibres? Where are the centromeres? Like, what's the difference? Little things I'll forget more easily. Or I get a global idea and it's just too much to look specifically [at the details], and then I'll just get a global idea.* (Source: Semi-structured interviews)

The above statement clearly reveals Eva's difficulty in understanding the rich and complex details of cell division. Specifically, by "forgetting" the specific machinery such as spindle fibres, centromeres, amongst others that drive cell division, she gained only surface knowledge of the processes of mitosis and meiosis.

Similar to the other participants, Olivia explained in her photovoice journal that her ADD is a barrier to achieving good grades: "*It is very difficult for me to keep my 100% attention on one thing, (it's even harder since I have ADD). I am certain I would get much better results from my studying since my attention would be solely focused on that one task*." Because her ADD was the central barrier that affected her most in her pursuit of science, she photographed her electronic devices and social media page (see Figure 2), which were constant sources of distraction in her learning process

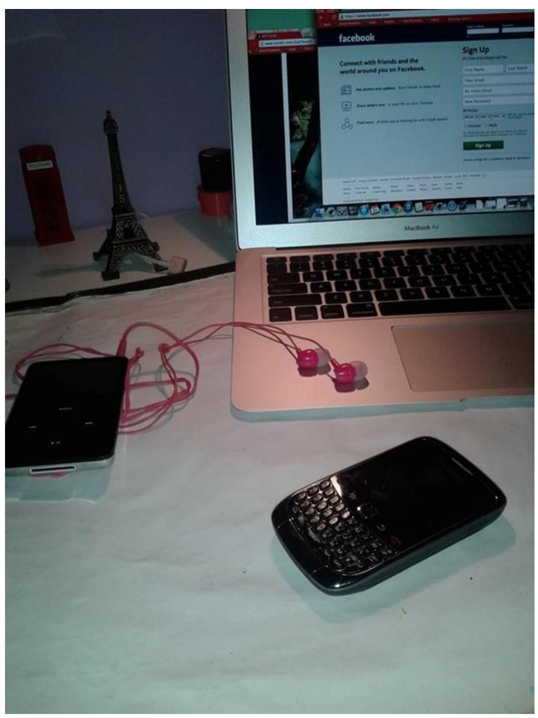

Figure 2. Olivia's photograph depicting sources of distraction as a barrier to learning science

Memory issues. Another learning difficulty that arose from my conversations with several science students (6 out of 11) was their difficulty to remember scientific terminologies and concepts. Both Penny (auditory processing disorder coupled with hearing issues) and Holly (learning disability in reading and writing) articulated their struggles in remembering definitions of key concepts. During the semi-structured interview, Penny explained: "*Like, I'm not really good with remembering words. So that takes me really [a long time] - because, like, you have to remember, like, what's the definition?"*

Similarly, even though Holly has not yet taken biology, she expressed feelings of anxiety and fear with regards to memorizing biological concepts, which might negatively shape future learning experiences.

> *I don't have a very good memory. Like, I can't just memorize something. A definition in calculus or in taking biology, I haven't take biology but I'm already scared because I can't just memorize all of it.* (Source: semi-structured interview)

Olivia and Megan, who have unspecified LD and ADHD, explained that their memory was a central barrier to learning in science classrooms. Both Olivia and Megan were unable to instantly recall new information that were provided during lectures. As indicated in the excerpt below, Olivia had difficulty in retaining incoming information from her teacher when she was engaged in other tasks such as writing notes: "*When I'm writing down things, my mind kind of shuts off, so I don't maybe hear things that are important from the teacher, because I'm trying to remember what he said before*."

As for Megan, her difficulty lies in retaining and retrieving information to construct her understanding of multi-stepped scientific models: "*If they were going through an explanation, there're steps in explanations. So I understand the first set, but then they go to the second and* *the third and let's say, by the fourth step, I'll forget about the first step*." Consequently, while engaging science tasks that required recalling information to solve science problems, Olivia and Megan struggled and eventually were unable to perform well on multi-stepped science tasks.

Difficulty in vocabulary acquisition, reading, and comprehending science text. More than half of the students (6 out of 11) shared their difficulties regarding learning complex science vocabulary, reading and comprehending science texts. In particular, Penny who was diagnosed with a reading and writing disability by a licenced psychologist, described her struggles in sounding and spelling words. As she explained in her photovoice journal, when a "*word started with a "z" or "x" I had no clue how to say it, so I would stare at it for like 15-20 mins until someone realizes that I was having trouble*." Consequently, Penny felt that her "mediocre" grades in science were due to her learning disability and the complex nature of the scientific language:

> *It's a struggle for me [to learn science] sometimes because the wording can be very advanced, and I don't understand what they're [teachers] asking me half of the time [on tests]. So I end up guessing, which is, sometimes, either good or bad. They [My grades] are mediocre.* (Source: Semi-structured interviews)

Sounding and spelling words was such a hardship and a painful experience for Penny that she took a picture depicting "WORDS" as part of her photovoice project as shown in Figure 3.

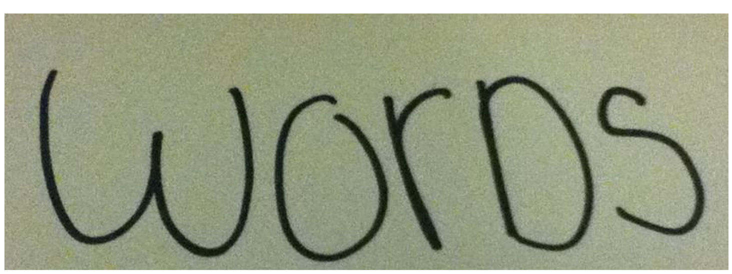

Figure 3. Penny's photograph depicting that sounding and spelling words is a barrier in learning science.

Similar to Penny, Clara also encountered issues with science texts. Specifically, Clara experienced comorbid disabilities which include dysorthographia (i.e., learning disability associated with problems in spelling, grammar, and speed in writing and spelling) and mild dyslexia that affect her reading and comprehension of science concepts. These disabilities manifest as reading errors mostly during exams. Because of the reading issues, Clara felt very discouraged and upset such that she pondered on the possibilities for not participating in exams:

> *I'll go in and do the exam, and I think I got it, and then I'll come out of the exam and most of the errors are actually reading errors, and you're completely devastated because there's nothing you can do. I've reread this exam three times, and I still see the same mistake. So that part is super annoying, and it makes you pretty much not wanting to do exams anymore, pretty much because you know you're going to make these mistakes*. (Source: Semi-structured interviews)

Additionally, Ricky who experienced learning disabilities in reading and written expression, explained that reading errors during exams is a major concern for his academic achievement in science. During exams, Ricky was often in a state of confusion because he was concerned about misreading questions: "*sometimes in the back of my head I doubt myself, because sometimes I might have misread something or whatever, or I think I might have misread something which can confuse me on a test*." Due to his LD and the complexity of science texts, Ricky found himself re-reading his chemistry text several times to develop a comprehensive understanding of concepts: "*For Chemistry unfortunately I need to like reread everything multiple times trying to find a relation in all these amount of words*…."

Altogether, drawing on my conversations with students, disability-related issues associated with vocabulary acquisition, reading, and comprehension were barriers to students' motivation and self-confidence in performing well on science assessments such as high-stakes tests and exams.

Theme 2: Feelings of being Academically Disadvantaged

An important and powerful theme that resonated across a large majority of narratives (10 out of 11 students) was students' feelings of being academically less capable than their typically achieving peers. Such feelings represented emotional barriers to these students' learning journey and academic achievement in science. It is noteworthy that these themes repeatedly surfaced across the three different data sources: semi-structured interviews, students' photographs, and photovoice interviews. From these data sources, it became clear that these 10 students felt that they were confined to the margin of science learning as compared to their peers without disabilities. Not only did these students evoke feelings of being "discouraged" and "frustrated", they also felt anger and irritation towards their unsatisfactory academic performance.

They even viewed themselves as minorities when they compared their journeys as science learners to their typically achieving peers. In their views, their learning journeys were laden with much hardship because they felt that they invested more efforts and time in studying the science concepts than their typically achieving peers. Yet, in addition to sharing concerns about obtaining lower science grades than their typically achieving peers, they also highlighted that their grades were not reflective of their efforts.

Ricky, who depicted himself as a highly ambitious science student, often compared his science performance to that of his typically achieving peers. Ricky explained that inspite of investing more time in studying and doing homework; his science grades were lower than his peers. Ricky's use of expressions such as "downer", "pisses me off", and "frustrated" demonstrated his heightened feelings and emotions regarding his inability to perform at the same academic level as his typically achieving peers:

> *I'm a very competitive person, so I sometimes do compare myself with someone without a learning disability and how they most of the time study less than I do and will still get a better grade than me breaking my back studying. It's a downer, it pisses me off sometimes and it gets me frustrated… I guess that they can understand the subject quicker than I do, so I have to do more homework and do more this to fully understand at their capability.*

As noted earlier, the feelings of being academically disadvantaged compared to their typically achieving peers, were echoed throughout the majority of photovoice projects conducted by students with LD. Three out of the five students, who participated in the photovoice project namely, Olivia, Megan, and Clara, unreservedly expressed their feelings of being academically less successful than their typically achieving peers in their photographs. These photographs represent the voices and the internal struggles of students with LD. Taking the roles of researchers, these students were empowered to represent their issues through photography. Through the photovoice process, Megan voiced her hurdles by taking a photograph depicting different types of muscle tissues (see figure 4) from her biology notes. She recalled her struggles in differentiating between the various types of muscle tissues (i.e., cardiac, smooth, skeletal), while her typically achieving peers did not seem to experience difficulties on the matter:

> *These are different levels of tissue. Well, I had trouble with this because it looked like; there are three levels of tissue here. But they all look the same to me…. I find some of my friends who have a learning disability will have the same problem as me. But the people without, I don't think they have too much of a problem. It seems like they know what*

they're doing. Like, they can tell the difference between these levels of tissue (Source: photovoice semi-structured interview)

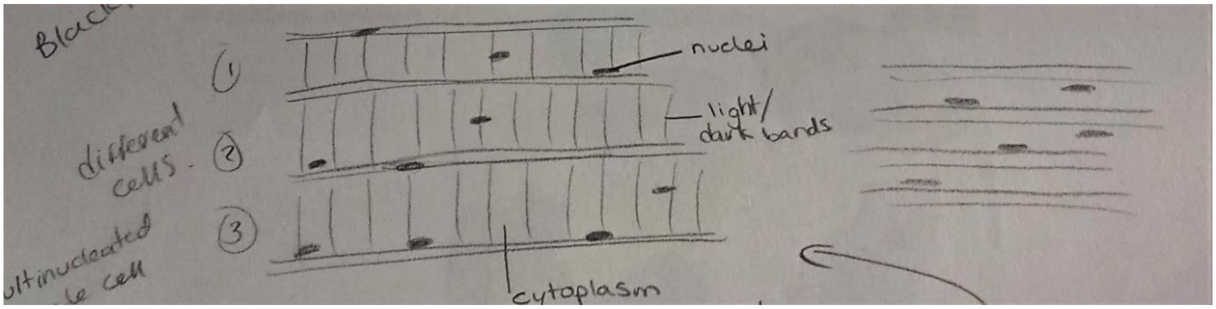

Figure 4. Photograph depicting Megan's difficulty in differentiating between muscle types as compared to her typically achieving peers

As shown in Figure 5, Oliva photographed her chemistry exam depicting a grade of 34 out of 60, and explained in her photovoice journal that she invested "*a lot of hard work*" which was "*going nowhere*" as compared to her typically achieving peers who "*won't necessarily study as hard or as long*" but still got better grades than her.

