Investigating the Inclusiveness of STEM Courses and Reducing Barriers by Using the Universal Design for Learning Framework

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INVESTIGATING THE INCLUSIVENESS OF STEM COURSES AND REDUCING BARRIERS BY APPLYING THE UNIVERSAL DESIGN FOR LEARNING FRAMEWORK

By

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B.S. University of Central Florida, Spring 2015
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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Physics in the College of Sciences at the University of Central Florida Orlando, Florida

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2020

Major Professor: Jacquelyn J. Chini
ABSTRACT

Students with disabilities are in postsecondary STEM courses and degree programs, but only a few studies have investigated how STEM courses can be designed to support students with disabilities. We began addressing this gap by interviewing students with diagnoses characterized by variations in executive functions about their experiences in postsecondary STEM courses. We analyzed the interviews through a social relational perspective of disability as this allowed us to identify how course structures disable students from effective engagement with STEM courses. We found STEM courses present heightened barriers compared to non-STEM courses, with common barriers including a lack of resources and guidance for how to engage with course content, insufficient time on assessments, and a lack of access to organized course content and deadlines. The consequences of these barriers are that students are disabled from keeping pace in the courses and experience more frequent episodes of severe anxiety. We additionally investigated the extent to which SCALE-UP physics courses and inquiry-based chemistry labs implemented inclusive practices based on the enactment of Universal Design for Learning (UDL) checkpoints. Through course observations, we identified that courses supported some UDL recommendations, such as encouraging group work and clarifying vocabulary, but did not enact the UDL recommendations of providing options and flexibility for engaging with tasks. To improve the inclusiveness of courses, we supported physics instructors and chemistry teaching assistants (TAs) in choosing and implementing new UDL-aligned practices. Instructors chose to implement a variety of practices, and the extent and effectiveness of implementation varied due to
differences in the consistency of implementation and whether implemented practices achieved intended goals. Overall, we find that STEM courses are not designed to proactively support students with disabilities and that students with disabilities and the UDL framework can support instructors in identifying how courses can be more inclusive.
ACKNOWLEDGEMENTS

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# TABLE OF CONTENTS

LIST OF FIGURES.............................................................................................................. XIII

LIST OF TABLES ................................................................................................................ XV

CHAPTER 1: INTRODUCTION ............................................................................................... 1

CHAPTER 2: FRAMEWORKS ............................................................................................... 6

  Common models of disability: Social versus medical ................................................. 6
  Social relational perspective of disability ................................................................. 7
  Language used in dissertation ................................................................................. 9
  Framework for implementing inclusive practices: Universal Design for Learning (UDL)
  ........................................................................................................................................ 11
  Framework for instructor intervention: Cognitive-Affective Model of Conceptual
   Change (CAMCC) ........................................................................................................ 15

CHAPTER 3: LITERATURE REVIEW .................................................................................. 17

  Representation of students with disabilities in postsecondary STEM .................... 17
  Legislation regarding disability .................................................................................. 19
  Accommodation are beneficial but insufficient ......................................................... 21
  Few studies have investigated the experiences of students with disabilities in STEM
   courses ....................................................................................................................... 22
  STEM instructors lack knowledge of how to implement inclusive practices .......... 24
  UDL is useful, but lacks operationalization ............................................................... 25
Lack of knowledge about implementing UDL in STEM contexts ........................................... 26
Summary .................................................................................................................................. 27

CHAPTER 4: RESEARCH QUESTIONS .................................................................................. 29

CHAPTER 5: STUDY ONE – DISABLING BARRIERS EXPERIENCED BY STUDENTS
WITH DISABILITIES IN POSTSECONDARY INTRODUCTORY PHYSICS ................. 31

Introduction .......................................................................................................................... 31
Frameworks utilized .............................................................................................................. 32
Research questions ............................................................................................................. 32
Methods .............................................................................................................................. 33
Analytic Framework .......................................................................................................... 33
Positionality ......................................................................................................................... 34
Participants, context, and data collection ........................................................................... 36
Process for analysis ............................................................................................................. 39
Power Dynamics ................................................................................................................ 41
Building the trustworthiness of our interpretations ......................................................... 41
Findings and discussion ...................................................................................................... 42
Challenging and beneficial diagnosis characteristics ....................................................... 46
Beneficial diagnosis characteristics ................................................................................... 46
Connections to literature .................................................................................................... 47
Challenging diagnosis characteristics ................................................................................ 47
Connections to literature .................................................................................................... 49
Recommendations for instructors. ................................................................. 50

ADHD is understood socially and understanding the diagnosis supports student agency ................................................................. 50

Understood in relation to others ........................................................................ 50

Connections to literature ...................................................................................... 51

Recommendations for instructors. ........................................................................ 52

Agency increased by understanding diagnosis characteristics ............................ 53

Recommendations for instructors. ........................................................................ 55

Course structures lead to disabling and supportive experiences .......................... 55

Personal practices affected by course structures ................................................. 56

Connections to literature ...................................................................................... 58

Recommendations for instructors. ........................................................................ 59

Insufficient time on tests introduced barriers ...................................................... 60

Connections to literature ...................................................................................... 62

Recommendations for instructors. ........................................................................ 62

Extra test time perceived as an “unfair” advantage .............................................. 63

Connections to literature ...................................................................................... 65

Recommendations for instructors. ........................................................................ 65

Disabling course structures have a greater effect on student learning in physics courses .................................................................................. 66
More time needed for learning and expressing conceptual understanding ........ 66

Connections to literature ................................................................. 67
Recommendations for instructors ..................................................... 68

Barriers to staying on pace and determining how to study ..................... 68
Connections to literature ................................................................. 70
Recommendations for instructors ..................................................... 70

SCALE-UP course supports and barriers ......................................... 71
Connections to literature ................................................................. 73
Recommendations for instructors ..................................................... 73

Summary ........................................................................................... 74

Limitations and recommendations for future research ........................... 76

CHAPTER 6: DISABLING BARRIERS EXPERIENCED BY STUDENTS WITH
DIAGNOSES CHARACTERIZED BY VARIATION IN EXECUTIVE FUNCTIONs IN
POSTSECONDARY STEM COURSES ................................................... 78

Introduction ...................................................................................... 78
Frameworks utilized ........................................................................... 79
Research questions ........................................................................... 79

Methods ............................................................................................ 81
Analytical Framework: Interpretative Phenomenological Analysis ............ 81
Recruitment, participants, and context ............................................... 82
Analysis process, positionality, and building trustworthy interpretations .... 84
Findings and discussion ........................................................................................................ 89

Students recognize supportive course practices ............................................................. 92

Summary and connections to literature. ........................................................................ 94

Recommendations to instructors. .................................................................................... 95

Accommodations were highly valued and frequently used ............................................. 96

Connections to literature................................................................................................ 98

Recommendations for instructors. ................................................................................ 99

STEM courses introduced barriers to keeping pace ....................................................... 100

Connections to literature................................................................................................. 102

Recommendations for instructors. ................................................................................ 103

STEM courses cause increased anxiety .......................................................................... 104

Connections to literature................................................................................................. 106

Recommendations for instructors. ................................................................................ 107

Interactions with others ................................................................................................. 108

Peers .................................................................................................................................. 108

Instructors......................................................................................................................... 109

Disability services officials ........................................................................................... 110

Connections to literature................................................................................................. 112

Recommendations for instructors. ................................................................................ 113

Summary and implications .............................................................................................. 114
Limitations and recommendations for future research .................................................. 117

CHAPTER 7: USING UNIVERSAL DESIGN FOR LEARNING TO INVESTIGATE AND IMPROVE THE INCLUSIVENESS OF STEM COURSES .............................................. 118

Introduction .................................................................................................................. 118

Frameworks utilized ...................................................................................................... 119

Research questions ...................................................................................................... 119

Methods ....................................................................................................................... 119

Recruitment & intervention design .............................................................................. 121

Instructor recruitment .................................................................................................. 121

Design of data collection and instructor intervention ............................................... 121

Student recruitment .................................................................................................... 124

Data sources and analysis process ............................................................................. 126

Course Observations: Universal Design for Learning Observation Measurement Tool (UDL-OMT) ........................................................................................................ 126

Instructor interviews .................................................................................................... 133

Student focus groups .................................................................................................. 137

Findings ....................................................................................................................... 138

Enactment of UDL-aligned practices before UDL professional development ...... 139

Checkpoints with high and low scores across all instructors ................................. 143

Differences across courses ......................................................................................... 143

Differences across instructors .................................................................................... 147
New UDL-aligned practices implemented after professional development and student evaluation of their enactment and effectiveness................................. 148

P1a.................................................................................................................. 155
P1b.................................................................................................................. 155
P2a.................................................................................................................. 157
C1a.................................................................................................................. 161
C1b.................................................................................................................. 164
C2a.................................................................................................................. 167

Summary and take-aways ................................................................................... 169

Enactment of UDL checkpoints before professional development .................... 173

Effectiveness of implemented practices after UDL professional development ..... 176

Recommendations for instructors ...................................................................... 178

Limitations and future research ......................................................................... 179

CHAPTER 7: CONCLUSION .................................................................................. 181

Research question 1............................................................................................ 181

Research question 2............................................................................................ 183

Cohort’s enactment of UDL compared to experiences reported by students with disabilities......................................................................................... 185

Enactment of UDL checkpoints in-class versus in written curriculum.............. 187

Physics: .............................................................................................................. 188

Across physics and chemistry ............................................................................ 192
Research question 3 ........................................................................................................................................... 193

Implemented practices versus barriers identified by students .......................................................... 194

Limitations ...................................................................................................................................................... 195

Future work ................................................................................................................................................... 197

Take-Aways ................................................................................................................................................ 199

APPENDIX A: STUDENT WITH DISABILITY PRE-INTERVIEW PROTOCOL ........ 203
APPENDIX B: STUDENT WITH DISABILITY POST-INTERVIEW PROTOCOL ...... 207
APPENDIX C: OPERATIONALIZATION OF OBSERVATION PROTOCOL ........ 210
APPENDIX D: VARIATIONS IN ALIGNMENT OF UDL-OMT OBSERVATION ITEMS
TO UDL CHECKPOINTS .............................................................................................................................. 217
APPENDIX E: AVERAGED UDL CHECKPOINT SCORES AND MEASURE OF
CONSISTENCY .............................................................................................................................................. 221
APPENDIX F: INSTRUCTOR PRE-INTERVIEW PROTOCOL .................................. 223
APPENDIX G: INSTRUCTOR POST-INTERVIEW PROTOCOL .............................. 227
APPENDIX H: STUDENT FOCUS GROUP INTERVIEW PROTOCOL ................. 230
APPENDIX I: INSTRUCTOR UNIQUE PRACTICES ................................................. 235
APPENDIX J: COMPARISON OF UDL ENACTMENT IN OBSERVATIONS AND
WRITTEN CURRICULUM .............................................................................................................................. 241
APPENDIX K: IRB APPROVAL .......................................................................................... 244
LIST OF REFERENCES ................................................................................................................................. 246
LIST OF FIGURES