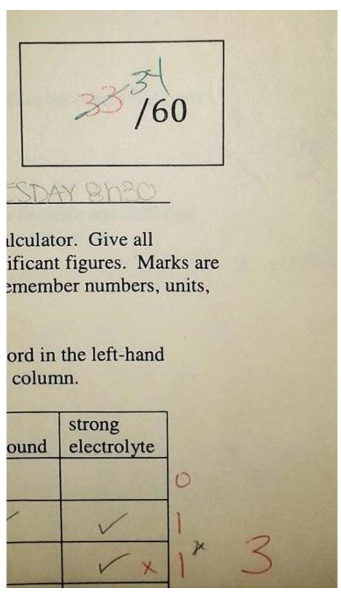

Figure 5. Photograph depicting Olivia's lower academic achievement in chemistry as compared to her typically achieving peers

Additionally, in both the interviews and photovoice project, Clara portrayed herself as an "*outcast*" and felt disconnected from the "*normal people*" because she struggled in learning science concepts as compared to her typically achieving peers who easily grasped taught concepts in her opinion. Moreover, as in the excerpt below, Clara felt "*empty*" when she compared her achievement to that of her typically achieving peers:

> *I look at other students and instantly believe that I am an outcast. In my science classes, I see students understanding things right away, experiencing these emotions of self-worth and accomplishment. I sit there and feel empty and alone because I have to work so much harder to be at the same level as them. These emotions are so strong at times that you feel as if you wanted to run away because you feel so low about yourself. (Source: photovoice journal)*

Clara's photograph in figure 6 depicts a transparent glass which represents herself as a student struggling with dyslexia as compared to the red glasses which embody her typically achieving peers. Moreover, in her own words, Clara felt that "t*he clear cup can try as hard as she can, but she will never be like the others*."

Figure 6. Photograph depicting Clara's perspectives of being academically different from her typically achieving peers

Altogether, co-constructing knowledge with typically achieving peers in inclusive science classrooms, might negatively impact students' perceptions and feelings about themselves such that they feel less capable, discouraged and unworthy in their pursuit of science.

Theme 3: Surface Learning Approaches

The theme – surface learning approaches – emerged from my conversations with more than half of the students (6 out of 11). Chin and Brown (2000) defined the learner who uses surface learning approach as one who "perceives the task as a demand to be met, tends to memorize discrete facts, reproduces terms and procedures through rote learning, and views a particular task in isolation from other tasks and from real life as a whole" (p. 110). Similarly, in this study, many participants explained that they relied on rote learning as a strategy. However, relying only on rote learning does not lead to a deeper and meaningful understanding of science concepts (Chin & Brown, 2000).

When discussing their learning practices, these students noted that their learning strategies were not well-suited for learning science concepts. For example, during the interview, Olivia explained that her learning technique for physics (e.g., mechanics) was ineffective due to it being centered on memorization rather than comprehension: "*I think that I'm trying too hard to memorize and for Science, especially Mechanics, it's not memorization, it's really like comprehension, so I think that my studying methods aren't 100% the best*."

Deborah, who also adopted rote-learning as a learning strategy, felt that "i*t's easier to have it memorized than try to actually understand it*." Given that Deborah experienced difficulties in understanding science concepts, she relied on rote learning as a strategy to retain the concepts in her memory. At the same time, she understood that such technique was not conducive to comprehending biological concepts. In her words, she stated: "*I just don't understand [the* *biological concepts], so I end up re-reading the same thing like 15 times without realizing that I read it. And then I just don't do it anymore*." Deborah's statement suggests that she felt discouraged and unmotivated to learn biology because she was unable to understand the concepts despite her persistent efforts.

As also emphasized by Eva, her declining performance in science spanning from high school to college was partly due to her memorizing the concepts rather than "*studying to understand the concept[s]*." As Eva noted, "*Well, I was really good in science. I would get, like, 90s and plus until I hit SEC 5 [Secondary 5 – Grade 10] and it got a lot harder, but I think it was mostly because I wasn't used to actually studying. I was used to memorizing.*" To Eva, studying and memorizing were distinct learning approaches:

> *Memorizing is really just like: here's a bunch of words, memorize definition, memorize pictures. Studying is really to understand the concept and to be able to rewrite it, to be able to put it in another situation, to be able to explain it. Like, really understanding the concept and having to grasp at it…. If you just memorize it, you won't be able to do anything with [solving] the [science] problem. I find with science, it is really you have to understand the concept and you really have to be able to, like, manipulate input in a situation.*

These findings indicate that these students seemed collectively conscious that rote-learning strategies were not geared towards effective learning and problem solving in science. Yet, they seemed to be unaware of effective learning strategies to support their comprehension of science concepts.

Classroom-related Issues

In the following, I discuss the classroom-related issues such as fast-pace of instruction, undifferentiated teaching approach, and lack of structure and consistency in teaching approaches that affected these students' learning in science.

Theme 4: Fast pace of instruction. When asked about challenges experienced in their science classrooms, some students (5 out of 11) felt that the rapid pace of instruction did not match their learning needs. As such, these students faced difficulties in adequately comprehending the taught science concepts, and spent a considerable amount of time studying the material. Unable to keep pace with their increasing work load, they felt that they fell behind in their science classes. As noted by Megan, she experienced difficulties in understanding the concepts due to the rapid pace of teaching in chemistry lectures: *"If the teacher's teaching something in chemistry, I find they would teach too fast for me. So it would take me so long to understand it and then I would fall behind."*

Victoria also echoed Megan's views and felt that the fast pace of teaching due to time constraints was a significant issue, which negatively impacted her learning process in biology classrooms. Victoria felt that there were inadequate opportunities for students to ask questions in her biology course: "*Everything was like super intense [in my biology classroom]. It was like, here's the lecture, there we go, here's the lecture, there we go; no time for questions. We only have an hour today; we only have an hour today*."

Additionally, like Megan and Victoria, Deborah also felt that her teachers' pace of instruction is "*excessively fast*". As such, during class, she experienced difficulty in "*paying attention*" and taking notes at the pace that the class was being taught. Consequently, Deborah observed that her class notes were not organized and difficult to understand after the class:

> *Well sometimes the teacher just goes excessively fast and since I'm not always paying attention all the time, I miss half of the material. And I can't take notes as fast as the teacher talks, so I end up having terrible notes because they're all over the place and don't make sense (Source: Semi-structured interviews)*

Altogether, the fast pace of instruction during class time affected students' comprehension of taught concepts, their ability to take notes, and limit the time available for them to ask questions on the material.

Theme 5: Undifferentiated teaching approach. The theme – undifferentiated teaching approach – emerged from several narratives (5 out of 11), which suggested that students with LD are not offered alternative ways to understand science concepts, rather science instructors' pedagogies are embedded in homogenous and uni-dimensional teaching approaches. The participants were marginalized in their respective science classrooms as their unique learning needs were not understood and met by their science teachers. In the following excerpt, Ricky shared his experience regarding his chemistry instructor's undifferentiated pedagogical approach during office hours offered by the instructor after the class.

> *He'll re-explain what is happening, like he did in class, like as a lecture and then try and like make it sound more sophisticated, but it just doesn't help. He doesn't need to use [words] that are unnecessary to explain to a student. He re-explains it using different words, but the same type of explaining*

The above excerpt seems to demonstrate that Ricky's chemistry instructor attempted to address his difficulties by using a set of different vocabulary, but was unable to offer different means (e.g., drawing, using concept maps) to explain scientific terms and concepts.

Likewise, Jake indicated that his chemistry instructor is "*pretty much one way*" and in his situation either the teacher "*kind of gave up*" re-explaining the concepts or Jake would "*get bored of him or sick of him just explaining it in one way*" that he would just say "*okay. I get it*," even though he did not understand the concepts. In the end, Jake left the meeting with his teacher without adequately understanding the concepts.

Consistent with Ricky's and Jake's experiences, Megan also felt that her chemistry teacher favoured only one way of explaining the science material. In her view, Megan explained that her teacher did not "*connect*" concepts, provide "*good examples*" for her to better visualize and grasp the material, and "*make up stories*" so that she could associate the abstract chemistry concepts to real-life situations.

> *He didn't go into detail and he didn't connect; like he didn't really give good examples, He'd explain something but he didn't say, oh if you mix this and this together it would create an explosion or whatever. He wouldn't make any stories with it.*

Additionally, Holly articulated her fear and frustration when seeking support from both her high school and college science teachers regarding difficulties that she experienced in understanding science concepts. She felt that her science instructors had difficulties in comprehending the complexity of her learning disability (i.e., dyslexia). Additionally, Holly observed that her science teachers were unable to employ effective instructional strategies geared towards facilitating her learning processes. She felt that seeking support from science instructors was "*wasting*" her "*time*" as they reiterated the taught concepts using similar strategies as in the classroom, which failed to support her learning. In her own words, Holly stated:

> *I'm very scared of my teachers most of the time just because most of my teachers in high school weren't very helpful with my learning disability and didn't really know what it was*

> *or know how to help me. So they would repeat what they said in class but that doesn't help me. I'm wasting my time coming to see you if you're going to repeat what was in class, I still don't understand what you're saying. That's wasting my time.* (Source: semi-structured interviews)

Altogether, these students felt the need for their teachers to employ different ways to explain the material. These data clearly indicate that these students have particular learning needs that could be met with diverse teaching approaches.

Theme 6: Lack of structure and consistency in teaching approach. In line with the issues on classroom practices, some students (4 out of 11) collectively described the teaching approach adopted by their science instructors as "*messy*" which led them to feel "*anxious*" and "*confused*." The "*messy*" and disorganized teaching approach aroused such intense feelings in Eva and Olivia that they felt compelled to center their photovoice project on taking photographs that depicted the "messy" teaching approach.

In particular, Eva photographed a "mess of wires" (see Figure 7) to depict her instructor's teaching approach. In her photovoice journal, Eva attributed the "*mess of wires*" to her chemistry teacher being "*very disorganized*" such that "h*e would skip from point to point, forget some stuff and come back to it*." Eva further noted that:

> *His lectures were a mess. His slides were a mess, sometimes he'd skip slides, sometimes [during lectures] he'd put slides that weren't there [on PowerPoint presentation that he gave to us prior to class], sometimes he didn't post the slides after. It was just crazy so that was hard for me. (Source: Photovoice interview)*

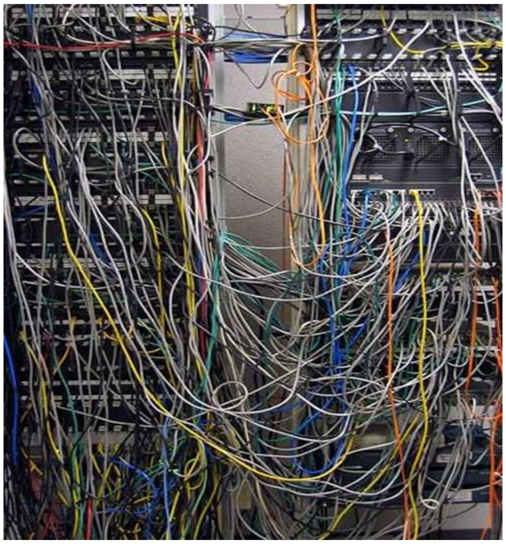

Figure 7. Photograph demonstrating Eva's views on her teacher's messy approach to teaching

Eva did not perform well in that specific chemistry class because she was unable to focus on the concepts due to her teacher's "*messy*" teaching: "*If it's a mess, I don't have the attention enough to be able to focus on a bunch of things…. If it's all in a mess, I learn it all in a mess and I don't do well on tests.*"

Most importantly, Eva connected her disability (ADHD) to the "*messy*" chemistry teaching approach. She felt that students without ADHD are able to effectively "*focus*" on the material despite the "*messy*" teaching. However, Eva believed that for students with ADHD, learning in a disorganized classroom was more problematic as these students had the tendency to "*zone out*" if they were unable to "*follow the teacher*."