Figure 1. Diagram showing how superordinate themes 1 and 2 give a description of participants’ understanding of having ADHD, and how understanding ADHD influenced superordinate themes 3 and 4, which describe participants’ experiences in postsecondary courses. This demonstrates how superordinate theme 4 includes barriers that existed throughout students’ postsecondary experience and were increased in their physics courses. Examples from findings are included in each section to clarify connections between superordinate themes.......................... 45

Figure 2. Diagram showing connections between superordinate themes. .................. 91

Figure 3. Timeline of data collection and professional development activities. Note that some instructors had two implementation semesters, which each had five observations. Student interviews were only conducted at the end of the final implementation semester. Monthly meetings are not shown in the figure for brevity. ........................................... 125

Figure 4. Average baseline semester UDL enactment scores by instructor and checkpoint. (A) Checkpoints related to multiple means of representation. (B) Checkpoints related to multiple means of action and expression, (C) Checkpoints related to multiple means of engagement. Error bars are standard error (error bars are larger for C1b, who had fewer observations). * denotes checkpoints with high enactment and † denotes checkpoints with low enactment. ‡ denotes checkpoints with meaningful differences across type of course and § denotes checkpoints with meaningful differences across instructors................................................................. 141
Figure 5: Scores for checkpoints aligned with in-class implemented practices chosen by each instructor. Error bars are standard error. ................................................................. 153
## LIST OF TABLES

Table 1: Universal Design for Learning version 2.2: Principles, guidelines, and checkpoints. 13

Table 2. Study one participant information 38

Table 3: Study one superordinate and sub-themes and their representation across participants. Organized by which research question each superordinate theme addresses. 43

Table 4: Participants’ diagnosis(es), age diagnosed, and the STEM course they were enrolled in at the time of the interview 84

Table 5. Superordinate themes identified along with which participants expressed alignment with the themes. Superordinate themes are organized under the research questions they address 90

Table 6: Instructor pseudonyms along with their course, cohort, and how many students were recruited for focus groups from their course. 125

Table 7: UDL Guidelines 2.2: principles, guidelines, and checkpoints [33] and which UDL-OMT items map to the checkpoints. 131

Table 8: Checkpoints with high enactment, low enactment, different enactment across course, and different enactment across instructors. 143

Table 9: Instructor choices of implemented practices and which checkpoints they enacted. (I) denotes that the practice occurred in class, (O) denotes that the practice occurred outside of class, and (B) denotes the practice occurred in and out of class. 151
Table 10: Practices implemented by instructors and student evaluations of practices.
Student evaluation columns denote the number of students who evaluated the practice as positive, negative, neutral, or N/A (did not discuss the practice). Values of 0 mean that no student evaluated the practice in the way denoted by the respective column. The last column gives the total students interviewed from each instructors’ course.

Table 11: UDL-OMT observation items along with our definitions and examples we used as operationalizations.

Table 12: UDL-OMT items with our alignment and Basham et. al’s (2020) alignment to UDL checkpoints. Underlined items denote checkpoints which were aligned differently.

Table 13: Average scores for UDL checkpoints for pre (baseline) and post (implementation) semester(s) for each instructor.

Table 14: UDL checkpoints and corresponding unique practices coded from instructor interviews. (I) denotes that the practice occurred in class, (O) denotes that the practiced occurred out of class, and (B) denotes that the practice occurred in and outside of class.

Table 15: Comparison of UDL enactment from in-class and written curriculum findings.
CHAPTER 1: INTRODUCTION

Students with disabilities make up 10-20% of postsecondary students and enroll in STEM courses at equivalent or higher rates than their peers depending on the type of institution [1,2]. Very little research has investigated the experiences of students with disabilities in postsecondary STEM contexts or whether postsecondary STEM courses are taught in a way which support students with disabilities. Instructors play a critical role in how students experience a course and whether a course is designed to support all students. However, postsecondary instructors across all disciplines lack knowledge about how to support students with disabilities [3-5]. The lack of research and instructor knowledge reflects a culture which has not considered how courses can be proactively designed to support students with disabilities. As educators, we have the responsibility to support all students in our courses and disabling course structures opposes the goal of all students being supported. Furthermore, disabling barriers can be in potential violation of legislation which prohibits intentional or unintentional discrimination on the basis of disability [6-10].

This dissertation presents three studies I led to investigate how students with disabilities experience STEM courses and how the Universal Design for Learning framework can be used to implement course practices which support students with disabilities. The first two studies specifically focus on disabilities which are characterized by variations in executive functions. Executive functions include cognitive processes
such as metacognition, flexible thinking, attention, working memory, planning, organization, and self-monitoring or progress [11,12]. We chose to specifically investigate diagnoses characterized by variation in executive functions since this includes many common diagnoses, such as ADHD [13], autism [14], anxiety [15,16], depression [15,16], and specific learning disabilities [12]. Most students with disabilities in postsecondary institutions identify with one of these diagnoses [17] and while several studies have investigated how to support students with visual or hearing impairments in STEM courses [18-20], few studies have investigated the experiences of students with diagnoses characterized by executive functions in STEM.

The first two studies explore the experiences of students with disabilities in postsecondary STEM courses and we use a social relational model of disability to identify how course structures interact with student diagnosis characteristics to result in supports or disabling barriers [21]. Diagnosis characteristics are personal qualities attributed to a diagnosis which are independent of social structures and can result in challenges or benefits in day to day life. For example, an example of a diagnosis characteristic expressed by our participants was getting easily distracted and requiring additional time to complete tasks. Disabling barriers are defined as characteristics of social structures which disable individuals with disabilities from access to and participation in social structures; in this study the disabling barriers of interest are related to course design [22]. Tests that do not provide sufficient time may be a disabling barrier associated with the diagnosis characteristics of being easily distracted and requiring additional time, disabling some students from effectively expressing
understanding. Both studies use the same theoretical and analytical frameworks. The first study focuses on the experiences of students with attention deficit hyperactivity disorder (ADHD) whereas the second study includes students from a variety of disabilities which all are characterized by variations in executive functions (i.e., cognitive processes including metacognition, memory, and planning). The first study is specific to students with ADHD as this diagnosis was represented in over 50% of the participants we recruited. By choosing to investigate one specific diagnosis in the first study, we were able to explore whether students from the same diagnosis reported similar or differing experiences. By choosing to investigate a range of diagnoses in the second study, we were able to explore whether students from differing diagnoses reported similar or differing experiences. In both studies, we identified how specific course structures interacted with a participant’s diagnosis characteristics to result in disabling or supportive experiences. From students’ experiences, we recommend practices and strategies instructors can implement to increase support for students with executive function disorders in STEM courses.

The third study presents efforts to evaluate the extent to which STEM courses enact the Universal Design for Learning (UDL) framework. We additionally investigated the impact of supporting physics and chemistry instructors in choosing and implementing UDL aligned practices and strategies in their courses and labs. The Universal Design for Learning framework is a commonly used framework in the K-12 setting for identifying how courses can be made more inclusive, but little to no work has investigated its implementation in postsecondary STEM [23]. We define inclusive to
mean practices which account for the variability in learners needs, interests, and abilities. To support instructors in implementing practices which increased their courses’ inclusiveness, the research team provided professional development for physics faculty and chemistry TAs regarding UDL and students with disabilities. The research team then worked with instructors to identify which UDL checkpoints had low enactment in their courses. Instructors chose practices they wanted to implement, and the research team monitored these implementations through observations and interviews with instructors and students. I will present data from these observations and interviews to identify how courses aligned with UDL before professional development, how courses changed after new practices were implemented, and whether instructors and students evaluated implemented practices as effective.

Before I present these studies, I present the models of disability used in this study (social model and social relational perspective of disability), definitions and distinctions for specific jargon we use throughout our studies, our framework for identifying inclusive practices (Universal Design for Learning), and our framework for working with instructors (Cognitive-Affective Model of Conceptual Change). Following this I provide a literature review which frames the importance of these studies. This literature review will present the minimum legislative requirements for supporting students with disabilities, the experiences of students with disabilities in postsecondary contexts, instructor knowledge regarding students with disabilities, and research regarding disability which have been done in postsecondary STEM contexts. The next three chapters will cover the three aforementioned studies, with each chapter including
the methods, findings, and discussion from each study. The final chapter of my
dissertation will be a conclusion which connects the findings and discussion sections
from the three studies into a narrative outlining the existing inclusive and disabling
structures in postsecondary STEM courses and how UDL can serve as a useful
framework for making STEM courses more inclusive.
CHAPTER 2: FRAMEWORKS

Common models of disability: Social versus medical

Disability can be conceptualized through different models. Models of disability vary in where they position the source of disability (e.g., within the individual versus within social structures), and how disability is defined impacts the framing of response to challenges experienced by people with disabilities. People who are able-bodied (i.e., do not identify with a disability), often hold a medical model perspective of disability [11]. In this model, disability is described as a consequence of a personal, functional limitation (i.e., impairment to be “cured” or “fixed”) [12]. Byproducts of the medical model include medication or technologies which have been developed in response to “limitations”. In postsecondary settings, this model is applied when instructors attribute the course performance of a student with a disability, whether good or bad, to perceived physiological differences in the student. Recommendations are therefore framed to address the perceived physiological differences (e.g. medication, telling a student to just be more focused).

Alternately, many people in the disability rights movement hold beliefs aligned with the social model of disability [13]. The social model situates disability within social constructs rather than within the individual. Social constructs are things made by people for people (e.g., manmade structures, learning environments, media). Applying the social model, Goodley (2016) states that “social, cultural, historical, economic, relational, and political factors disable individuals” and that “disabled individuals” can be given access through the reduction of social barriers (p. 9) [24]. An example of the
application of the social model in postsecondary settings is if an instructor identifies their course practices as the reason why students with disabilities are not performing well and enacts changes in course practices as a response. In the third study we use the social model to identify course structures as the reason students with disabilities are disabled from effective engagement.

While there are other perspectives of disability, the medical and social models have been driving forces in modern Western industrialized societies' social structures and legislation and are relevant to our context; different models may be more relevant in other contexts, such as the Global South [14].

Social relational perspective of disability

In the first two studies, we applied the social relational perspective of disability, a particular take on the social model that emphasizes the relationship between impairment and disabling social structures [9]. Under this model, Thomas (2004) defines disability as “...social exclusion on the grounds of impairment” (p. 15) and impairment as “... the embodied socio-biological substance – socially marked as unacceptable bodily deviation – that mediates the social relationships in question” (p. 15). Thomas posits that while impairments have a biological source (i.e., they are not caused by social structures), impairments are socially understood (i.e., they are identified and understood through comparison to others).

The social relational perspective acknowledges that impairments shape individuals’ experiences. Thomas (2004) argues for the inclusion of this perspective of
impairment in the social model, which traditionally ignores personal characteristics (i.e., impairments) and only focuses on social structures [25]. While the social relational perspective maintains the social model stance that social structures create barriers that disable people, it also defines “impairment effects” as other limitations a person may experience due to their impairment that cannot be remediated by social change. Thomas (1999) demonstrates the difference between impairment effects and disability with a personal example: “…the fact that I cannot hold a spoon or a saucepan in my left hand is an effect of my impairment and does not constitute disability in the social relational sense.” (p.43) [15].

In place of Thomas’s impairment effects, we used the term “diagnosis characteristics” to make space for both the limiting and/or negative characteristics individuals associate with their diagnosis as well as positive byproducts that individuals associate with their diagnosis. Diagnosis characteristics better aligns with the affirmative model of disability, which posits “…a non-tragic view of disability and impairment which encompasses positive social identities, both individual and collective…” (p.569) [16]. For example, Swain and French describe that disabled individual’s impairments may lead them to have increased empathy for others in oppressive situations [16].

Our use of the social relational perspective has two significant effects on the first two studies. First, we identified disabling course structures based on students’ perceptions of the interactions between their diagnosis characteristics and course structures that resulted in barriers or provided supports. Thus, we had to investigate student’s diagnosis characteristics in order to identify when students experienced
course structures that interacted with those diagnosis characteristics. Second, we targeted our recommendations at the course structure level since instructors and institutions have the agency to adjust course structures to reduce barriers and support access. An example of our application of the social relational perspective that courses not providing breaks is a disabling barrier since it does not provide flexibility for students who encounter diagnosis characteristics of easily being distracted.

**Language used in dissertation**

In this dissertation we use a variety of terms related to disability and we define the terms in this section along with providing context for when the terms will be used. When investigating the experiences of students with disabilities, we found that some students reported negative experiences due to others and/or the participant having perspectives that disability was a negative aspect of the participant’s identity. This is a form of *disability stigma*, specifically the belief that an individual has less value due to perceived differences from others which are associated with a disability diagnosis [26]. *Disablism* is the application of disability stigma to result in beliefs, processes, and practices which exclude individuals who have, or are perceived to have, a disability from everyday life [27]. Alternatively, *ableism* includes beliefs or practices which emphasize being “able-bodied” (i.e., not having a disability) as the norm and ideal state. The contrast between *disablism* and *ableism* is that *ableism* lifts up those who are able-bodied, whereas *disablism* puts down those who have a disability or are perceived to have a disability [28]. *Disability stigma*, *ableism*, and *disablism* are interconnected,
and we seek to detail the nuances between the terms to support clarification for why the terms are used throughout the following studies.

Throughout all three studies, we use the terms accessibility and inclusiveness to describe the extent to which practices and strategies are supporting the variability of learners. Accessibility and inclusiveness are interconnected, and the distinctions between the two can differ depending on the study.

We define fully accessible to mean that something is physically usable by all individuals. Becoming fully accessible is the ultimate goal, but things can also have varying levels of accessibility based on the breadth of individuals who are supported in using the structure in question and the extent to which usability is provided. For example, if a graph is provided to students, it should be provided in such a way that every student is able to receive the key pieces of information on the graph. Visual elements are not sufficient, as not all individuals have equal capabilities to receive visual information; therefore, information should also be provided in alternative formats such as alternative text readable by a screen reader, braille, or in a 3D format where features can be felt. Accessibility guidelines often include specific recommendations and guidelines for how various content types should be designed to allow access for all individuals. Examples include the WCAG guidelines which outline how to make websites accessible for all individuals [29].

Inclusive means that something is designed with the variability of learners’ needs, interests, and abilities in mind. In our definition, inclusive includes accessibility, but inclusive also includes considerations for differences in motivation, areas of comfort,
financial needs, and any other variations which individuals may have from each other. Things which are inclusive do not only consider whether something is physically accessible, but also whether an individual would feel welcome, safe, and/or motivated to engage with whatever the thing may be. An example of an inclusive design would be a class project where students have some choice in what to investigate along with how they can present their results. This allows students to choose something they are interested in and utilize a presentation technique which they feel capable and confident in using. Frameworks which emphasize inclusiveness often include general recommendations since there are too many variations across individuals to provide specific recommendations which will support all students. Universal Design for Learning is one framework which emphasizes inclusiveness, and does so through recommendations to provide options, flexibility, and supports for how students engage with a course [30].

Framework for implementing inclusive practices: Universal Design for Learning (UDL)

To characterize the inclusiveness of course practices, we used the Universal Design for Learning (UDL) framework. We define inclusive to mean that a social structure is designed to meet the variability in individual's needs, interests, and abilities. UDL has its origins in Universal Design for architecture, a framework with the intentions of designing physical spaces to be accessible for the widest variety of users possible proactively instead of retroactively. To accomplish this, Universal Design provides seven guidelines which outline considerations for how a physical space can be
designed to be accessible for users with diverse needs: equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and size and space for approach and use [31]. By designing physical spaces for users with diverse needs, you in turn make physical spaces more accessible for everyone. Examples of structures which embody these guidelines include ramps, curb cut outs, and easy-to-press buttons on automated doors.

Universal Design for Learning was developed in the 1990s by the Center for Assistive Technology (CAST) and aimed to bring the principles behind Universal Design into the learning environment [30]. In conjunction with previous psychology research [32] and the philosophy behind Universal Design, CAST developed a framework to support the variability in learners’ needs, interests, and abilities. This framework includes three principles which identified three areas of considerations: multiple means of engagement, multiple means of representation, multiple means of action & expression. In short, these categories stress that students need to have options and supports for receiving course material, engaging with course material, and expressing understanding of course material. The three principles break down into nine guidelines which further break down into 31 checkpoints that provide specific areas of consideration to support all learners [33]. Table 1 lists the UDL version 2.2 principles, guidelines, and checkpoints.
Table 1: Universal Design for Learning version 2.2: Principles, guidelines, and checkpoints.

<table>
<thead>
<tr>
<th>Principle</th>
<th>Guideline</th>
<th>Checkpoint</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide Multiple Means of Representation</td>
<td>1.1</td>
<td>Offer ways of customizing the display of information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>Offer alternatives for auditory information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>Offer alternatives for visual information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.1</td>
<td>Clarify vocabulary and symbols</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.2</td>
<td>Clarify syntax and structure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>Support decoding of text, mathematical notation, and symbols</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.4</td>
<td>Promote understanding across languages</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>Illustrate through multiple media</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.1</td>
<td>Activate or supply background knowledge</td>
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<td>Highlight patterns, critical features, big ideas, and relationships</td>
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<td>3.3</td>
<td>Guide information processing, visualization, and manipulation</td>
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<td>3.4</td>
<td>Maximize transfer and generalization</td>
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<td>Provide Multiple Means of Action and Expression</td>
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<td>Vary the methods for response and navigation</td>
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<td>4.2</td>
<td>Optimize access to tools and assistive technologies</td>
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<td>Use multiple media for communication</td>
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<td>Use multiple tools for construction and composition</td>
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<td>Build fluencies with graduated levels of support for practice and performance</td>
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<td>6.1</td>
<td>Guide appropriate goal setting</td>
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<td>Support planning and strategy development</td>
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<td>Facilitate managing information and resources</td>
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<td>Principle</td>
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<td>Provide Multiple Means of Engagement</td>
<td>Provide options for recruiting interest</td>
<td>6.4</td>
<td>Enhance capacity for monitoring progress</td>
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<td>Provide options for sustaining effort and persistence</td>
<td>7.1</td>
<td>Optimize individual choice and autonomy</td>
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<td>Optimize relevance, value, and authenticity</td>
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<td>7.3</td>
<td>Minimize threats and distractions</td>
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<td>Provide options for self-regulation</td>
<td>8.1</td>
<td>Heighten salience of goals and objectives</td>
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<td>8.2</td>
<td>Vary demands and resources to optimize challenge</td>
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<td>8.3</td>
<td>Foster collaboration and community</td>
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<td>8.4</td>
<td>Increase mastery-oriented feedback</td>
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<td>9.1</td>
<td>Promote expectations and beliefs that optimize motivation</td>
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<td></td>
<td></td>
<td>9.2</td>
<td>Facilitate personal coping skills and strategies</td>
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<td></td>
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<td>9.3</td>
<td>Develop self-assessment and reflection</td>
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</table>

UDL and Universal Design both use the argument that by designing social structures to support individuals with disabilities, you consequently support everyone. We recognize that this argument is a form of interest convergence, a framing which says that advances for marginalized populations only get implemented when the advances also support the majority population. Traxler and Blue (2020) express that arguments such as these are often necessary “…because a justice-based argument is historically not enough” [p. 142] to result in change [34], and we agree. However, we want to clarify that our primary intent is to determine how courses can better support students with disabilities.
We used UDL in this dissertation to classify if and/or how instructional practices in STEM courses align with UDL checkpoints. Based on the alignment of course practices to UDL checkpoints, we can identify what aspects of a course are inclusive and what aspects of a course need to be modified to better students with disabilities and subsequently all students.

**Framework for instructor intervention: Cognitive-Affective Model of Conceptual Change (CAMCC)**

Since instructors are key stakeholders in how a course is designed, we prioritized working with instructors to make courses more inclusive. To increase the likelihood that instructors would have meaningful changes in their practices and beliefs concerning inclusive practices, we used Gregoire’s Cognitive-Affective Model of Conceptual Change (CAMCC) [35]. The CAMCC proposes that to increase the likelihood of effective pedagogical change, three conditions should be met: 1) instructors should be given evidence that existing practices are ineffective, 2) instructors need to believe that the proposed pedagogy is effective, and 3) instructors need sufficient time and resources to implement pedagogical changes [35]. When any of these conditions are not met, barriers can occur which result in superficial changes to teaching or a rejection of the proposed pedagogy entirely. Previous studies which have implemented CAMCC to support STEM instructor pedagogical changes have reported that meeting these conditions does support long term changes in instructors’ beliefs and practices [36,37]. CAMCC was used by Project ACCESSS in the third study to design how STEM
instructors were recruited, trained, and supported in implementing more inclusive practices in their courses.
CHAPTER 3: LITERATURE REVIEW

Representation of students with disabilities in postsecondary STEM

In US postsecondary schools, students with disabilities make up between 10-20% of students [38,39] and enroll in STEM majors at higher or equivalent rates as students without disabilities, depending on the type of institution [2]. In European countries, statistics on the enrollment of students with disabilities varies between 5-30% [40]. Regarding enrollment in postsecondary countries outside of US and Europe, there is a lack of data regarding the enrollment of students with disabilities in postsecondary institutions [41], though some countries are beginning to collect this data. One example is Zambia which reports that 3% of college students have a disability [42] and China which in 2015 only had 9,542 students with disabilities accepted into universities (less than 1% of total enrollment) [43]. Additionally, an international study conducted across 49 countries across all continents found that in K-12 students with disabilities are more likely to not attend schooling than individuals without disabilities [44]. Because students with disabilities are less likely to be enrolled in K-12 schools in most countries, we expect that postsecondary enrollment is also comparatively low for students with disabilities in most countries.