> *I think somebody who doesn't have ADHD has a lot more focus and can try to follow a teacher. For me, it's already hard just to follow the teacher in class like not to zone out. If I have to follow you everywhere going from A to B to D to C to A, of course I'm going to get lost and I'm going to zone out. It's already more demanding for me to focus on something.*

Echoing Eva's views, Penny also related their difficulties in learning biology to "messy" teaching. Penny felt that the biology teacher did not "*follow the process, or the steps*" in explaining biological processes such as filtration in the kidneys. Penny also experienced issues in understanding the "*disorganized*" lecture notes provided by her biology instructor because they were disconnected, and the concepts were not systematically and sequentially linked to weave a comprehensive account of filtration by the kidneys:

> *It's too messy. I don't think it's well organized, like, the notes. Because I was looking at the kidneys and half of the stuff was just all spread out. It wasn't like: nephron, and the renal corpus goes in the nephron, and the glomerulus. It [the process] was all over the notes, like, it [the steps] was either at the front or the back.*

From Victoria's perspective, the lectures conducted with the aid of PowerPoint presentations were not consistent with the notes provided by the instructor. Consequently, due to these inconsistencies, Victoria felt "*scatter brained*" and was confused while trying to understand and learn the taught material:

> *Scatter brained is not a good teacher aspect. Our [biology] lectures were so rushed and they were so confusing because the PowerPoints wouldn't match the notes, the notes wouldn't match the power points that it just became, like her scatter braininess in class made me scatter brained when I was studying.*

These students' perspectives on teaching approaches seemed to be shaped by their particular learning needs. These findings indicate that these students require a structured teaching approach with material being presented within a highly organized and consistent format.

Discussion

This study captured the unheard voices and perspectives of students with LD on their learning barriers in science classrooms. Bronfenbrenner's (2005) ecological model offered a useful lens to interpret the findings; unlike the medical model of disability which focuses only on within-individual deficits, and the social model of disability which considers only the social and environmental barriers experienced by individuals with disabilities. In this study, Bronfenbrenner's ecological model allowed me to identify both within-individual barriers (e.g., difficulties in focusing and paying attention, memory issues, difficulties with vocabulary acquisition, reading, and science text comprehension) and environmental issues (e.g., fast pace of instruction, undifferentiated teaching approaches, and lack of consistency and structure in teaching approaches) and the interactions among these barriers in my work with students with LD at Mountain CEGEP.

Considering within-individual challenges, many participants viewed their learning disabilities as permanent barriers preventing their academic success in science subjects. These findings are consistent with a study conducted by Thompson-Ebanks (2014), who found that undergraduate students' disabilities (i.e., learning disabilities and psychiatric issues) were contributing factors to their academic failure and college withdrawal. Furthermore, Thompson-Ebanks (2014) found that the most common limitations experienced by students with disabilities involved difficulties in paying attention and with memory. Similarly, in the present study, students reported that attention problems were central barriers in learning science, both within and outside of classroom settings.

Furthermore, students with auditory processing disorders coupled with hearing issues; learning disability in reading, writing and mathematics, unspecified learning disabilities with

AD/HD, also explained that they experienced issues with their memory which made it difficult for them to retain information surrounding science materials presented in the classrooms, and also while studying on their own. Individuals with learning disabilities in reading and math are known to experience difficulties with their memory (Andersson, 2008; Berg, 2008; Gathercole, Alloway, Willis, & Adams, 2006; Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007; Palladino, Cornoldi, De Beni, & Pazzaglia, 2001; Moll, Göbel, Gooch, Landerl, & Snowling, 2016; Swanson & Zheng, 2013). As also explained in the *Handbook of Learning Disabilities* (2013), memory is complex and deals with encoding, processing, and retrieving information and these cognitive processes are directly associated with students' academic performance in areas such as reading and problem solving (Swanson & Zheng, 2013).

Difficulties with reading, vocabulary acquisition, and science text comprehension were also reported by participants with LD as negatively impacting their learning and engagement in the sciences. In the same vein, Therrien and colleagues (2011) also highlighted that language disabilities surrounding reading and writing were among the most significant factors negatively affecting the science achievement of students with LD. Similarly, Mullins and Preyde (2013) interviewed ten students with invisible disabilities (co-morbid diagnoses of dyslexia and ADHD, and other mental health issues) and found that these students experienced difficulties in comprehending assigned readings, and took "twice as long to read" or "twice as long to write" as compared to their typically achieving peers (p. 152).

In their extensive study addressing students' science reading rates, Parmar, Deluca, and Janczak (1998) investigated the reading issues of elementary and high school students with disabilities as compared to their typically achieving students. Parmar et al. (1998) concluded that students with unspecified mild disabilities have significantly lower reading rates as compared to their typically achieving peers. Specifically, students with mild disabilities across grade levels (grades 2 to 6) read fewer words from a science passage correctly as compared to their typically achieving peers. Furthermore, Parmar et al. (1998) found that although the number of correctly read words generally increased for all students as grade levels increased, students with LD consistently performed below their typically achieving peers. Factors including deficits in reading fluency, problems decoding texts, difficulties in recognizing and comprehending words, and lack of prior knowledge may potentially help to explain these discrepancies in students with LD's performance vis-à-vis the reading and comprehension of science texts (Botsas, 2017; Mason & Hedin, 2011).

However, students' difficulties in reading, vocabulary acquisition, and comprehension of science text cannot be solely attributed to their reading deficits. Environmental factors namely the manner in which science textbooks are written and teaching strategies contributed to the challenges experienced by students with LD in reading and comprehending science concepts. For example, many researchers emphasized that high school science textbooks are "poorly written, lack structure, fail to provide sufficient definitions of essential vocabulary, and are inconsistently or poorly organized" (Botsas, 2017; Mastropieri et al., 2006; Mastropieri, Scruggs, & Graetz, 2003; Scruggs & Mastropieri, 2007; Seifert & Espin, 2012, p. 237), and are often written using densely worded paragraphs which students with LD find difficult to decode (Yager, 1983; Seifert & Espin, 2012). Participants in this study also voiced that college science textbooks — especially chemistry textbooks — were challenging to read and to comprehend.

In terms of teaching strategies, Wexler, Mitchel, Clancy, and Silverman (2017) also reported that high school science teachers rarely implemented vocabulary and comprehension strategies in their science classrooms, which could be beneficial to improve students' reading and comprehension of science texts. Therefore, coupled with the students' within-individual difficulties with science texts, others factors such as characteristics of science text books and teachers' instructional approach also played a role in affecting the reading practices, vocabulary acquisition and comprehension of science concepts for science students with LD. Such was the case in this study where students with LD experienced difficulties in reading due to interactions between their disabilities and environmental factors (e.g., nature of science textbooks and lack of initiatives from instructors to teach science vocabulary).

In addition to specific learning disabilities, participants within the present study also outlined other within-individual stressors such as emotional issues (e.g., experiencing anger, frustration, and anxiety), which negatively impacted their academic achievement in science. The participants' feelings of "frustration," "anger," "discomfort," "fear," and "being different" stemmed from their dissatisfaction with their academic achievement in science. The negative feelings (e.g., anger, frustration, fear) were amplified when the participants compared themselves to their typically achieving peers. These findings (i.e., students' negative feelings such as anger, frustration, and fear) are in line with the empirical studies conducted by da Silva Cardoso et al. (2016), Fullarton and Duquette (2016), Garrison-Wade (2012), Hong (2015), Kendall (2016), and Mullins and Preyde (2013). For example, Hong (2015, p. 218) reported that college students with disabilities felt "irritated and disheartened" when they compared their academic performance to those of their typically achieving peers.

Similar to my study's findings (i.e., students' negative feelings), Hong (2015) stated that college students with disabilities felt that their typically achieving classmates "put in less effort and still make better grades" while they have to work harder than their typically achieving peers to pass their courses (p. 218). Similarly, during their conversations with university students with dyslexia, ADHD, and mental illness, Mullins and Preyde (2013) found that these students did not perform as well academically as their peers, regardless of the amount of effort they invested in their studies. Owing to unsatisfactory academic outcomes, students with LD in the study felt discouraged and were unwilling to continue pursuing the sciences. Similarly, students with LD within the present study also shared feelings of disengagement and reluctance to continue studying science.

The fast pace of instruction has been previously documented in the literature regarding secondary and postsecondary students with disabilities (Mastropieri, Scruggs, Graetz, 2003; Boyle, 2012; Kendall, 2016). For example, according to Kendall (2016), university students reported that their lecturers spoke too fast and presented the material at a very rapid pace. The fast pace of instruction is even more problematic for students taking science which is considered to be one of the most challenging subjects for students with LD given that science contains abstract concepts with a highly complex vocabulary (Boyle, 2012; Marino, 2010). Failing to keep up with the fast-paced science lectures, students with LD are more likely to have class notes that were not complete and lacked accuracy (Boyle, 2012). Similarly, in this study, students reported that their science notes were incomplete, disorganized and disconnected, which made studying their notes after class even more challenging. Additionally, due to the fast pace of instruction, the participants took longer to understand the concepts as they needed to learn the material on their own, and consequently, they fell behind in understanding the content as the semester progressed. Mastropieri, Scruggs, and Graezt (2009) reported that science instructors were compelled to teach at a fast pace to complete their syllabus in time for the high-stakes exams at the end of the school year. Clearly, due to the heavy and dense science curriculum at postsecondary level, instructors have adopted a fast-paced instruction to complete the mandated curricula.

In addition to the fast-pace of instruction, another ecological barrier impeding students' learning and engagement in science was the undifferentiated teaching approaches adopted by some instructors. This study's findings on undifferentiated teaching approaches are consistent with the work of Mullins and Preyde (2013) who reported that Canadian university students with dyslexia, ADHD, and mental illness viewed their instructors' teaching approach as one-dimensional. Furthermore, the participants in Mullins and Preyde's (2013) study believed that their postsecondary education was "set up for one type of learner, from which they felt systematically oppressed" (p. 156).

Additionally, the lack of differentiated teaching approaches in postsecondary institutions to facilitate learning for students with disabilities, is also documented in empirical studies exploring instructors' perspectives in teaching students with disabilities. Recently, Gokool-Baurhoo and Asghar (2019) reported that Quebec college science instructors perceived LD as a complex construct, making it difficult for them to identify the potential academic barriers affecting these students in science classrooms. Many college science instructors also felt that they lacked the skills and knowledge to differentiate their teaching practice to accommodate the diverse academic needs of students with LD (Gokool-Baurhoo & Asghar, 2019). West et al. (2016) reported that, in the US, many college instructors did not enact inclusive strategies (e.g., using multiple means of representing taught concepts) while teaching students with disabilities (i.e., specific learning disabilities, ADD, ADHD, mobility limitations, mental illness/psychological or psychiatric conditions). To make matters worse, few educators have been trained to implement diverse teaching approaches that facilitate the learning process of students with LD (Abu-

Hamour, 2013; Baker, Boland, & Nowik, 2012; Becker & Palladino, 2016; Behling & Linder, 2017; Gokool-Baurhoo & Asghar, 2019; Zhang et al., 2010). Therefore, it is not surprising, that many college students are articulating the need for the educational system to change such that a diversity of teaching approaches is mandated to meet their academic needs (Mullins & Preyde, 2013).

Participants within the present study also viewed their instructors' teaching approaches as lacking both consistency and structure. Based on available literature, no evidence of these findings were previously reported within other research studies, which explored students' views on the barriers they encountered in science classrooms. Within the present study, most participants referred to their teachers' instructional practices as "messy" and "disorganized" and students found that their science instructors were not drawing adequate connections between the science concepts being taught. As confirmed by a study conducted by Gokool-Baurhoo and Asghar (2019) on barriers encountered by Quebec college science instructors in teaching students with LD, these instructors seemed unaware that structured teaching approaches might support science students with disabilities in successfully learning science. Specifically, with a structured teaching strategy, students with LD might be more engaged to learn science and improve their academic performance.

The present study adds to the literature by highlighting that each participant was personally embedded within a unique science learning ecology which differed distinctly from other participants with LD. While for some participants, their science learning ecology was highly complex with multiple interacting within-individual and environmental barriers, others experienced fewer interacting barriers that hindered their learning journey. For example, one of the participants (i.e., Penny) attributed her difficulties in learning science to multifaceted within-individual issues (such as memory problems, attention problems, and reading problems), in addition to environmental barriers (including ineffective teaching approaches and structural problems within the science classrooms). On the other hand, another participant (i.e., Jake) explained that his within-individual deficits (which included attention problems) and environmental factors (such as ineffective teaching approaches) affected his academic achievement and engagement in learning science.

The present study has also shown that students' experiences in learning science were diverse and differed from one another based on environmental factors such as different science courses (biology, chemistry, physics), settings (laboratory and classrooms) and science tasks (studying, exams, and assignments). While for some students with reading issues, courses such as biology and chemistry were particularly challenging, they nevertheless seemed to excel in other courses namely physics and math. It is clear that students' respective disabilities are expressed differently in specific contexts.

This study also highlighted specific scientific concepts from biology (namely mitosis and meiosis, muscular systems, and the process through which kidney filtration occurs) as being particularly challenging for students with LD. This suggests that future studies need to explore effective learning strategies to support students with LD in understanding complex scientific concepts, especially in biology. In Quebec, such research is crucial, especially with reforms being implemented in the natural sciences at the CEGEP level in 2020, which will require students to take more biology courses. Currently, college students in Quebec are required to take more courses in physics and chemistry than in biology. However, Quebec's Ministère de l'Éducation et de l'Enseignement supérieur plans to introduce additional biological science courses focusing on ecology, environmental science, and sustainability to increase students' knowledge and awareness of ecological and climate change issues. As discussed earlier, this suggests that students with LD taking biology courses will require additional and effective support mechanisms to their academic success.

Implications

This study has important implications for supporting students with LD in learning science with regards to their respective challenges. As shown by this study, the within-individual issues (i.e., coping with their disabilities, using effective learning strategies, negative emotions) negatively impact the learning, engagement and motivation of students with LD. In some cases, the participants felt so discouraged due to their low grades in science that they contemplated of dropping out from the science programs. Yet, less attention has been given to intervention-based strategies designed for college science students with LD to cope with their within-individual difficulties. To this end, White and Massiha (2015) highlighted the need for close monitoring of science students' academic and special needs through an "integrated program of interventions" which would offer rapid access to both academic and personal services (p. 89). Within such an integrated program of interventions, White and Massiha (2015) recommended an academic skills course for students with disabilities addressing study skills, test-taking skills, and learning strategies in STEM. However, further research would be needed to evaluate the potential impacts that such initiatives might have towards improving students' academic performance in STEM programs.

Another strategy to support college students in STEM to cope with their disabilities and ensure their retention in STEM programs is mentoring (Dunn, Rabren, Taylor, & Dotson, 2012; Gregg, Galyardt, Wolfe, Moon, & Todd, 2017; Gregg, Wolfe, Jones, Moon, & Langston, 2016; White & Massiha, 2015). Most recently, Gregg et al. (2017) designed an e-mentoring program wherein mentors (teachers) guided and supported mentees (students with disabilities diagnosed with LD, ADHD, and autism) on various aspects of their personal and academic lives. The e-mentoring program took the form of virtual-mentoring sessions over Skype and Facebook, and the program components addressed topics including study skills, how to live successfully with a disability, and how to persevere within science and math programs (Gregg et al., 2017). The authors observed that the program improved students' self-determination (e.g., ability to make informed decisions) and self-advocacy skills (e.g., ability to effectively communicate and to assert their needs and rights) (Gregg et al., 2017). Despite these positive results, no significant improvement was observed in these students' reported self-efficacy (i.e., evaluation of their perceived science competence). More alarmingly, a decrease in science aspiration and desire to pursue further studies or careers in STEM were noted among the participants. It is clear that diverse intervention-based strategies need to be explored to support students with LD in coping with their within-individual issues, especially in the context of CEGEP science classrooms which represent a unique microsystem.

In addition to within-individual issues, participants from the present study also explained that the contextual characteristics of the STEM learning environment – including the fast pace of instruction, the use of undifferentiated teaching approaches, and the lack of consistent and structured teaching approaches – impaired their learning in science. These findings clearly indicate the need to improve instructional practices for students with LD at the CEGEP level. Specifically, students with LD in higher education can benefit from the universal design for learning (UDL) approach which rely on multisensory means of representing taught concepts, engaging students in learning science, and multiple forms of expression to assess students' comprehension of taught concepts (Baurhoo & Asghar, 2014; Black, Weinberg, & Brodwin, 2015; Schreffler, Vasquez III, Chini, & James, 2019). For example, as indicated by Baurhoo and Asghar (2014), to teach science concepts in higher education, instructors can integrate tactile (e.g., use of 3D models, manipulatives), visual (e.g., animations, simulations, videos), and auditory (e.g., audio-taped presentations) instructional strategies within their lectures. When teaching the topic surrounding biomolecules, teachers can ask students to draw the different biomolecules (visual), make 3D models with play-dough to represent the molecules (tactile), and develop podcasts (auditory) on these concepts (Baurhoo & Asghar, 2014).

Multiple means of engaging with class material (e.g., constructing hands-on models, or using worksheets to illustrate students' understanding of taught concepts) can be utilized to trigger and sustain students' interest and engagement throughout their learning process (CAST, 2011). In particular, the UDL teaching approach utilizes multiple cooperative learning strategies (e.g., engaging students in peer-based activities) to support students in maintaining their efforts and engagement in learning taught concepts (CAST, 2011; Baurhoo & Asghar, 2014).

Inquiry-based approaches and peer-based learning strategies are consistent with UDL's aims to improve students' engagement and academic performance. The benefits of inquiry-based approaches and peer-based learning strategies in improving engagement and academic performance have been investigated for high school science students with LD (Bay, Staver, Bryan, & Hale, 1992; Dalton, Morocco, Tivnan, & Rawson, and Mead, 1997; Mastropieri et al. 1998; Mastropieri et al. 2006; Mastropieri, Scruggs, & Graetz, 2003; McCleery & Tindal, 1999; McDuffie, Mastropieri, & Scruggs, 2009; Simpkins, Mastropieri, & Scruggs, 2009; Therrien et al. 2011; Vavougios, Verevi, Papalexopoulos, Verevi & Panagopoulou, 2016). While some of these studies noted that inquiry-based approaches improved science learning and achievement for students with LD (e.g., Bay et al., 1992; Dalton et al., 1997), others pointed out that although students with LD progressed as well as their typically achieving peers on post-tests after experimental interventions, the majority of students with LD did not perform as well on high-stakes standardized testing at the end of the school year (e.g., Mastropieri et al., 2006; Simpkins et al., 2009). Consequently, the benefits and limitations of inquiry-based approaches need to be explored further for college science students with LD. Moreover, college science instructors also need to be trained regarding the benefits of these strategies to engage and academically support their students with LD.

Rather than focusing solely on written exam formats, a variety of assessments such as multiple choice questions, short essays, drawing, performing, writing blogs, designing and conducting simple experiments could be used to track science students' learning and academic achievement in higher education (Baurhoo & Asghar, 2014). Graphic organizers and visual displays (e.g., concepts maps illustrating the relationships between taught concepts) could also be used by teachers to gauge students' understanding of science concepts. In their recent meta-analysis, Dexter, Park, and Hughes (2011) concluded that graphic organizers improved factual comprehension and vocabulary knowledge of secondary students with LD in science. Graphic organizers also represent an alternative means for students to construct relationships among abstract science concepts in a more visual format (Dexter, Park, & Hughes, 2011; Hughes, Maccini, & Gagnon, 2003; Ives & Hoy, 2003; Kim, Vaughn, Wanzek, & Wei, 2004; Nesbit & Adesope, 2007; Rivera & Smith, 1997). As such, graphic organizers might be an effective learning tool for the students who prefer a visual mode of learning. In addition, graphic organizers might be effective for participants in this study who reported difficulties in their comprehension of taught concepts and vocabulary acquisition in biology.

Overall, rather than focusing on students' disabilities and deficits, the UDL approach capitalizes on the cognitive strengths of students with LD by offering them multiple ways to construct their understanding of science concepts (Baurhoo & Asghar, 2014). Moreover, university students with disabilities confirmed that a curriculum based on UDL could effectively support their learning (Black, Weinberg, & Brodwin, 2015). In conclusion, by integrating the UDL approach within science classrooms, science instructors could help create an inclusive environment allowing diverse learners to actively participate in their learning without feeling stigmatized (Baurhoo & Asghar, 2014). Moreover, a UDL-based approach engages and motivates diverse students to learn in ways that best suit their academic needs (Baurhoo & Asghar, 2014).

Altogether, findings from the present study (i.e., surface learning strategies employed by students, undifferentiated teaching approaches, and lack of consistency and structure in teaching approaches) indicate the need for more research on individualized intervention-based strategies to best support students in coping with their respective disabilities. As highlighted by Fichten, Heineman, Havel, Jorgensen, Budd, and King (2016), and Schreffler, Vasquez III, Chini, and James, (2019); the benefits of the universal design model in higher education have yet to be demonstrated empirically. Therefore, the potential benefits of intervention-based strategies grounded in the UDL approach need to be investigated further as a means of improving the learning, engagement, and academic achievement of college science students with LD. Such research initiatives may be particularly important given that most studies on universal design approaches were conducted within pre-K to Grade 12 settings, which demonstrated mixed results in improving engagement and learning for diverse learners (Ok, Rao, Bryant, & McDougall, 2016).

Furthermore, there is a need for more rigorous research designs and procedures (e.g., single-case research designs at the nascent stage; true-experimental design groups; concurrent measures such for students' academic performance and social skills) in order to assess the efficacy of UDL-based interventions (Ok et al., 2016). For example, by employing a true experimental study design (i.e., experimental vs. control groups), the efficacy of using multiple means of instruction could be compared to a single means of instruction (i.e., UDL approach vs. traditional approaches) on students' engagement, learning, and academic achievement in STEM classrooms.

Overall, given that students with LD are heterogeneous (i.e., have different learning disabilities) and experience unique barriers (i.e., a unique combination of within-individual and environmental issues), it is crucial that intervention strategies implemented to improve their learning and academic achievements are tailored towards their distinctive difficulties and academic needs.

Conclusion

The present study contributes to the literature by showcasing the multifaceted within-individual and environmental barriers affecting the learning and engagement of college science students with LD in Quebec. While previous studies in science education have pinpointed inadequate inclusive practices and accommodations for postsecondary science students with disabilities (Dunn et al., 2012; Gregg et al., 2016; Hendrik et al., 2010; Thurston et al., 2017), the present study showed that each student with LD is embedded within a distinctive microsystem embodying unique and specific issues. For some students, their within-individual barriers (e.g., memory issues) seemed to impact their learning most, while for others, environmental barriers (e.g., teaching strategies) were the main barriers affecting their learning and engagement in the sciences. For this reason, future studies exploring the barriers and intervention-based strategies for students with LD, would benefit from using Bronfenbrenner's theoretical framework.

The Bronfenbrenner's (2005) ecological model takes into account the complexity of interactions between within-individual characteristics and contextual factors (e.g., interactions between students with and without LD during the activities; attitudes held by typically achieving students towards students with LD; and the acceptance level of students with LD by their peers). Specifically, barriers stemming from the person (i.e., the within-individual characteristics affecting the learning performance of individual), the context (i.e., environmental factors that influence learning, such as teachers' attitudes, teaching strategies, peer interactions and curriculum in the science classroom), and the process (i.e., how teaching and learning are being practiced in particular contexts to bring about cognitive development) need to be considered in developing intervention strategies that are multifaceted and can simultaneously address a variety of within-individual and environmental barriers.