It is challenging to identify whether the variations in statistics are due to differences in how students are diagnosed, differences in data collection methods, or differences in the inclusivity of postsecondary institutions [45]. Regardless, we can say with confidence that in the US, students with disabilities are enrolling in postsecondary institutions as STEM majors. In countries outside the US or Europe, the enrollment of
students with disabilities is likely to not be as high and so studies in these contexts should investigate the barriers students with disabilities encounter to postsecondary enrollment.

Diagnoses of students with disabilities vary, and students with different diagnoses will likely have different experiences. Some diagnoses are more common than others, and most students with disabilities at postsecondary institutions have diagnoses that are associated with variations in executive functions [17]. Executive function processes include thinking metacognitively, flexible thinking, attention, working memory, planning, organization, and self-monitoring or progress [11,12]. Diagnoses which are characterized by variations in executive functions include ADHD [13], autism [14], and specific learning disabilities [12]. Anxiety and depression (included in the mental illness/psychological or psychiatric condition category) are not diagnosed based on qualities which fall under executive function disorders, but studies have found correlations between the severity of experienced anxiety and whether the individual has variations in executive function [15,16]. In the report by Raue and Lewis (2011), we find that students with diagnoses in the categories of autism, mental illness/psychological or psychiatric conditions, ADHD, autism, and specific learning disabilities make up 66% of students with disabilities in postsecondary institutions; 2%, 15%, 18%, and 31% respectively [17]. Diagnoses of ADHD, learning disabilities, autism spectrum disorder, and anxiety are sometimes called invisible, hidden, or non-apparent disabilities because they do not carry a physical marker and may not be apparent to outside observers. The non-apparent nature of diagnoses associated with differences in executive functions
may be one of the reasons little research has explored the experiences of students with related diagnoses in STEM courses.

**Legislation regarding disability**

Since the presented studies all occurred in the US, we will provide a quick overview of the legislation regarding disability in the US as the postsecondary legislative requirements set the bar for the minimum supports that postsecondary institutions must provide students with disabilities.

Society and social structures historically have introduced systematic discrimination for individuals with disabilities and in response to this governments have generated legislation which prohibits discrimination on the basis of disability. Evidence of the universality of the recognition and opposition to the systematic discrimination of individuals with disabilities is the Convention on the Rights of Persons with Disabilities treaty which was drafted by the United Nations General Assembly to affirm the human rights and freedoms of individuals with disabilities and was signed by 81 countries and the European Union [6]. Within in the US, the requirements for K-12 education environments fall under the Individuals with Disabilities Education Act (IDEA), whereas the requirements for postsecondary learning environments fall under Sections 504 and 508 of the Rehabilitation Act of 1973 and the American with Disabilities Act (ADA).

In the K-12 setting, IDEA gives schools the legal responsibility to identify students who exhibit disability characteristics and offer diagnostic services free of charge [7]. Formal diagnoses are made by a medical professional [46] and if a student
is diagnosed with a disability, IDEA also requires the development of an individualized education program (IEP) for the student, which outlines how the student will be supported to achieve their academic and functional goals as well as the supports and services that the school will provide [7]. When students transition to the postsecondary setting, IDEA no longer applies. Sections 504 and 508 of the Rehabilitation Act of 1973 [8] and ADA [10] apply in the postsecondary learning environment and mandate equal access to course content and learning, when possible. If equal access is not possible within the existing structures, then the institution must “provide appropriate academic adjustments as necessary to ensure that it does not discriminate on the basis of disability” (e.g. accommodations) [47].

Accommodations are extra supports provided to individual students, often by an institution’s disability services office (DSO), to provide students with disabilities similar access to the course as other students. For example, a student with ADHD may receive a quiet testing environment as an accommodation because typical classroom noises affect their concentration and ability to demonstrate their understanding of course material. Accommodations are legally mandated based on requirements stating that if equal access is not possible within existing environments, then institutions must “provide appropriate academic adjustments as necessary to ensure that it does not discriminate on the basis of disability” (e.g. extra test time, note taking services, and interpreters) [23]. Many students make use of accommodations, with the extra test time accommodation being reported as the most common support service offered to students with disabilities [48]. The legislative requirements for supporting students with
disabilities reduce as a student transitions from K-12 to postsecondary, resulting in a reduction in supports as students transition from K-12 to postsecondary settings.

**Accommodation are beneficial but insufficient**

Due to the minimal legislative requirements, accommodations are often the main support for students with disabilities in postsecondary environments [23]. Some commonly used accommodations include extra test time and reduced distraction environments, and some less common accommodations include transportation services and being allowed to auditorily record class sessions [49]. To use accommodations, students often must meet with the disability services office and instructors are then notified of which students have access to which accommodations.

Many studies have investigated student use of accommodations and most students do report accommodations support their learning and expression of understanding [49-54]. For example, Mullins and Preyde (2013) found that students reported accommodations as “imperative for their success” [p. 153] and Ofiesh et. al (2015) found that accommodations of extra test time allowed students with ADHD time to take breaks when attention was being taxed [50,54]. However, accommodations are also reported by students to not fully meet their needs, possibly due to accommodations being provided based on the diagnosis label as opposed to the actual needs of the student [49,51]. Accommodations can also risk students with executive function disorders losing their anonymity regarding their disability [50,55-58]. For example, students may notice that a student with an EFD is absent at a test due to an
accommodation which necessitates taking the test in a separate environment. Anonymity regarding an individual’s diagnosis is valued by students as there is an underlying stigma towards disability which can result in students with disabilities being viewed as less capable or negatively by others. Therefore, students may avoid using accommodations to ensure their peers or instructors do not become aware of their diagnosis [55-57]. Accommodations may also go unused due to instructor resistance to providing accommodations [52,58,59] or students choosing not to pursue accommodations due to desires to be self-sufficient [52,57].

The consequence of all these factors is that accommodations, while useful, can be insufficient for and/or unused by students with disabilities. Therefore, it is important that courses are designed so that the need for external supports such as accommodations are as minimal as possible.

**Few studies have investigated the experiences of students with disabilities in STEM courses**

Significant work has investigated the experiences of students with disabilities in postsecondary institutions, and have found that students with disabilities encounter barriers such as insufficient time on tests and instructor resistance to providing accommodations [49-51,59-63]. Little of this work is specific to a discipline (e.g., physics, chemistry) [55,64-66]. This lack of research is significant because disciplines vary in the content they present and how they present it [67]. For example, it is known that physics courses can introduce novel challenges for students, examples including
the content being work intensive and the requirement to apply math to predict or explain phenomena [68].

To begin investigating the inclusivity of STEM courses, we advocate for the centering of individuals with disabilities in studies that aim to support individuals with disabilities. Social movements regarding disability rights [69] express the importance of centering people with disabilities when aiming to enact changes regarding inclusivity, as individuals with disabilities know what is best for themselves [70]. Prior research which aimed to increase the inclusiveness of STEM departments [71] and prepare faculty for supporting students with disabilities [72] have reported that centering individuals with disabilities supported the endeavors to increase the inclusiveness of departments and courses. In our context, we define centering to mean the intentional attentiveness to the experiences and perspectives of a group of people. Centering is especially important for populations which have been traditionally marginalized and under-investigated, such as individuals with disabilities, as this exposes how social structures introduce barriers for these populations.

It is well known that students with disabilities encounter barriers in postsecondary courses and that STEM courses introduce unique challenges; however little research has investigated the intersection of these ideas. This reveals a need for research regarding the experiences of students with disabilities in STEM courses.
STEM instructors lack knowledge of how to implement inclusive practices

Because of the value of academic freedom in the US, instructors are largely responsible for how courses are designed [73], though we recognize that other factors also play a role such as department, university, or government policies [74]. Academic freedom is a complex idea, but the relevant aspect of academic freedom for our study is that instructors can "…teach without external control in his or her area of expertise…" (p. 50) [73]. In the US and many European countries academic freedom is highly valued, though this is not the case across the world [73]. This section will focus on instructor knowledge regarding inclusive practices, but in contexts where instructors have less control over their courses, other stakeholders may be more appropriate to consider, such as departments and governments.

Instructors at the postsecondary level, across all disciplines, are not prepared to design their courses in a way which supports students with disabilities [3-5,75-78]. Instructors often only learn how to support students with disabilities after having interacted with students with disabilities in their courses [72,79], and therefore new teachers have little experience and knowledge in this area [77,80]. Postsecondary STEM instructors in particular often have little to no pedagogical training [81], and therefore have even less official training regarding how to support students with disabilities [82,83].

While some work has identified how STEM courses can be modified to support students with disabilities, the majority of this work has focused on how to support students with visual or hearing impairments [18-20]. This is likely because of the visible
nature of these diagnoses and the clear barriers which emerge due to interactions between student’s impairments and course structure. Students with non-apparent diagnoses encounter differing challenges [50,51,55,63,64], and the unseen nature of these diagnoses combined with the preferred anonymity of some students with non-apparent diagnoses [55-58] means that instructors cannot rely on enacting practices in response to learning about students diagnoses. Instead courses should be proactively designed to be inclusive, i.e. designed with the variability of learners needs, interests, and abilities in mind.

STEM postsecondary instructors lack preparation regarding how to support students with disabilities, and there is a lack of research about how STEM courses can be designed to support students with disabilities. This reveals a need for research which investigates what inclusive STEM courses looks like and how instructors can be supported in designing courses which are inclusive.

**UDL is useful, but lacks operationalization**

Within the past two decades, UDL has begun to be widely used and accepted as a means of increasing the inclusiveness of a course. Within the US, evidence of the adoption of UDL is that two of the main policies regarding education and students with disabilities, Individuals with Disabilities Act and the Higher Education Opportunity Act of 2008, explicitly cite UDL as a recommendation for supporting individuals with disabilities [7,84]. The majority of research about UDL has been done in US contexts, although researchers have begun to investigate implementing UDL and whether UDL
implementation is effective in K-12 schools in other countries such as Japan, Singapore, and Canada [85-87].

Across all contexts of UDL implementation, there is a lack of operationalization of what it looks like to implement UDL checkpoints [88,89]. Thus, most of the studies investigating the effectiveness of UDL implementation have centered around instructor perceptions of the implementation. Few studies have investigated UDL implementation by evaluating the extent to which UDL checkpoints were enacted in course practices [85,86]. The lack of research on the operationalization of UDL checkpoints and the effectiveness of UDL checkpoint enactment is a barrier to determining how to effectively enact UDL in a variety of content areas and academic levels.

**Lack of knowledge about implementing UDL in STEM contexts**

Varying academic levels and content areas will result in differences for what it means to enact UDL checkpoints. In previous studies, we found that students with disabilities encountered barriers and supports which were unique to STEM postsecondary contexts [55,64-66]. When the scope of UDL implementation is narrowed to postsecondary contexts, previous literature reviews have found few studies regarding the implementation of UDL or similar frameworks [90-92]. We are only aware of a few studies which have investigated including UDL in professional development for postsecondary STEM instructors and academic mentors [23,90], however the research which has been conducted does not present how training or measurements of effectiveness of UDL implementation aligned with the UDL principles, guidelines, or
checkpoints [92,93]. Some research has investigated the alignment of UDL checkpoints to popular physics and chemistry curriculum, but these studies investigated the curriculum by itself as opposed to within courses where the curriculum is used [94,95].

The evaluation of UDL as an effective means of increasing the inclusivity of a course, coupled with a lack of research regarding UDL implementation in postsecondary STEM courses, reveals a need for research which investigates how the UDL framework can be applied in postsecondary STEM courses and whether UDL implementation in postsecondary STEM courses does increase inclusion.

**Summary**

Students with disabilities are enrolling in postsecondary STEM courses and majors [2,38,39] and, due to legislative requirements, receive supports in the form of accommodations [23]. However, accommodations are insufficient [49,51] and not always used [52,57-59]. Due to course practices and instructors, students with disabilities also report barriers to learning and expression of understanding in post-secondary courses [49-51,59-63]. Therefore, we argue that courses should be designed in a way that supports all students with minimal need for external services. There are gaps in the research about what aspects of STEM courses introduce barriers for students with disabilities [55,64-66], though research has found that soliciting insight from students with disabilities about their experiences is an effective means of identifying and addressing barriers [71,72]. Universal Design for Learning also provides a promising framework for characterizing how inclusive a course is [7,84], though
minimal research has investigated the enactment of UDL checkpoints in STEM contexts [23,90-92,94,95]. One potential reason why STEM courses don’t intentionally support students with disabilities is that STEM postsecondary teachers have not received professional development or support for how to implement inclusive practices [3-5,72,75-79,81-83]. A few studies have used UDL to frame professional development for postsecondary instructors, both in and out of STEM contexts, however no research we are aware of has aligned their professional development and/or measures of effectiveness of professional development to the UDL guidelines and checkpoints [92,93].
CHAPTER 4: RESEARCH QUESTIONS

In response to the lack of knowledge about the experiences of students with disabilities in postsecondary STEM, studies one and two investigated students’ experiences in postsecondary STEM courses. We specifically sought to investigate what disabling or supportive experiences students with disabilities had in STEM courses due to interactions between diagnosis characteristics and course structures (i.e., aligned with the social relational perspective). This led to the following research questions:

1. What supportive or disabling course structures do students with disabilities encounter in STEM and non-STEM courses due to interactions between course design and diagnosis characteristics?
   a. Do students with differing diagnoses encounter differing supportive or disabling structures and if so why?

In response to the need for instructor support in implementing inclusive practices, we worked with instructors to identify disabling barriers within their courses and to implement new practices which could reduce barriers by increasing inclusivity. However, we recognize that STEM courses are not “blank slates” regarding inclusivity, and so first we evaluated the extent to which existing course practices in STEM courses were inclusive. We also seek to compare these findings to the experiences reported by students with disabilities to see if students with disabilities and the UDL framework report similar or differing barriers and supports. Finally, we investigate how our
measures of UDL checkpoint enactment during in-class sessions compare to previous studies which investigated the enactment of UDL checkpoints in written curriculum

2. What teaching practices and strategies are STEM course and lab instructors using, and how do these align with UDL recommendations for inclusive practices?
   a. How do the areas of high and low enactment of UDL checkpoints compare to the disabling and supportive course practices identified by students with disabilities?
   b. How do the areas of high and low enactment of UDL checkpoints during in-class STEM sessions compare to findings from previous studies which investigated the enactment of UDL checkpoints in STEM written curriculum?

To evaluate whether UDL professional development and support resulted in new, inclusive teaching practices, we investigated the practices instructor chose to implement after UDL professional development and the extent and effectiveness of implementation. We also investigated whether implemented practices addressed the barriers expressed by students with disabilities in our interviews.

3. What is the effect and effectiveness of working with instructors to implement new practices which align with UDL recommendations?
   a. Did the new practices instructor implement address barriers identified by students with disabilities?
CHAPTER 5: STUDY ONE – DISABLING BARRIERS EXPERIENCED BY STUDENTS WITH ADHD IN POSTSECONDARY INTRODUCTORY PHYSICS

Introduction

Students with disabilities make up a significant portion of postsecondary students and enroll in STEM courses at equivalent or higher rates than their peers depending on the type of institution [1,2]. Previous work has identified that curricula for introductory physics courses have not been designed to support students with disabilities [95] and postsecondary instructors across all disciplines lack knowledge about how to support students with disabilities [3-5], even though United States laws prohibit discrimination against students with disabilities and mandate equitable access to course materials [8,10].

Using a social relational perspective of disability, we posit that course structures interact with an individual's diagnosis characteristics to result in disabling barriers for students with disabilities [21]. Disabling barriers are defined as characteristics of social structures which disable individuals with disabilities from access to and participation in social structures; in this study the disabling barriers of interest are related to course design [22].

There is a significant lack of research investigating the experiences of students with disabilities in postsecondary physics courses. To add to this knowledge base, we investigated the experiences of students with attention deficit hyperactivity disorder (ADHD) in introductory physics courses at a single institution. We interviewed students with ADHD to explore how they understood their diagnosis, i.e. diagnosis
characteristics, and the practices they implemented to succeed in postsecondary courses. By identifying this information, we were able to distinguish how physics courses interacted with participants’ diagnosis characteristics and implemented practices to result in supportive or disabling experiences. From students’ experiences, we recommend practices and strategies instructors can implement to increase support for students with ADHD, especially in introductory physics courses.

**Frameworks utilized**

As mentioned in the introduction for this study, we use the social relational perspective of disability as our framing for how to identify disabling and supportive course structures; i.e. identifying how course structures interact with students’ diagnosis characteristics to result in students being disabled or supported in engaging with the course. We do not reference UDL in this study, however the practices we recommend do align with the framing that courses should support the variability of learners needs, interests, and abilities.

**Research questions**

Due to the lack of knowledge about the experiences of students with disabilities in postsecondary STEM, we investigated students’ experiences in postsecondary STEM courses. We specifically sought to investigate what disabling or supportive experiences students with disabilities had in STEM courses due to interactions between diagnosis characteristics and course structures (i.e., aligned with the social relational perspective), which also led to participants describing their views of their diagnosis characteristics.
1. What diagnosis characteristics do students with ADHD associate with their diagnosis, and how do students view these diagnosis characteristics?

2. What course structures interact with students’ diagnosis characteristics to support or disable students with ADHD in physics and non-physics courses?

**Methods**

We chose to collect data through individual interviews to provide depth versus generalization of findings. In this section we describe our analytic framework, interpretative phenomenological analysis, and the positionality of our research team. Next, we discuss our recruitment of students with ADHD. We also outline the analysis procedure and steps taken to increase the trustworthiness of our interpretations of participants’ experiences.

*Analytic Framework*

We analyzed the interview transcripts generated in this study with interpretative phenomenological analysis (IPA) because this framework acknowledges that we are researchers interpreting the lived experiences of others [96]. IPA follows a hermeneutic theory and methodology, which proposes that to investigate an individual’s lived experiences, the investigator must interpret the words and mindset of the individual in question [97]. In IPA, this interpretation process is acknowledged as having two levels: the researcher is making sense of participants who are making sense of their
experiences. The researcher also has the capacity to make connections participants may be unaware of, such as across participants’ experiences or in relation to previous research [96]. Due to the focus on the detail and breadth of experiences of each participant, Smith and Osborn recommend small sample sizes; they suggest six participants for researchers new to using IPA [96].

We selected this methodology because it respects the unique perspective each participant holds towards disability. At the same time, IPA acknowledges the researchers’ role as active interpreters, which was critical in this study as we needed to actively interpret participant’s responses throughout analysis to identify course structures which interacted with participant’s diagnosis characteristics. We also recognized that significant work has been done regarding disability, and IPA supports the use of this previous work as a rich lens to contextualize our findings.

Positionality

In this section we document the backgrounds of the researchers involved in analysis and how we chose to respond to, or take into account, these backgrounds in our interpretive phenomenological analysis of participants’ experiences. Since we are active interpreters of the data, our identities, background knowledge, and experiences will affect the interpretations we generate. By acknowledging our identities, we can better account for how they may affect our interpretations of data [98,99]. Three researchers (W. J., K.L., and C.B.) worked collaboratively during analysis. Our research team represented a range of dis/ability identities, including non-disabled, diagnosed with
ADHD, and undiagnosed but identifying with diagnosis characteristics associated with ADHD. One of us was a graduate student (W.J.) and the others were undergraduate students (K.L., C.B.). We come from a variety of disciplinary backgrounds, including physics and non-physics backgrounds.

The IPA framework emphasizes a “participant-oriented” analysis and therefore recommends researchers bracket (i.e., set aside) their experiences or perspectives when interpreting participants interpretations of experiences [96,100]. However, researchers may be unaware of when they are bringing personal experiences or perspectives into the interpretation. In alignment with the IPA framework, we aimed to have interpretations be based on what participants intended to express rather than what we researchers have experienced. By intentionally forming a research team from a variety of backgrounds, we sought to provide external checks (i.e., other researchers) who could identify when a researcher’s personal experiences or perspectives regarding disability were leading to interpretations which went beyond what participants intended to express [101].

At the same time, we highly valued including researchers who were students and who identified with a disability, as we believed they were well equipped for this analysis due to their intimate familiarity with how course structures can support or disable them due to interactions with diagnosis characteristics. We still did not want to assume that participants’ experiences regarding ADHD and course structures were the same as researchers’ experiences regarding ADHD and course structures. Therefore, though one researcher did identify with ADHD, we did not give increased weight to their
interpretations since we did not want to assume the experiences of participants were the same as this researcher’s experiences. All researchers’ perspectives were sought to be equally valued to support interpretations being aligned with the experiences participants were intending to express.

Participants, context, and data collection

Participants were recruited from introductory physics and chemistry courses at a large southeastern research-intensive university. Recruitment was done through emails which the university’s disability service office sent on our behalf to students registered with their office. We also requested that the course instructors send this email to all students to recruit students who identified with a disability but had not registered with the disability service office, and we contacted students who confirmed that they identified with a disability. Participants took part in one-hour long semi-structured interviews at the beginning and end of the semester. The interviews focused on the student’s experiences in their college courses, with an emphasis on their STEM courses and how their diagnosis interacted with their college experiences. A limitation of the interview protocol is that it was not intentionally designed to have participants explicitly identify diagnosis characteristics. There were only two questions with specific prompts regarding how participants’ diagnoses interacted with their course, and follow-up questions were also not intentionally focused on having participants identify diagnosis characteristics. The pre and post interview protocol used can be found in Appendix A
and Appendix B respectively. The graduate student researcher (W. J.) conducted the interviews. Audio-recordings of the interviews were transcribed verbatim for analysis.