The present study has adopted a unique methodological approach by combining semi-structured interviews with photovoice. These techniques complemented each other and offered a richer and more comprehensive understanding of the complexity of barriers faced by science students with LD. While the semi-structured interviews offered a general perspective on the barriers that these students experienced during their process of learning science, the photovoice projects provided deeper insights into the specific and most significant barriers affecting these students' learning. For example, analysis of the semi-structured interviews showed that students with LD felt academically less able than their peers. On the other hand, the photovoice projects highlighted multiple science tasks – including learning biological concepts (e.g., muscle structures), and stress surrounding performing in exam situations – in which students with LD encountered heightened challenges, in comparison to their peers. Similar to Jurkowski's (2008) findings, I found that the photovoice approach enabled data collection from locations (e.g., laboratories and home settings) where researchers traditionally had no physical access.

This study present certain limitations such that the perspectives of all college science students with LD on barriers encountered at the CEGEP level are not represented. Therefore, more research studies are warranted on the diverse types of barriers encountered by science students with LD in other college settings. Future studies might benefit from using diverse methodological approaches (e.g., mixed methods approaches involving questionnaires, photovoice, and interviews) to uncover multiple and complex difficulties encountered by students with LD.

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Chapter 6: General Discussion, Implications, and Conclusion

Previous studies have sought to explore the views of instructors and students with disabilities on issues surrounding teaching and learning practices for students with disabilities in higher education (Abu-Hamour, 2013; Baker, Boland, & Nowik 2012; Costea-Bărluţiu & Rusu, 2015; Love et al., 2015; Murray, Sniatecki, Perry, & Snell, 2015; da Silva Cardoso et al., 2016; Fullarton & Duquette, 2016; Kendall, 2016; Stampoltzis, Tsitsou, Plesti, & Kalouri, 2015; Thompson-Ebanks, 2014). However, these previous studies focused mainly on students with disabilities in universities in the US, thereby failing to document the specific needs and issues experienced by students with LD who are increasingly present within Quebec's CEGEP classrooms.

At the same time, the existing literature does not capture the complex interactions occurring between individual and environmental issues. Additionally, the literature fails to take into account the ways in which they impact the teaching and learning practices for students with disabilities in postsecondary contexts. For example, Denhart (2008) explored only social barriers encountered by students with LD, but neglected to discuss the impact of these students' respective disabilities on their engagement and learning in postsecondary settings. Drawing on Bronfenbrenner's (2005) ecological model, the present dissertation sought to address these research gaps by exploring the views of a special needs educator, CEGEP science instructors and students with LD on within-individual and environmental barriers affecting educational practices for science students with LD.

Unlike previous research studies which relied on quantitative methods for their inquiry, in this thesis, several qualitative approaches—namely semi-structured interviews, photovoice, reflective journals— were employed to document the voices of the participants and the researcher. In the following section, the summarized findings are presented. The next section also illuminates the dissertation's original contributions to knowledge, and implications of findings. The directions for future research are also discussed.

Summary of Findings

This dissertation is the first to simultaneously explore the voices of various social agents (i.e., special needs educator, science instructors, and students with LD) regarding teaching and learning practices for science students with LD within the CEGEP context. The findings stemming from each study are summarized in Table 1, and are depicted below.

Table 1. Teaching and Learning Barriers in regards to Science Students with LD

Special Needs Educator (Chapter 3-Manuscript 1)	**Science Instructors (Chapter 4-Manuscript 2)**	**Science Students with LD (Chapter 5-Manuscript 3)**
- Students' fear of being negatively perceived by their science instructors and peers due to their LD	-Instructors' insufficient knowledge and skills in teaching students with LD	-Learning difficulties in science
-Negative attitudes of science instructors regarding the diagnosis of students with LD	-Lack of information on students' respective LD	-Students' perceptions of being academically disadvantaged as compared to typically achieving peers
- Science instructors' lack of awareness of diverse instructional approaches	- Lack of appropriate prior training and professional development opportunities	-Surface learning strategies adopted by students with LD
	- Difficulty in establishing	- Teaching issues (e.g., fast

	working relationships with students with LD.	pace of instruction; undifferentiated teaching approaches; lack of consistency and structure in teaching approaches)

In Chapter 3 (Manuscript 1), I positioned myself within the Bronfenbrenner's ecological model, both in my roles as a special needs educator and a college biology instructor. In doing so, I documented and reflected on my observations and conversations with students with LD on the issues they faced in CEGEP science programs. Simultaneously, I also captured moments shared with CEGEP instructors surrounding their dilemma and struggles in teaching science to students with LD. Based on my analysis, both students with LD and their instructors agreed that science instructors lacked the requisite knowledge, skills, and instructional strategies to make science accessible to diverse learners.

Chapter 4 (Manuscript 2) built on the findings of Chapter 3 (Manuscript 1), and through semi-structured interviews, further explored science instructors' barriers in teaching and supporting students with LD. Findings from Chapter 4 showed that the CEGEP science instructors experienced both individual and environmental barriers (as shown in Table 1) in teaching students with LD. The barriers that were most commonly reported by these science instructors included: difficulty in establishing working relationships with their students with LD; lack of information regarding the disability types of their students; and lack of knowledge and skills in teaching science students with LD.

Drawing on semi-structured interviews and photovoice projects, Chapter 5 (Manuscript 3) focused on the voices of students with LD to showcase the issues impeding their learning and academic success in CEGEP science programs. The major issues encountered by these students with LD included: cognitive barriers (i.e., deficits in attention, memory, reading and comprehension); difficulties in learning science content; and lack of appropriate teaching approaches employed by their science instructors.

Overall, findings from this thesis demonstrate that barriers encountered by science instructors in teaching students with LD, and by students with LD in learning science can be complex and multifaceted. In the next section, I discuss the original contributions of this dissertation and its implications for research and practice in science, inclusive, and special needs education.

Original Contributions to Knowledge and Implications

Chapter 3 (Manuscript 1) is the first comprehensive study that draws on autoethnography to discuss my insights as a special needs educator and a biology instructor in attempting to explore and understand the issues encountered by students with LD in learning science. In Chapter 3, I document the case of Amber, a student with LD, who was failing my biology course. By mapping the possible issues experienced by Amber in learning biology within Bronfenbrenner’s (2005) ecological model, I offer a practical way that other practitioners (i.e., teachers and special needs educators) can draw upon to make sense of their students’ barriers. By employing Bronfenbrenner’s ecological model, I highlight that students’ issues are not only within-individual or environmental, but a combination of both. As such, instructors need to critically assess their teaching strategies and modify them in response to their students’ needs instead of attributing their students’ lack of success to their disabilities.

Drawing on Bronfenbrenner's ecological model, Chapter 4 (Manuscript 2) is the first study to show the dynamic interactions taking place between CEGEP science instructors' within-individual and environmental barriers in teaching science students with LD. To the best of my knowledge, no previous studies have been conducted in Quebec and Canada to make sense of the barriers that science instructors face in teaching students with LD at the postsecondary level. More specifically, this work demonstrates that CEGEP science instructors' insufficient knowledge and skills in differentiating science instruction for students with LD is intricately linked to key environmental factors: lack of information on students' specific disabilities and insufficient effective professional development (PD) programs. These barriers result from the fact that neither the Office for Students with Disabilities nor students with LD shared information on the students' specific disabilities with science instructors. Consequently, science instructors face tremendous difficulties in being able to explore, identify and implement appropriate strategies to address the needs of their students with LD.

While previous studies called for professional development (PD) programs to inform and guide science instructors in effectively educating their students with disabilities (Kahn & Lewis, 2014; Mumba et al., 2015; Norman et al., 1998), this study uniquely pinpoints that PD programs are available, but they fail to equip science instructors with the tools and strategies necessary to teach diverse learners.

Moreover Chapter 4 (Manuscript 2) uniquely draws and expands on Ertmer's (1999) framework describing first-order and second-order barriers to analyze and categorize barriers experienced by the science instructors. Previously, this framework has been employed solely in research studies focusing on technology. Ertmer's framework permitted me to discern first-order barriers (i.e., external to the instructors) from second-order barriers (i.e., internal to the instructors). Categorizing second-order barriers were particularly important in this study as such barriers (i.e., science instructors' lack of knowledge and skills in teaching students with LD) are difficult to overcome (Ertmer, 1999). Therefore, these barriers need to be addressed by using multiple strategies which could include but are not limited to hands-on training in implementing strategies to support students with LD within and outside of the classrooms; and theory classes on the characteristics and needs of students with LD.

Chapter 4 also brings a unique dimension to the literature on teaching science students with LD by showcasing a few strategies developed and implemented by CEGEP science instructors to academically support their science students with LD. For example, some of the CEGEP science instructors discussed the importance of being approachable and empathetic. One biology teacher, Stefani, mentioned that she always repeated to the students to come for individual tutorials in her office, and even keep candy in her office to appear more inviting and approachable. While empathy and approachability are characteristics that hold value for students with LD (Hartman-Hall & Haaga, 2002; Mytkowicz & Goss, 2012; Orr & Hammig, 2009), very few studies have focused on the ways that teachers could cultivate empathy and approachability to work with their students with LD (Harris, 2015; Peck, Maude, & Brotherson, 2015). As such, it is crucial that future research explore strategies that support teachers in becoming more approachable and empathetic towards their students with LD, who have shown to be very sensitive and emotional in this thesis.

In turn, Chapter 5 (Manuscript 3) adds to the literature by depicting the diverse issues that students with LD experience in their learning of science concepts. For example, some studies (e.g., Hong, 2015; Thompson-Ebanks, 2014) attributed students' feelings of embarrassment regarding their LD as a major barrier in preventing them to seek support from their teachers. On the contrary, science students with LD in this study have continuously sought support from their science teachers, but their teachers were unable to differentiate science instruction to make the content accessible to them. For this reason, students with LD in this study did not visit their instructors during office hours to improve their comprehension of taught science concepts.

Moreover, in contrast to the majority of studies (e.g., da Silva Cordosa et al., 2016; Erten, 2011; Hong, 2015; Garrison-Wade, 2012; Marshak et al., 2010; Strnadová, Hájková, & Květoňová, 2015) which showed that typically achieving students have negative perceptions of students with LD; this study demonstrated that science students with LD did not experience negative views from their peers at the CEGEP level. In fact, most of the students in the study reported that their peers did not make them feel different but treated them as their equals. For example, Olivia shared that her friend in their chemistry class was not bothered that she took her exam in the OSD because of her LD. In her own words, Olivia shared: "*They[My typically achieving peers] don't say anything mean, I never felt a difference, I don't feel a difference with him[a friend in chemistry class]. He asks me questions a lot [about chemistry concepts].*" It is interesting to note that Olivia's friend valued her knowledge and asked her questions about taught chemistry concepts. The positive attitudes of the typically achieving peers can support students with LD to feel more confident in their academic abilities.