We recruited a total of nineteen students from introductory physics and chemistry courses across three semesters. Eleven of these students identified with a diagnosis of ADHD. We chose to focus on these eleven participants to both reduce our sample (in line with recommendations for sample size for IPA) and to investigate whether individuals with a similar disability diagnosis reported similar experiences in postsecondary STEM courses. To further focus and reduce our sample, the lead author did a preliminary search through the eleven participants’ transcripts, going line by line and identifying instances where participants made explicit connections between their diagnosis and how it affected their interaction with their postsecondary courses. Due to our social relational perspective of disability, these statements were necessary to identify a participant’s diagnosis characteristics, which in turn were necessary to identify disabling barriers. W.J. selected five participants for analysis based on the numerous, explicit statements made during both of their interviews (beginning and end of semester) about how their diagnosis affected their interactions with day-to-day life. Though participants were recruited from both introductory physics and chemistry courses, these five participants were coincidently only in introductory physics courses.

At this university, introductory physics students have a choice between two styles of courses: traditional lecture or SCALE-UP. SCALE-UP courses combine typical lecture, recitation, and laboratory course components, and instructors are encouraged to reduce lecture time to allow time for students to engage with content through
worksheets, labs, practice problems, and other student-centered activities [102]. To support in-class group work, the SCALE-UP course uses a unique classroom environment (e.g., large round tables). Research has shown that SCALE-UP increases course-level learning outcomes and particularly supports course outcomes for underrepresented populations, such as women and Black, Indigenous, and People of Color students [102]. However, we are not aware of any work that investigates the experiences of students with disabilities in SCALE-UP courses. While students have a choice between traditional and SCALE-UP physics courses at this university, many students who have not previously taken a SCALE-UP course are not aware of these differences when enrolling, even though short course descriptions are provided in the online course registration portal. Table 2 displays the participants’ pseudonym, the age at which they were diagnosed with ADHD, and style of course they were enrolled in.

Table 2. Study one participant information

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age of Diagnosis</th>
<th>Style of course</th>
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<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>Lecture</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>SCALE-UP</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>SCALE-UP</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>Lecture</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>SCALE-UP</td>
</tr>
</tbody>
</table>

1 We did not collect additional demographic data such as race, gender, or LGBTQ identity as we did not frame our study with using an intersectionality lens. Since little to no work has investigated the experiences of students with disabilities in STEM courses, we desired to keep the scope of our study limited to the experiences which emerged from interactions with participant’s disability identity.
Process for analysis

Following the IPA process described by Smith and Osborn (2003), we started with each researcher independently reading and re-reading the transcripts. Next, we generated “comments” that summarized, made connections across, and/or provided a preliminary interpretation of instances where a participant identified a diagnosis characteristic or expressed an interaction between a diagnosis characteristic and some course structure. Once one of the researchers identified one of the instances defined above, we notified the other researchers and discussed what the participant expressed and how to annotate the idea. After commenting on an entire transcript, we then went through each comment and generated “themes”, “… which aim to capture the essential quality of what was found in the text” (p. 68) [96]. To identify the superordinate themes (main points), we reviewed the themes expressed by each participant. To facilitate this process, we each independently generated a short narrative of the ideas and experiences that we identified to be the most salient across the participant’s themes. We discussed these narratives to reach consensus about the superordinate themes a participant expressed. The graduate student researcher (W.J.) then organized the themes under these superordinate themes, with each theme only being represented in one superordinate theme. The superordinate themes, and the themes organized underneath them, were presented to the other researchers (K.L., C.B.) for their feedback and revisions. We discussed this organization and reached a final agreement on which themes should be represented under each superordinate theme.
We worked through these analysis steps independently and iteratively for each participant. Because each participant could uniquely identify diagnosis characteristics, we aimed to not have the findings from one participant influence our analysis of another's interview transcript at this stage.

Finally, we met to generate an overall table of superordinate themes based on the superordinate themes from every participant. IPA focuses on describing similar experiences from multiple participant’s perspectives. In alignment with this goal, we identified sub-themes based on ideas that two or more participants expressed. Further organization was necessary due to the number of sub-themes generated, so we generated superordinate themes which grouped the sub-themes and allowed us to present a cohesive narrative for our findings.

In the previous meetings, we did not document which specific participants expressed each subtheme. To address this lapse in record keeping, each researcher independently went through each subtheme and identified which participants expressed the subtheme. We then met again to reach consensus on which participants expressed each subtheme. Each participant was represented in at least one of these superordinate themes. The graduate student (W.J.) then organized this list of superordinate themes into a narrative account and connected findings to previous literature [96]. All three researchers gave their input about this narrative, and the final result is presented in this paper. It is important to note that at every step of analysis, we checked any claims or interpretations against the transcripts “to make sure the connections work for the primary source material – the actual words of the participant” (p. 72) [96].
Power Dynamics

To address the power dynamics\(^2\) between the graduate student (W.J.) and undergraduate students (K.L, C.B.), we established norms that every researcher’s perspective was equally valuable. To support the established norms, researchers were encouraged to present their interpretations and disagree if they had differing opinions. If a disagreement occurred during analysis, we discussed the topic until an agreement was reached among all researchers. Though many disagreements occurred, every discussion of these disagreements resulted in all researchers agreeing on one interpretation. The intent of these practices was to support each researcher’s interpretations being equally valued, but we acknowledge that the imbalance of power between researchers can result in this goal never fully being achieved [103]. The consequence is that the graduate student’s interpretations may have been more accepted, despite intentional efforts to prevent any researcher’s interpretations being dominant.

Building the trustworthiness of our interpretations

The lead researcher (W.J.) trained the other two researchers (K.L. and C.B.) in the IPA process. In these independent training sessions, the lead researcher went through an example transcript with the other researcher to practice identifying instances where a participant made explicit connections between their diagnosis, impairment, and their experiences in college courses and generating comments and themes.

\(^2\) We recognize that variation among aspects of our identities, such as gender, race/ethnicity, disability status, age, and position within the university, resulted in imbalances in power and authority.
As described in the positionality section, the research team represents a range of
disability identities, which increased our ability to generate trustworthy interpretations.
While there are numerous studies that have identified impairments commonly
associated with ADHD [13,104], we followed recommendations found in IPA literature to
bracket (i.e., put aside) our prior perspectives and experiences regarding disability
during analysis [96]. We only generated comments and themes based on what the
participant expressed regarding their diagnosis characteristics and which of their
diagnosis characteristics interacted with course structures. Additionally, researchers
were encouraged to question each other’s generated interpretations and inquire how a
participant’s statement expressed that idea. Since researchers had varied perspectives,
differing interpretations could arise and researchers would have to defend their
interpretations based on what participants expressed. This process supported
interpretations being more aligned with the participants own descriptions of their
experiences and is a form of ongoing peer review, which Creswell and Poth (2018)
identify as helpful in building trustworthy interpretations [105]. While IPA allows for
making connections to previous literature throughout analysis, we chose to make these
connections after first presenting participant’s perspectives. This decision was made to
emphasize the uniqueness of each participant’s experience of disability [69].

Findings and discussion

We identified four superordinate themes across participants: 1) diagnosis
characteristics could be challenging or beneficial, 2) ADHD is understood socially and
understanding their diagnosis supports student agency, 3) course practices lead to disabling and supportive experiences, and 4) disabling course structures have a greater effect in physics courses. Table 3 shows these superordinate themes organized under the relevant research questions, along with their subthemes and the participants who expressed them.

Table 3: Study one superordinate and sub-themes and their representation across participants. Organized by which research question each superordinate theme addresses.

<table>
<thead>
<tr>
<th>Superordinate themes</th>
<th>Sub-themes</th>
<th>Participant</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ1: What diagnosis characteristics do students with ADHD associate with their diagnosis, and how do students view these diagnosis characteristics?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Diagnosis characteristics could be challenging or beneficial</td>
<td>Beneficial diagnosis characteristics</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Challenging diagnosis characteristics</td>
<td>x</td>
</tr>
<tr>
<td>2. ADHD is understood socially and understanding their diagnosis supports student agency</td>
<td>Understood in relation to others</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Agency supported by understanding of diagnosis</td>
<td>x</td>
</tr>
<tr>
<td>RQ2: What course structures interact with students’ diagnosis characteristics to support or disable students with ADHD in physics and non-physics courses?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Course structures lead to disabling and supportive experiences</td>
<td>Personal practices affected by course structures</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Insufficient time on tests introduced barriers</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Extra test time as “unfair” advantage</td>
<td>x</td>
</tr>
<tr>
<td>4. Disabling course structures have a greater effect in physics courses</td>
<td>More time needed for learning and expressing understanding</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Barriers to staying on pace</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>SCALE-UP course supports and barriers</td>
<td>x</td>
</tr>
</tbody>
</table>
Superordinate themes 1 through 3 refer to participants’ general postsecondary experiences; the experiences reported here may have also occurred in the participants physics courses, but they did not exclusively occur in physics courses. Superordinate theme 4 reports experiences participants attributed exclusively to physics courses.

Though we identify diagnosis characteristics and participant perspectives of them, we do not provide recommendations for how these diagnosis characteristics can be reduced or eliminated. Such an approach would be aligned with the medical model. Rather we report the diagnosis characteristics and how participants understand them because we identified the course structures that interacted with diagnosis characteristics to result in supportive or disabling experiences. We report how participants view their diagnosis characteristics to reveal the negative impact of our ableist culture, especially because disability stigma became a disabling barrier that prevented students from using accommodations. Figure 1 shows how all the superordinate themes tie together to describe the supportive and disabling experiences of participants in physics courses.
Figure 1. Diagram showing how superordinate themes 1 and 2 give a description of participants’ understanding of having ADHD, and how understanding ADHD influenced superordinate themes 3 and 4, which describe participants’ experiences in postsecondary courses. This demonstrates how superordinate theme 4 includes barriers that existed throughout students’ postsecondary experience and were increased in their physics courses. Examples from findings are included in each section to clarify connections between superordinate themes.

Findings will be presented by first expressing our interpretations of participant’s perspectives within each superordinate theme. We found that many participant perspectives were aligned with a medical model view, likely due to the persuasiveness of this perspective in our society, including academic institutions, which is markedly ableist [106]. We seek to report participant’s interpretations of their experiences, but we also use our knowledge as researchers to contextualize these findings using a social relational perspective lens. The result is that our interpretations are structured to identify
how course structures interact with diagnosis characteristics to result in disabling or supportive experiences.

We follow participants’ perspectives with how the perspectives relate to previous research, and/or recommendations for how instructors can reduce identified course barriers. In alignment with the social relational perspective, all recommendations are targeted at how course structures or instructor perceptions can be modified. This contrasts with a medical model view which would recommend practices for changing students and/or their behavior.

**Challenging and beneficial diagnosis characteristics**

Since supportive or disabling course practices are characterized by interactions with participants’ diagnosis characteristics, we first must investigate participants’ diagnosis characteristics. Participants identified diagnosis characteristics of ADHD which included difficulties with focus, being prone to distractions, difficulties with keeping mental track of tasks and structures, and frequently ruminating about abstract concepts taught in their courses. These diagnosis characteristics were reported as beneficial or challenging based on their impact on day to day life.

**Beneficial diagnosis characteristics**

Participant 2 and Participant 5 identified positive effects their ADHD had on their learning, but only Participant 5 gave specific examples of what the positive effects were. When Participant 5 was asked if having ADHD has shaped their experience in their physics course, they expressed that a diagnosis characteristic of having ADHD for them
was thinking more often, especially about abstract concepts which were taught in their courses and how they were connected. Participant 5 shared how this diagnosis characteristic benefitted their learning in physics courses: “Um, in, in some manners I think about it [physics] a lot more, I think, than a lot of other people do. Just because that’s, there’s a lot more thoughts always coming in. I feel like one thing I can do a lot better than maybe other students can is just very well abstract things. Um, like see that, "Oh, yeah. I think I used this over here, and so it could be relatable over here because, you know, followed a similar pattern…” Thus, Participant 5 viewed their rumination about abstracts concepts, an ADHD diagnosis characteristic, as positively affecting their learning in physics.

Connections to literature

The affirmative model of disability embraces the idea that diagnosis characteristics can be beneficial, challenging the traditional view of normality by asserting that an individual’s diagnosis characteristics can result in a positive identity [107].

Challenging diagnosis characteristics

All five participants identified challenges arising from diagnosis characteristics which they explicitly connected to having ADHD. These diagnosis characteristics included difficulties with focus, being prone to distractions, and difficulties with keeping mental track of tasks and structures (e.g. how a course is designed, reoccurring commitments, interactions between school and social life). Participant 3 shared that
difficulties with focus were associated with having ADHD and that maintaining focus was a time intensive and exhausting task. Specifically, Participant 3 stated: “...it takes me a long time to focus. So... since it [focusing on task] takes me so long and since my focus time is so low... it takes a long time to get focused. It doesn’t last that long. So... after that energy expends, then it’s like, okay, get focused again.”

Participant 2 identified being easily distracted as a characteristic of their ADHD diagnosis and that this affected their learning during lecture because they were likely to get distracted: "Yes, 'cause I have ADHD, so it’s really easy for me to get distracted, so when someone’s lecturing I just kind of, the moment I like lose focus for a little bit and I come back and I don’t know what’s going on."

Participant 1 expressed that they had only recently been diagnosed with ADHD, and they were beginning to understand themselves better by investigating the diagnosis of ADHD. When asked if they had encountered any challenges due to their diagnosis, Participant 1 identified a challenge with remembering the tasks required of them from school and their social life and described that they have addressed this challenge by having their schedule in a digital format: “...actually the biggest barrier for me was understanding exactly how it is I should structure my life [shows google calendar on phone to interviewer]. If, this was something that I, if I hadn’t started doing, my life would, I don’t know where it’d be.”
Connections to literature

Challenges with focus, attention, and keeping track of tasks are markers that clinical psychologists use when diagnosing individuals with ADHD [46]. We see that participants don’t characterize their diagnosis characteristics as markers given by external, third parties, such as clinical psychologists. Rather we see that the participants self-identify with these diagnosis characteristics and that they use this understanding of their diagnosis to understand themselves and how they interact with the learning environment. The challenges described here are attributed to personal qualities (i.e., diagnosis characteristics) which are independent of social structures. This finding aligns with the social relational perspective’s argument that diagnosis characteristics have qualities that cannot be remedied by social change. However, in later sections we report how course structures do interact with these diagnosis characteristics to result in disabling barriers.

Our findings also reveal that participants identified more negative impacts on their learning than positive impacts. This imbalance can result in a view of ADHD as being inherently negative. Previous studies in which students with ADHD were interviewed or surveyed have also found students identified more negative diagnosis characteristics than positive diagnosis characteristics. Negative self-views of ADHD can cause students to have lower self-esteem and a lower perceived ability to succeed in college [63,108,109].
**Recommendations for instructors.**

If instructors hold the viewpoint that ADHD is inherently negative, a consequence could be lower expectations of students with disabilities or doubting their ability to succeed [110-112]. This could lead to instructors not engaging with students with disabilities or being less willing to enact practices to support students with disabilities. Therefore, we recommend that instructors recognize and celebrate the variability in learners’ needs, interests, and abilities. By doing so, instructors support a culture which celebrates diversity, rather than marginalizing differences.

**ADHD is understood socially and understanding the diagnosis supports student agency**

Participants primarily expressed diagnosis characteristics in comparison to others, specifically in the context that tasks were more challenging for participants than their peers, resulting in negative self-views for some participants. Some participants found that by understanding their diagnosis, they were able to identify strategies that increased their likelihood for success.

**Understood in relation to others**

Participants expressed varied perspectives about their diagnosis characteristics; this is not surprising since participants’ perspectives are shaped over time and influenced by factors including when they were diagnosed, the supports they’ve received, and their interactions with others [113,114]. A sub-theme identified in all participants’ interviews was that diagnosis characteristics were almost always referenced in comparison to others, and “others” were typically participants’ peers in
their courses. For example, Participant 1 expressed the consistent feeling that it takes them more effort to accomplish the same tasks as their peers: “I tell myself that everyone here has the efficiency of a God, whereas I have to do more work for the same or less results. And that's just something that I've always had to deal with…”

When Participant 4 was asked if they had encountered any barriers to learning due to having ADHD, they responded with comparisons to their peers. Specifically, they identified that a diagnosis characteristic of having ADHD was that they required more time to process and would make more mistakes than their peers. They also identified that these diagnosis characteristics made them have lower self-worth in the past: “…for me feeling like I'm less than anyone else, like, I used to feel like that, I guess, just because, like, I think it's a little bit of more time for me to process things and, like, I tend to make a little bit more mistakes than what other people do…”

These findings show us that diagnosis characteristics were primarily characterized by the participant’s ability in some area, and participants frequently used their perceptions of peers’ abilities as a benchmark for their own. This finding is in line with the social relational perspective, which proposes that diagnosis characteristics are socially understood [21].

Connections to literature.

The majority of participants’ comparisons to others were framed such that the participant felt less capable compared to their peers. Previous studies have also reported the negative consequences of such comparisons on students’ motivation and
self-efficacy [63,108,109]. The TEAM-UP (Taskforce to Elevate African American Representation in Undergraduate Physics and Astronomy) report produced by the American Institute of Physics found that it was critical that instructors emphasize that all students can be “…a welcomed and contributing member…” (p. 11) of the physics community [115]. While this report was focused on how to increase the underrepresentation of African American students, we believe this recommendation can also support students of other marginalized identities.

Recommendations for instructors.

In an earlier paper, we present an experience with an introductory physics instructor’s bias from a student who identified with an executive function disorder. The student shared with the instructor that the student would be using the extra test time accommodation, and the instructor responded in surprise since they perceived the student to be strong in the content and didn’t expect the student to have a disability [64]. In an interview, the student explained: “He [the instructor] thinks that ‘Oh, because she’s strong in the subject, she wouldn’t have a disability. She doesn't need accommodations.’ So the fact that he found out, he was like ‘I'm so shocked, like.’ I guess he was being like biased or stereotypical.” We interpret the instructor’s response as an example of ableism, “a set of beliefs, processes and practices that produce – based on abilities one exhibits or values – a particular understanding of oneself, one’s body and one’s relationship with others of humanity, other species and the environment, and includes how one is judged by others” (Wolbring, 2007:quoted in Goodley, 2014,
As Baines states, “When a student with a disability is negatively perceived by those around him, he can be restricted in his access to valued opportunities that might be related to abilities he would like to develop in relation to personal goals” (pg. 36) [116].

Ableist mindsets dominate our society and academic institutions, leading to the marginalization of individuals with disabilities through courses which are not designed to support individuals with disabilities and instructors who doubt the capabilities of students with disabilities [117]. Every student deserves instructors who believe they can succeed. Because our society is shaped by ableism, each of us is capable of ableist assumptions. Instructors can support students with disabilities by reflecting on their ableist beliefs and moving towards a perspective that all students can succeed. By shifting from a mindset of ableism to a mindset where all students are perceived to be capable, we move towards an inclusive and supportive classroom environment where all students feel valued and supported [118].

**Agency increased by understanding diagnosis characteristics**

Participants 1, 2, 3, and 4 shared how understanding their diagnosis characteristics has empowered them to make informed decisions about how they chose to view their diagnosis, allowing them to push back against internalized disability stigma, and to recognize the course structures that support their success.

Participants 1, 2, 3, and 4 all identified that they once held negative viewpoints towards their diagnosis and its diagnosis characteristics, however they began to
generate more positive views of their diagnosis when they began to view their diagnosis as a way to understand how they think and behave. A critical part of this process was a recognition that challenges don’t have to be viewed as challenges, and that there are positive diagnosis characteristics associated with having ADHD. Participant 1 encapsulates these ideas saying: “Yup, but but it’s [perspective about disability] changing ’cause, um, I’ve realized that, you know, this weakness has become my strength…it’s kind of perspective that it’s something I have to work on cause it’s something that, you know, [indiscernable], um, realizing that a weakness doesn't have to be a weakness forever.”

Regarding the recognition of supports needed for success, Participant 1 shared that they had investigated the medical diagnosis of ADHD soon after being diagnosed. They stated how this investigation had helped them to understand that order and structure are valuable to them because organization was a cognitive challenge: “And, uh, attention deficit disorder is an executive function disorder, so I'm understanding why I love order and structure so much is because I don't have it and within my cognitive processes. So, when I have it in an exterior fashion it's like, it's like this is how I wish my brain would be. But it's not, so I have it on paper.” We recognize that this quote seems to be aligned with a medical model of disability (i.e., disability being situated in the individual); however, instructors play a critical role in providing students the information and tools necessary for student organization, a consequence that aligns with the social relational perspective of disability. For example, a student can be inhibited from
structuring their studying if an instructor does not provide access to course content or doesn’t provide timelines for when content knowledge will be assessed.

Recommendations for instructors.

By understanding their diagnosis, participants encountered a double-edged sword that benefitted them through an increased understanding of themselves but could also harm them due to negative comparisons to others. We recommend instructors provide a variety of strategies for engaging with course content so that students can engage with and practice using different methods, a process which can help students identify what is most effective for them. For example, instructors can provide multiple ways for students to review the same content outside of class (e.g., book, Power Point slides, links to instructional videos). To reduce the negative comparisons to others, we recommend instructors value and celebrate the differences that their students bring, for example, by making statements acknowledging that there is variation among learners and normalizing challenges with learning physics content. Error management training is an instructional strategy specifically focused on normalizing the process of making mistakes, and many studies have found that this perspective leads to increased learning due to its support of emotional control and metacognition [119,120].