Chapter 5 (Manuscript 3) also contributes to the literature by showcasing that each student with LD is embedded within a unique ecological framework, wherein they experience distinctive interconnected within-individual and environmental issues. For example, Deborah, one of the participants, experienced multiple within-individual issues (i.e., difficulty with memory and attention; feelings of being academically disadvantaged as compared to typically achieving peers; surface learning strategies), and fewer environmental issues (i.e., teachers' fast pace of instruction). On the other hand, Jake, another participant, faced fewer within-individual issues (i.e., trouble paying attention in class) and environmental issues (i.e., difficulty in learning with the undifferentiated teaching approach). Chapter 5 (Manuscript 3) clearly invites researchers to first explore the within-individual and environmental difficulties of their potential participants with LD before designing interventions to academically support them in science. Given that students with LD differ in terms of their personal challenges, intervention-based strategies to support students with LD in effectively learning science need to be tailored to suit their individual needs

However, this has not been the case - previous intervention-based studies (e.g., Mastropieri et al.,1998; McCleery & Tindal, 1999; Mastropieri, Scruggs & Graetz, 2003; McCarthy, 2005; Simpkins, Mastropieri & Scruggs, 2009; McDuffie, Mastropieri, & Scruggs, 2009; Mastropieri et al., 2006; Scruggs, Mastropieri, Bakken, & Brigham, 1993) considered students with disabilities to be a homogeneous group, neglecting to take into account the distinctive differences in their individual difficulties and needs. None of these studies have explored the difficulties of their participants before implementing the respective interventions. Not surprisingly, most of these intervention-based studies failed to support students with LD in improving their academic achievement, and performing academically as well as their typically achieving peers. As emphasized by Rizzo and Taylor (2016, p. 12), “the “one size fits all” approach to inquiry-based instruction fails to meet the needs of students with disabilities.” Moreover, as pointed out by Mulvey, Chiu, Ghosh, and Bell (2016), most of these intervention-based studies were completed more than a decade ago, “leaving much unexamined with respect to science instruction for students with special needs” (p. 555). As previously highlighted, before conducting an intervention, the researchers need to interview the prospective participants and take into account their difficulties during the planning phase of their intervention-based research.

The present study is the first to show that the experiences of students with LD in learning science were discipline-related. While some of them experienced tremendous difficulties in biology and chemistry, they seemed to excel in other courses such as mathematics and physics. For example, Clara, one of the participants, shared that in Electricity and Magnetism (a physics course), she did “better than a student that has no disability” and had “one of the highest grades.” Clara mentioned that her typically achieving peers would contact her to request her help in that particular course. Unfortunately, very few studies have portrayed students with LD as capable of excelling in science programs. Instead, most studies have portrayed students with LD as struggling learners in science, neglecting to emphasize that they might be excelling in certain science courses. It is crucial that these students’ successes are highlighted so that they feel valued and capable. The academic success of these students with LD can be employed to motivate them when they feel unworthy and devalued during their struggles in other courses.

Moreover, Chapter 5 calls upon researchers to focus on the authentic issues experienced by students with LD that need to be addressed within their classroom settings. For example, Chapter 5 (Manuscript 3) also uniquely illuminates that certain biology concepts — such as mitosis and meiosis, filtration within the kidneys, the structure of muscle groups, and respiration — were particularly challenging for students with LD. This finding is significant for special needs and inclusive education such that it invites researchers to design research-based interventions on learning strategies to help students with LD in effectively learning these specific topics during lectures, lab activities, and remedial tutorial sessions.

By drawing on the margin-center metaphor coined by hooks (1984), this thesis found that most students with LD position themselves within or outside the margin of science classrooms. Specifically, the majority of students explained that they were cognitively different from their peers, who understood the science concepts at a faster pace, studied fewer hours than them, and performed significantly better than them on science tests and exams. Moreover, this thesis pinpoints that science students with LD are sensitive with regards to difficulties they encounter due to their disabilities. In other words, throughout my interactions with the majority of them, they seemed very upset and angry – using words such as: “downer”, “pisses me off” and “frustrated” – when discussing their academic performance in comparison to their peers and teaching approaches adopted by their teachers. Because their inner turmoil and emotional dilemmas seem to be major barriers impeding their well-being, these socio-psychological stressors need to be addressed through research-based intervention practices.

Overall, the present thesis offers a unique example of how Bronfenbrenner’s (2005) ecological model can be used to conceptualize multiple interrelated studies within the different microsystemic environments at play within CEGEP settings. Specifically, this thesis is the first to have drawn on Bronfenbrenner’s (2005) ecological model theory to conceptualize three interrelated research studies that sought to explore difficulties experienced in teaching and learning practices for students with LD. Bronfenbrenner’s (2005) process-person-context model, described in Chapter 3, deepened our comprehension of the dynamic interactions and interrelationships between multiple social agents (i.e., special need educator, students with LD, and their science instructors), as well as their environment with respect to teaching and learning practices for science students with LD. This thesis also highlights the usefulness of Bronfenbrenner’s ecological model in helping to interpret the interrelated relationships between within-individual issues and environmental issues faced by CEGEP science instructors and their students with LD.

Previously, other studies focused only on the perspectives of individual social agents such as either instructors’ perspectives (e.g., Abu-Hamour, 2013; Becker & Palladino, 2016; Behling & Linder, 2017; Baker et al., 2012; Zhang et al., 2010), or students’ perspectives (e.g., da Silva Cardoso et al., 2016; Erten, 2011; Hong, 2015; Garrison-Wade, 2012; Marshak et al., 2010; Strnadová, Hájková, & Květoňová, 2015) on respective barriers. As compared to the previous studies documenting barriers surrounding students with disabilities, Bronfenbrenner’s ecological model allowed me to compare the views of social agents (i.e., a special needs educator, college science instructors, and students with LD) across different microsystemic environments. One key finding emerged across all three studies: science instructors lacked effective teaching approaches to meet the specific needs of science students with LD. The fact that this concern was highlighted by all groups of participants indicates that science instructors are in urgent need of effective PD programs to improve their science teaching with regards to students with LD.

Unfortunately, very few studies have focused on examining the impact of appropriate instructional strategies for college science students with LD. Although the Universal Design for Learning (UDL) approach has been highly recommended to teach students with disabilities, a sparse number of empirical studies have investigated the specific ways in which the UDL approach could be adapted to postsecondary science classrooms to support students with LD (Black, Weinberg, & Brodwin, 2015; Schreffler, Vasquez III, Chini, & James, 2019). For example, only four studies were discussed in the most recent review on UDL practices for postsecondary STEM students with disabilities (Schreffler et al., 2019). It is imperative that researchers invest their efforts towards exploring effective instructional strategies for students with LD, and in designing PD programs, which will train science instructors to use multiple means of presenting taught concepts, engaging and assessing diverse learners in inclusive science classrooms.

Bronfenbrenner (2005, p. x) stressed that “research should begin to focus on how children develop in settings representative of their actual world (i.e., in ecologically valid settings).” Based on Bronfenbrenner’s (2005) insights—as well as on the fact that instructors’ and students’ barriers are both within-individual and environmental in nature—I propose that intervention-based research studies need to be designed to address the set of barriers across the interconnected multiple levels of Bronfenbrenner’s ecological framework.

Given that students with LD encounter both cognitive issues and environmental barriers, I believe effective integrated intervention-based strategies need be designed so as to target both sets of barriers. For example, if students with LD exhibit memory and processing deficits, which prevent them from performing adequately in science subjects, then a special needs program (e.g., after-school intervention-based initiatives) may partially equip them with effective strategies to deal with their issues. Such a similar strategy has been developed and implemented by Bergey, Parrila, Laroche, and Deacon (2019), who explored the benefits of a peer-led study strategies program for first-year university students to support them in improving their academic self-efficacy, self-reported study strategies, use of support services, academic achievement, and persistence to continue in their programs. The peer-led study strategies program (e.g., strategies for motivation, study strategies, and strategies to improve academic performance) offered support to students with and without reading difficulties through peer-led workshops. The peer-led study strategies initiative significantly improved the students’ motivation and willingness to seek support from the accessibility center to deal with issues regarding their respective disabilities. However, the program did not improve students' academic self-efficacy and use of study strategies.

It is, therefore, crucial to also interview students with LD surrounding coping mechanisms that were beneficial for their academic success and retention in their academic programs. These self-reported mechanisms need to be integrated and evaluated in intervention-based programs for students with LD. One such study was conducted by Barga (1996) who interviewed 9 undergraduate students with LD on coping mechanisms that they developed throughout their educational careers. Three coping mechanisms emerged which included: benefactors' support (e.g., seeking emotional support from parents, help for homework); study skills and management strategies (e.g., time management strategies); and self-improvement techniques (e.g., learning to communicate effectively).

Any such strategies focusing on overcoming and coping with individual difficulties would require additional pedagogical components focusing on improving instructional practices within the classroom as well. This is because, as evidenced in this thesis, students with LD not only encounter individual difficulties but also environmental issues which are associated with classroom practices. Future research could explore whether such integrated intervention-based strategies can support students with LD in improving their academic performance in science subjects, and in progressing to similar academic levels as their typically achieving peers.

Another highlight of this thesis is its use of diverse methodological approaches in data collection, which helped in further triangulating the findings. The autoethnographic approach adopted in Chapter 3 (Manuscript 1) uniquely captures the dilemmas of science instructors and students with LD, viewed through my eyes as a special needs educator and biology instructor.

This thesis explores autoethnography as a research method which allowed me to develop a meaningful narrative by embedding the voices, experiences, and stories of other individuals, and connect them with my own stories.

Chapter 5 (Manuscript 3) uniquely employs the photovoice methodology to showcase the voices of underrepresented college students with LD in their daily struggles in CEGEP science programs. During the photovoice project, many barriers (e.g., difficulties in using microscopes, issues in identifying muscles tissues) affecting science students with LD emerged, which were not captured during the general semi-structured interviews. Therefore, the photovoice project lends a unique perspective into barriers that students did not discuss during the interviews, and complements the issues that emerged from the interview data – thereby, offering a deeper and more comprehensive insight into difficulties that CEGEP science students encounter in their classroom and laboratory settings. Moreover, the photovoice approach offered insights on barriers from locations (e.g., science laboratories, homes) that were not accessible to me as a researcher and special needs educator.

Some of the students felt that the photovoice project empowered them to voice their perspectives on their struggles. I also believe that the photovoice method enabled them to unchain themselves from the "cycle of marginalization" (Agarwal & Spohn, 2017, p. 3), and to create awareness in their community by taking and showcasing photographs regarding issues that matter to them, as well as changes that are required in their educational institutions to support their learning and academic success in science. As discussed in Chapter 5 (Manuscript 3), this study offers a concrete example on how semi-structured interviews can be combined with the photovoice approach, and also demonstrates how both data collection tools complemented each other and helped in triangulating the findings.

Directions for Future Studies

This thesis draws on a qualitative approach to offer an in-depth and comprehensive understanding of the participants' issues on teaching and learning practices for students with LD at Mountain CEGEP. Future studies aiming at exploring barriers experienced by teachers and science students with LD might consider exploring views from multiple participants across various CEGEPs. In addition to adopting a qualitative approach, other studies could benefit from a quantitative approach (i.e., using surveys with closed-ended questions) to explore views of a larger group of participants located in multiple CEGEPs, and generalize the findings to the same or broader populations. A quantitative approach will permit researchers to explore the relationships between various barriers and assess the impact of these barriers on the academic performance, graduation, or drop-out rates of science students with LD

This study captured only the perspectives of a special needs educator, students with LD, and instructors on barriers encountered in teaching and learning science for students with LD. Future studies might aim at exploring the views of typically achieving peers and families on barriers impacting the engagement, learning processes, and academic achievement of science students with LD. Because typically achieving peers work closely with students with LD in science laboratory settings and for assignments, they might have additional insights on barriers that their peers with LD encounter. Moreover, parents of students with LD can also offer their views on their children's struggles in learning science. By listening to the "insider" voices of multiple stakeholders who have close relationships with students with LD, a more complete portrait of the issues that these students encounter might come to light.

This research solely focuses on the barriers experienced by students with LD in learning science, and their science instructors in making science accessible for students with LD. Thus, further research is necessary to explore strategies that address the barriers reported in this doctoral thesis. For instance, future researchers can explore the views of experts (e.g., educators, counselors) on useful strategies that have been developed and employed in authentic teaching and learning settings to academically support science students with LD in CEGEPs. Moreover, research grounded in true experimental and quasi-experimental designs, to investigate the effectiveness of UDL approaches (i.e., multiple means of representation, engagement, and assessment) coupled with interventions on within-individual barriers is much warranted to support CEGEP science students with LD in their pursuit of science.

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Appendix A

Summary of Major Studies on Barriers Experienced by Students with Disabilities in Learning Science

Studies	Research Contexts	Participants	Experimental Procedures/Data Collecting Tools	Salient Findings
da Silva Cardoso, Phillips, Thompson, Ruiz, Tansey, and Chan (2016)	United States	College STEM students with self-reported disabilities (*n* = 6) Self-reported disabilities included: One individual with schizophrenia, one with anxiety disorder, one with bipolar disorder, one with attention deficit/hyperactivity disorder (ADHD), cognitive delay, and depression, one with muscularskeletal condition, one with Tourette and ADHD	-Semi-structured interviews on barriers and facilitators to postsecondary education	-Difficult relationships with peers who do not understand their disabilities and perceive them as "lazy," not hardworking, "not good enough" (p. 379) -Peers' lack of understanding towards accommodations offered to students with disabilities -Faculty's lack of awareness and understanding of disabilities -Students' with disabilities fear the stigma from peers and faculty -Students with disabilities lack of confidence in their academic abilities to perform well in STEM programs
Carlisle and Chang (1996)	United States	Elementary teachers (*n* = 35); students with LD (*n* = 10); typically achieving students (*n* = 30)	Survey, observations, and interviews Two cohorts of students (including students with and	-In all 3 years, students with LD rated themselves as less capable in learning science as compared to typically achieving students

			without LD) were followed for 3 years (Grades 4 to 6 and 6 to 8) and each year, the students were asked to evaluate their capabilities and efforts in science	
Hedrick, Dizén, Collins, Evans, and Grayson (2010)	United States	Undergraduate students (*n* = 4467) with 2,833 enrolled in STEM curricula and 1,634 in non-STEM programs Students with disabilities (*n* = 1,335) with conditions such as LD (24 %), ADHD (23 %), psychological conditions (16 %); medical/systemic impairment (10 %); deaf/hard of hearing (8 %); mobility impairment (6 %); blindness/low vision (6 %); speech disorders (4 %); brain injury (2 %); autism spectrum disorders (1 %).	The National Survey of Student Engagement (NSSE) which measures student engagement and institutional performance	-Students with disabilities perceived their campus environment as less supportive as compared to their typically achieving peers -Supportive Campus Environment measures favourable for: student success, and cultivating positive working and social relationships among diverse groups (peers, faculty members, and staff)
Jenson, Petri, Duffy, Day, and Truman (2011)	United States	College students with disabilities (*n* = 20) 1 student with speech impairment, 1 with visual impairment, 1 with ADHD, 3 with physical impairments, 4 with	-During focus groups, students were provided with clickers to rate their views (Likert scale 1 – 5) about statements on their disabilities -Students were invited to react and discuss to the	- Students with disabilities reported barriers between themselves and their peers because of differences in the academic achievement -Students with disabilities reported stress as a barrier to

		LD, 4 with autism, and 4 with psychiatric disorders	collective clicker responses	their academic performance and achievement
Mastropieri, Scruggs, Boon, and Carter (2001)	United States	Elementary students (*n* = 75) 24 typically achieving students, 48 students with LD, 2 students with mild mental retardation, and 1 student with autism	-Students explored the concept of density with oil, water, and other materials through hands-on experiments -Students were asked to make predictions, observations, and draw conclusions -Students responses on their predictions, observations, and conclusions were graded and scored. -The scores were statistically analysed to compare the performance of the different groups of students (e.g., typically achieving vs. those with LD with higher IQ)	-Students with disabilities who had a lower IQ scored lower on making predictions, and generalizing their findings from the experiment, as compared to typically achieving students and students with disabilities who had a higher IQ
Mastropieri, Scruggs, and, Butcher (1997)	United States	High school students (*n* = 54) 20 typically achieving students, 18 students with LD, and 16 students with mild mental retardation	-Students investigated the pendulum motion by manipulating the lengths of the pendulum through a hands-on activity. Students were coached through the activity. -During the activity, students were asked questions regarding	-Students with LD required more coaching than their typically achieving peers -Only 50 % of students with LD as compared to 90 % of typically achieving students were able to show their comprehension of pendulum motion when asked to apply their knowledge to new

			their observations made when manipulating the lengths of pendulums. They were also asked questions that required them to apply their knowledge of pendulum motion to new situations. -Their answers were scored and comparisons were made across the three groups of students (i.e., typically achieving students, those with learning disabilities, and those with mild mental retardation)	situations
Parmar, Deluca, and Janczak (1994)	United States	Typically achieving students (*n* = 202) and students with mild disabilities (*n* = 120) from 7 to 15 years of age	-Students were instructed to read two texts: science composition on space and a non-science story passage -Data was collected on the number of correctly read words in 1 minute	-Students with disabilities read a lower number of words correctly in both the science and non-science texts across grades 2 to 7. -Science texts had novel concepts, unfamiliar words (e.g., planet, mankind), and multiple pieces of information in each paragraph as compared to the story passage, which comprised of common vocabulary (e.g., party, friends) used in the students' daily lives

Parmar, Deluca, and Janczak (1994)	United States	Typically achieving students (*n* = 29) and students with LD and behavioural disorders (*n* = 21) from 10 to 14 years of age 19 students were in sixth grade, 17 were in seventh grade, and 14 were in the eighth grade	-The students participated in a listening and reading science vocabulary test. -A science picture vocabulary test was designed where pictures were constructed to represent 140 science concepts. -For the listening format, students were instructed to point to choose a picture out of four pictures to represent the science word read by the researchers. -For the reading test, students read a text on a science concept and chose a picture out of the four that best represented the science concept read.	-Typically achieving students outperformed students with LD and behavioural issues on both the listening and reading tests. -Students with LD and behavioural issues performed significantly better on the listening test compared to the reading test -Students with LD and behavioural issues had difficulties in effectively comprehending the science texts.
Scruggs and Mastropieri (1994)	United States	Elementary students (Grade 1 – 5) (*n* = 14) 8 students with LD (IQ = 88 – 127) and 6 with mild mental retardation (IQ = 42 – 73)	-Students were invited to study organisms and their response to different environmental conditions through hands-on, inquiry-based approaches -Field notes and observations of students discourses and products on experiments conducted	-Students with disabilities experienced difficulties in sorting and classifying, making predictions or inferences based on prior knowledge, and drawing conclusions -Difficulties in reasoning logically through teachers' scaffolding of activities -Inattention and off-

			-Teachers' interviews	tasks behaviours exhibited during classroom activities
Thurston, Shuman, Middendorf, and Johnson (2017)	United States	Principal investigators (PIs) from multiple research groups conducting research on postsecondary students with disabilities	PIs' annual and evaluation reports, questionnaires sent to PIs	-Students with disabilities are underprepared for postsecondary education due to less challenging STEM curricular -STEM faculty's lack of knowledge and skills in accommodating and working with students with disabilities -STEM faculty's lack of understanding and acceptance of postsecondary students with disabilities -STEM tutors' insufficient knowledge about disabilities and lack of strategies to assist academically assist students with disabilities

Appendix B

Summary of Major Studies on Barriers Encountered by Science Instructors with their Students with Disabilities

Studies	Research Contexts	Participants	Data Collecting Tools	Salient Findings
Carlisle and Chang (1996)	United States	Elementary teachers (*n* = 35); students with LD (*n* = 10); typically achieving students (*n* = 30)	Survey, observations, and interviews	-Teachers rated students with LD as having significantly less adequate science learning capabilities as their typically achieving peers. -Teachers place students with LD at lower levels of achievement than their typically achieving peers in learning science
Kahn and Lewis (2014)	United States	K-12 science teachers (*n*=1,088)	Survey instrument (with mostly closed, and open ended questions)	-Lack of training in teaching science to students with disabilities -Lack of knowledge on teaching strategies -Insufficient time to prepare for teaching students with disabilities -Negative attitudes towards students with disabilities -Lack of responsibility towards students with disabilities
Love et al. (2014)	United States	STEM faculty (*n* = 5) from a land grant institution	Interviews	-Lack of resources to accommodate students with disabilities -Difficulty in identifying, understanding, and supporting students with disabilities, especially those with LD -Lack of institutional

				support and guidance in supporting students with disabilities - Inadequate training on offering accommodations to students with disabilities -Large size classrooms -Time restrictions in planning and adapting their lectures for students with disabilities -Confidentiality restrictions on students' disability types
Moin, Magiera, and Zigmond (2008)	United States	High school science teachers (*n* = 53)	Observations and Interviews	-Insufficient support and guidance from administration in enacting inclusive science classrooms for students with LD -Insufficient co-scheduled (with special needs educator) lesson planning time to differentiate science instruction for students with LD -Lack of training in co-teaching students with LD in science -Special needs educator lack prior science knowledge to effectively support students with LD
Mumba, Banda, Chabalengula and Dolenc (2015)	United States	High school chemistry teachers (*n = 61*)	Surveys with mostly closed ended questions	-Lack of knowledge and training in special and inclusive education -Insufficient knowledge

				about US laws on special education -Lack of confidence in teaching inclusive chemistry classrooms -Difficulty in managing students with disabilities in inquiry-based classrooms
Ngubane-Mokiwa and Khoza (2016)	South Africa	STEM lecturers (*n* = 6) at technical and vocational education and training institution	In-depth e-interviews and observations	-Lack of knowledge on teaching resources for students with disabilities -Lack of training in teaching students with disabilities -Lack of knowledge and skills in teaching STEM to students with disabilities
Norman, Caseau, and Stefanich, (1998) Stefanich, Norman, and Egelston-Dodd (1996)	United States	Elementary teachers (*n* = 43), middle level science teachers (*n* = 54), high school science teachers (*n* = 46), and science methods professors (*n* = 46)	Questionnaires with mostly closed ended questions	-Limited knowledge and preparedness in differentiating science instruction for students with disabilities -Insufficient training in teaching students with disabilities -Instructors’ prejudicial and emotional barriers in teaching students with disabilities -Insufficient time to plan individualized lessons for students with disabilities -Difficulty in managing science classrooms with regards to students with disabilities

				-Lack of support from administrators and special education teachers in teaching students with disabilities
Robinson (2002)	United States	High school Grade 9 - 12 science teachers (*n* = 4)	Classroom observations and interviews	-Time constraints to plan and adapt science lessons for students with disabilities
Spektor-Levy and Yifrach (2017)	United States	Middle school science teachers (*n* = 215)	Questionnaires with closed ended questions (*n* = 215) Interviews (*n* = 7)	-No support and assistance from the administration and special education teachers in teaching students with LD -Lack of knowledge and understanding of teaching practices for students with LD -Lack of structure and norms in the inclusion of students with LD

Appendix C

Interview Guide for CEGEP Science Teachers

Warm-up and background

- How long have you been working as a science (physics/biology/chemistry) teacher?
- What inspired you to become a physics/biology/chemistry teacher?
- Tell me about your experience teaching physics/biology/chemistry?

Teaching methods and students with LD

- How do you usually teach science (physics/biology/chemistry)?
- Could you please give me some examples.
- Do you usually have students with learning disabilities (LD) in your classroom?
- What type of LD do your students usually have?
- Tell me about your experience working with students having a LD
- What aspects have you found challenging? What difficulties have you personally encountered while teaching students with LD? What aspects have you enjoyed?
- Have you felt the need to alter your teaching practices? If yes, how have you modified these practices and why?
- Do you have one-to-one working sessions with LD students? Please tell me about these experiences

Difficulties experienced by students with LD

- From your experience, what difficulty do you think students with LD might experience in physics/biology/chemistry class? (any types of difficulties?)
- From your experience, what concepts in biology do you think might be difficult for students with LD?
- From your experience working with students with LD, why do you think LD students have difficulties to understand such concepts?
- How have you usually explained concepts that were difficult for students with LD?
- How do you assess that your teaching strategy work with students with LD?
- What changes did you bring in your teaching methods/strategies as compared to when you first started your career?
- What do you think brought about a change in your teaching strategy?
- Do you share your strategies with new teachers?
- What advice would you give to beginning/new teachers who are working/teaching with students having a LD for the first time?
- Why do you think these advice are important for beginning teachers? How would these advices help the beginning teachers in their teaching approach?
- What different types of assessments do you usually give to students? From your experience, what difficulties to you think students with learning disabilities on the different types of assessments? Could you please give some examples
- How do you usually engage students at the beginning and during your classrooms? Have you encountered any barriers in engaging students with LD in your classrooms? What strategies do you use to help students with LD to stay on task and motivated?

- Do you feel that you have enough support from the college to work with students with LD?

Concluding questions

- Would you like to share other experiences in explaining difficult scientific concepts to students with LD?
- Is there anything you would like to share?
- Would you like to ask me some questions?

Appendix D

Codes and Categories Indicating Barriers Experienced by Science Instructors in Teaching Students with LD

Category 1: Lack of information on students' disabilities
Codes:
FO - not given information on disability
FO - don't know the disability type
FO - no information on adapting to students' needs
FO - kept in the dark about students with LD
FO - wish to know more about students' disabilities
FO - don't get details on particular situations of students

Category 2: Accommodations for test-taking
Codes:
FO - logistics of test-taking are challenging
FO - difficult for teachers to get to the exam place

Category 3: Reluctance to share their disabilities, academic difficulties and seek individualized support
***Codes*:**
FO - students' unwillingness to share disabilities
FO – students not giving teachers enough information about disability
FO - students don't request help from teachers
FO - students don't approach teachers about disability
FO - students with LD are very hesitant
FO - students don't communicate with teachers
FO – students don't take the advantage of seeing teachers
FO - students don't come for help
FO - students don't see teachers voluntarily

Category 4: Lack of engagement in learning
***Codes*:**
FO - blank slate
FO - no engagement in class

Category 4 (*cont.*): Lack of engagement in learning
***Codes*:**
FO - seemed disengaged
FO - no real effort
FO - hadn't reviewed notes

Category 5: Disruptive and anxiety-ridden behaviours
***Codes*:**
FO - difficulty in managing students' anxiety
FO - difficulty in getting students to focus
FO - students shut down
FO - very vocal or hyper
FO - students misdirecting anger
FO - students disrupting class flow

Category 6: Lack of training to teach students with LD
Codes:
FO - not trained in dealing with those things
FO - don't get any training
FO - don't have any formal background with special needs students
FO - even though I've gone to many learning conferences

Category 7: Large class size
Codes:
FO - classroom with 30 or 40 kids
FO - difficult when you've got 45 students
FO - hard with 40 of them
FO - can't go to 40 students

Category 8: Insufficient knowledge and skills to teach students with LD
Codes:
SO - hard to tell what strategies are working
SO - don't know where they're having difficulties
SO - confusion of learning disability with lack of aptitude
SO - don't often know how to best help them
SO - don't know what to look up or what to look for in terms of teaching tools
SO - don't know where to approach them

Appendix E

Interview Guide for Science Students with LD

Warm up

Tell me about yourself

- What program are you in at CEGEP?
- Which year are you in your program?
- What are you favourite courses so far?
- Why do you like these courses in particular?

Learning disabilities – History and Diagnosis

- Tell me about your learning problems/disabilities. Could you please describe your LD?
- When were you diagnosed?
- How do you feel about your learning disability?
- How do you view yourself as someone with a learning disability label? In what ways does the disability label affect you?

Learning disabilities – Perspectives on abilities

- How do you view your abilities in science? What can you say about your performance in science courses that you are taking at the CEGEP? How does that make you feel? Why do you feel that way? (Mastery experiences, Bandura (1982))
- If you were asked to rate your ability in learning science on a scale of 1 (lowest) to 10 (highest), where would you be? Why? (Burnham, 2011)
- How do you compare your ability in science as compared to your peer without a learning disability? Why do you feel that way? (Vicarious – Bandura (1982))
- What have your teachers told you about your abilities in science? Did that change how you feel about your ability in science? (Burham, 2011)
- Do you think the ways you rate/view your ability affect your performance on tests and exams in science? If no/yes, please explain.
- How do you feel about your upcoming science courses? Please explain (Burnham, 2011) Probe: What kind of feelings when you think of upcoming science courses? What kind of thoughts come to your mind when you think of the new science courses that you would be taking?

Learning and Learning strategies

- How much time do you spend studying for science courses? Do you believe that you spend enough time studying? If yes/no, please explain
- Could you please describe how you learn science concepts? In other words, what learning techniques/methods do you use to learn science concepts?
- Could you please elaborate why you have adopted these learning techniques?
- Do you think that your learning techniques contribute to your success in science? If yes, could you please explain why?
- What particular problems do you encounter in learning science concepts? Could you please explain.

- Are you able to solve the problems you encounter? If yes, could you please explain how
- What other type of learning techniques have you found helpful in science? Could you please elaborate on why you think those techniques were successful?
- Did you receive advice on a particular learning strategy that you could be helpful for you? Who advise you on this strategy? Could you please elaborate whether the strategy was particularly helpful for you? Why do you think it was helpful?
- If you were asked to recommend a particular learning strategy for someone who has the same learning disability as you, what would you recommend?
- Why would you recommend that particular strategy?

Learning – classroom – sociospatial context

- What learning problems do you encounter in your classroom? What problems affect your learning in the classroom?
- Have you encountered any problems in learning new materials that the teacher explains in your science classroom?
- Could you please describe the type of problems that you encountered regarding learning new concepts in the classroom?
- According to your opinion, do you think that these problems that you discussed could be minimized? If yes/no, could you please explain why?
- How do you think the teacher could modify his/her teaching or any practice to help you to understand the scientific concepts better?
- What do you do when you are having difficulty to understand a particular science topic?
- Do you contact your science teachers to seek for help? If no, why do you not contact them?
- If yes, how does your teacher respond to your learning problems?

Teachers' support, attitudes and teaching strategies

- Tell me about your favourite science teacher
- Why is he/she your favourite science teacher?
- How does he/she teach his/her science class?
- What aspect of his/her teaching you liked most? Why?
- What aspect of his/her teaching you are not comfortable with? Why?
- Was the teacher notified of your learning disability? How did he react? Did he approach you to discuss your LD?
- Does she/he provide accommodations to you irrespective of the help that you receive from the student access centre? If yes, could you please elaborate?
- Does the teacher meet with you after class to discuss your academic performance of you did not perform well in the test? If yes, could you please describe the meetings?

Tell me about your least favourite science teacher

- Why is he/she your least favourite science teacher?
- How does he/she teach his/her science course?
- What aspect of the teaching you are not comfortable with? Why?
- What aspect of the teaching you liked most? Why?

- Does she/he provide accommodations to you irrespective of the help that you receive from the student access centre? If yes, could you please elaborate?
- Does the teacher meet with you after class to discuss your academic performance of you did not perform well in the test? If yes, could you please describe the meetings?

Peer

- Do you work with your peer during science class sessions? Could you please elaborate?
- Do you usually work with your peer during the science classes?
- Could you please describe the type of work that you do with your peer in science classes?
- Does working with your peer help you understand science concepts better? If yes/no, please elaborate.
- Are your peers aware of your learning disability? If yes/no, could you please explain?
- Do you think that having a learning disability affect the way your peer see you and work with you during classes? If yes/no, could you please explain?
- Do you have a study buddy for your science classes outside of school?
- If yes, could you please describe your study sessions with your buddy?
- How would you describe the importance of studying with a buddy?
- Do you think that working with a friend has significantly helped your learning process?

Conclusion

- Is there anything you would want to add regarding learning problems that students with LD face in learning science in CEGEP?
- What do you think about this interview?
- Do you have any other comments please?
- Do you have any questions for me?

Appendix F

Codes and Categories Indicating Barriers Experienced by Students with LD in Science Learning

Category 1: Memory Issues
Codes:
- "I'm not really good with remembering words"
- "I'm trying to remember what he said before."
- "I have a hard time with like memory"
- "When I get nervous or anxious, I don't remember anything."
- "It takes me longer to remember things"
- "I'll forget about the first step"
- "I was having trouble memorizing each different part"
- "I have issues with memory"
- "I don't have a very good memory"

Category 2: Science Text Comprehension
Codes:
- "wording can be very advanced"
- "I have really hard time spelling"
- "I don't understand the terms that they say"
- "The names of each part [of the microscope] were long and they were unfamiliar to me"
- "I have trouble reading"
- "I need to like reread everything multiple times"
- "I might have misread something"
- "Most of the errors are actually reading errors"

Category 3: Focus and Attention
Codes:
- "I tend to not pay attention to certain little details"
- "I have trouble focusing"
- "I will still always end up being distracted by something or someone."
- "I can get easily distracted by anything, just noises around me.
- "I have trouble concentrating"
- "I can't focus for the entire hour and a half of a lecture"
- "I try and listen but I get distracted by everyone else"
- "I get distracted very easily a lot"
- "I can't concentrate ever"
- "I'm not able to concentrate for long enough most of the time."
- "I have a very short attention span"

Category 4: Academically less capable than their peers
Codes:
- "I put so much effort…my friends won't necessarily study as hard or as long"
- "Other people can study really fast and it takes me twice or three times the time"
- "…took a lot more effort for me to concentrate and understand the material"
- "I have to study 10 times harder than anyone just to get a passing grade"
- "They get better grades than I do."
- "They get it a lot faster than I do."
- "I know I'm not as smart as they are."
- "I have to put double the work and time into a science course than other people who don't have ADHD"

Category 5: Lack of Interest/Engagement
Codes:
- "I'm just completely disinterested or uninterested"
- "I don't put a lot of effort into actually trying to understand"
- "If the subject is not interesting to me, then I'm just going to, you know, move on."
- "I get bored with it[biology]"
- "If I don't like the [science] class, then I'm not going to do well"
- "I can't find anything to keep me interested in the science homework"
- "If I'm interested, I'll learn better and it's easier"

Category 6: Learning Strategies
Codes:
- "It's easier to have it memorized than try to actually understand it."
- "I think the memorization I should probably slack off of and try to really understand."
- "My studying methods aren't 100% the best"
- " I'm not very good at teaching myself new things"
- "I'll just read a problem and I just won't know where to start."
- "I wasn't used to actually studying. I was used to memorizing."

Category 7: Rapid Pace of Instruction
Codes:
- "The teacher just goes excessively fast"
- "They would teach too fast for me"
- "Here's the lecture, there we go, here's the lecture, there we go; no time for questions"
- "They'll give me a quick or so-so answer"

Category 8: Lack of structure in science classrooms
Codes:
- "It's always a different partner and that's honestly what gets me the most anxious,"
- "The teacher goes on to another subject, then comes back, and then goes off, and then comes back"
- "She doesn't follow the process"
- "The teacher jumps a lot between concepts"
- "very disorganised"
- "He skips between sections"
- "PowerPoints wouldn't match the notes"
- "Her scatter brainedness in class made me scatter brained"

Category 9: Teaching Strategies
Codes:
- "He didn't go into detail and he didn't connect"
- "He didn't really give good examples"
- "He wouldn't make any stories with it"
- "They would repeat what they said in class but that doesn't help me"
- "He re-explains it using different words, but the same type of explaining"
- "He's pretty much one way"
- "We'll just get bored of him or sick of him just explaining it in one way"