Course structures lead to disabling and supportive experiences

Participants stated that they encountered challenges related to organization and time to complete tests. To address these challenges, participants implemented strategies such as using a planner and developing study strategies that allow for
distractions. Using the social relational perspective, we focus on how courses could support or disable students from using their personal strategies based on the level of course organization. While students discuss their use of personal strategies, we do not focus on the development of personal strategies in response to diagnosis characteristics, as this is aligned with a medical model approach.

Participants also expressed that the time given on tests was insufficient for them to express their understanding. The barrier of insufficient time on tests could be alleviated by using extra test time accommodations, however participants reported that extra test time had negative stigmas associated with it. A medical model approach would encourage students to develop better test taking strategies, however by using a social relational perspective we identify the time provided during tests as the barrier. We also identify disability stigma as a social structure which introduces disabling barriers to making use of testing accommodations.

While participants discussed their choices regarding medication, discussing medication use does not align with our social relational-informed focus on social structures. We urge instructors not to discuss the topic of medication use with their students (particularly, without student initiation), including “jokes” about medication use, as this is a personal topic outside of instructor’s purview.

**Personal practices affected by course structures**

To address challenging diagnosis characteristics, all five participants implemented individual efforts which included using a planner for organization and
developing study strategies that incorporated breaks. Participants reported how they could be disabled from effectively using these practices due to course structures.

The frequency and importance with which participants discussed organization strategies, such as using a planner, suggest that organization strategies were an important personal practice which participants employed. Organization was mentioned by four out of the five participants, with Participants 1, 2, 3 and 4 expressing planners as being key to their success. For example, Participant 2 shared how they use a planner to organize every aspect of their life: “I write everything I have to do, including social engagements like when I’m going to see my boyfriend, when we have plans, when I have plans with my friends, everything. If I lose it, I wouldn't remember anything”. Participant 4 shared that being organized was critical specifically because they have ADHD, and that when instructors didn’t provide PowerPoints before class it could inhibit the participants’ use of their own organizational skills: “I don’t like the teachers that they don’t have, like, a game plan, right? So, they’ll just, like… not put the Power Point up, like, until the day after…I get mad when teachers aren’t organized just because, like, I know how hard it is, like, as a student with ADHD, like, I have to stay organized and if teacher isn't organized, it makes my job, like, 20, 30 times harder.”

For the participants to make use of their planning strategies, they needed to know deadlines for assignments, assessments, and mastery of specific learning objectives. Participant 1 shared that it is critical for their success that their instructor provide a schedule of the course: “A tentative schedule is something I particularly rely on because, again, I need to plan and if I don't have that, that's not going to work.”
When this information was provided, the participants were able to structure their time for studying and completing assignments. When this information was not provided, participants encountered difficulties in planning their time outside of class, which participants shared could result in poor test preparation or even having to withdraw from courses. Diagnosis characteristics lead to the value of organization, but course structures influenced whether students were supported or disabled from using organizational strategies.

Participant 2 shared that taking frequent study breaks was a personal practice that supported their study time related to their diagnosis of being easily distracted. However, allowing time for breaks required that the participant had a large block of time set for studying: “... I need large blocks of time to get really small parts done because I need to do a little bit and then do something to relax and allow myself to get distracted and then come back, do a little bit.” While this strategy was helpful outside of class, Participant 2 reported how long lectures without breaks disabled them from using this strategy during class. In response to this, Participant 2 implemented their own breaks during class by leaving the class for a set period of time, “…generally I like go to the bathroom to just chill... I did that in high school, I've never been good at lectures, so I just go to the bathroom and hang out…”

Connections to literature.

Every strategy mentioned by participants was self-developed and this development process took time, knowledge of their diagnosis characteristics,
experience, and practice. Perry and Franklin (2006) similarly found that students with ADHD developed strategies based on their understanding of their ADHD and diagnosis characteristics [63]. When participants understood the effects that ADHD had on their lives, they were better able to identify or develop strategies to engage with their courses. Organization was one of the predominant strategies reported, and previous research where students with ADHD were interviewed has also found that organization is a critical skill for students' success [50,53].

By using a social relational lens, we see that the implementation of these strategies often hinged on whether a course provided certain supports. For example, a student cannot plan their studying if they don’t have access to course content or don’t know when they will be assessed on the content. When courses are not designed to support students' knowledge about and use of appropriate study skills, students are forced to spend time finding the best ways to study. These challenges are compounded for students with disabilities whose diagnosis characteristics require more time to complete tasks. The result of this interaction is that participants were disabled from effectively engaging with some of their courses.

*Recommendations for instructors.*

To support students in making use of organizational strategies, instructors should provide deadlines outlining when assessments and assignments are due. To facilitate students in achieving these goals, course content should be available digitally in one
location so that students can easily access it. The sooner deadlines and course content are available, the better equipped students are to plan their learning outside of class.

To support students staying attentive in class, we recommend instructors provide opportunities for students to be momentarily disengaged with content without suffering from missing content. This can include providing breaks but can also include providing activities where students have flexibility in the means and timing for completing tasks. In our later section for SCALE-UP courses, we provide a quote from Participant 2 which describes how collaborative problem solving is an example of a flexible activity.

**Insufficient time on tests introduced barriers**

Participants expressed varying barriers regarding time for tests, with Participants 3 and 5 not encountering significant barriers and Participants 1, 2, and 4 seeing time for tests as a significant barrier. Participants 3 and 5 stated that they were able to maintain focus during tests, so their diagnosis characteristics did not interact with tests. When asked if using testing accommodations would affect Participant 5’s test performance, they said: “Um, I don’t think so ‘cause I don’t think I really felt, uh, very distracted in the test.”

On the other hand, Participants 1, 2, and 4 encountered barriers regarding time on tests, and they reported that the barriers were due to not having sufficient test time. Having sufficient test time was important due to diagnosis characteristics such as being distracted during the test time and the fact that they had a longer processing time than their peers. Participants articulated that the accommodations of extra test time and
reduced distraction environment provided through the university’s disability services office alleviated these barriers. Participant 4 expressed that extra test time significantly reduced the stress they experienced from being concerned about the amount of time they had to complete tests: “Oh, it [extra test time] helps so much. ‘Cause, like, you’re not even worried about the time at that point. You’re just, like, doing problems. You’re taking your time and solving them. You know. You’re not, like, stressing, like, ‘Oh my god, how much time do I have left?’”.

Though testing accommodations were reported as beneficial by some participants, they also introduced new barriers since the testing accommodations occurred in a separate environment. When using the extra test time accommodation, participants would miss announcements or corrections made by the instructor during the test and were often unable to ask the instructor questions during the test. Participants also expressed concern that other students could potentially notice their absence during tests, which could prompt questions of their whereabouts. Participant 4 shared how these questions outed them as using accommodations: “The only time people figure it out is, like, when they’re like, um, ‘save me a seat for the test’, and I have to be like, ‘Oh, I’m not taking the test with you guys’ … And that’s the only way they figure out.” In the next sub-theme, we present how this potential “outing” resulted in negative perceptions from peers regarding participants’ accommodation use.

To receive accommodations, participants typically had to provide evidence for their diagnosis to the disability services office at the university. For one participant, this resulted in them not being able to receive accommodations due to the cost of being
diagnosed. Fortunately, this individual stated that accommodations were not necessary for their success, but for a student who does need extra test time the cost of receiving a diagnosis could have been a disabling barrier.

*Connections to literature.*

Our findings align with previous studies where students with disabilities have reported the benefits of testing accommodations [50,53,54], but we also find that not all students with ADHD consider them critical for their success and the requirement and cost of diagnosis can be a barrier to accessing necessary accommodations.

*Recommendations for instructors.*

Since one of the course barriers is insufficient in-class time for assessments, we recommend instructors reflect on whether their learning objectives require that students express understanding within a constrained time. If not, then we encourage instructors to design assessments so that ample time is provided for all students. Options include having all students complete assessments in separate testing centers which allow more time than provided in a class period or offering alternative forms of assessment (e.g., projects) which are done outside of class.

To support students who are using extra test time accommodations, instructors can make plans with the student or disability service office about how the student can contact the instructor during the test time (e.g., providing the disability service office a phone number versus relying on email). Instructors can reduce the chance that peers will notice the absence of students using accommodations by having students sit in
randomly assigned seats during exams. This supports students in keeping their confidentiality regarding accommodation use.

**Extra test time perceived as an “unfair” advantage**

Negative perceptions held by participants and their peers regarding extra test time were specific to the idea that extra test time gave students an unfair advantage. This negative perception is a social structure which had the consequence of disabling students from wanting to make use of services they found beneficial. Three participants (Participants 1, 2, and 4) were using extra test time accommodations during their physics courses. Participants 2 and 4 reported that, in the past, they felt that accommodations were unfair and subsequently did not use them in previous courses. Specifically, they felt guilty about having an unfair advantage over their peers and/or that they wanted to prove that they could succeed without the accommodations. For example, Participant 2 shared how they tried not using extra test time, stating: “so in this past semester I felt, I felt really bad about using [extra test time accommodations] because then it was just, I do have ADHD, I'm kind of like, I do have ADHD but it's not fair like I don't like looking at my peers and being like I'm doing better because I have whatever. So I stopped using it and for physics, for Physics 1 my first test I did really badly and it was because I like knew the information, but the way I learn I had to like go through step by step, this is how this goes, this is how this goes and we didn't have enough time for that…” Participant 1 also experienced guilt and negative self-perceptions from using extra test time. Though Participant 1 reported continuing to use
testing accommodations because of the significant benefits they experienced, they did not make any explicit statements that those negative perspectives have changed. Here Participant 1 shares their mindset regarding their past and present negative feelings experienced due to using accommodations: “... [sigh] it [requesting accommodations] made me feel weak...it's still a little uncomfortable because I mean I, for example, I don't I don't tell my friends about it.” Accommodations are implemented to reduce discriminating barriers, and participants have reported that they are effective in doing so. However, it is concerning that these supports can result in participants experiencing such negative self-perceptions as students are going to be unlikely to use a resource that results in them feeling less than others.

Participants 1 and 4 also expressed that some peers seem to hold the perspective that the extra test time accommodation is an “unfair” advantage. Participant 4 discussed that interactions with friends who said they were jealous of the participant’s use of the extra test time accommodation led the participant to not make use of the extra time: “I used to- I used to feel bad about it almost like, I used to feel, like, kinda guilty, ‘cause, like, everyone else was, like, getting half the time I was taking when I had tests, so, like, in the beginning, I actually just went to class and just took my tests, like, with the rest of the class, just because, like, some of my friends were, I mean, I wouldn't say making fun of me for it but they were just, like, kind of jealous of me...” Participant 1 reported that they hadn’t heard anyone explicitly share negative views towards extra test time, but the participant still knew these negative views of accommodations existed,
stating: “... I haven't necessarily been exposed to it, but I know there's a stigma around it [extra test time], and it's still something I guess I just have to deal with for now.”

Connections to literature.

Previous studies reported students with disabilities experience views from their peers that extra test time provides an unfair advantage [50,63]. In our study, we found that others’ negative views can interact with participants’ own views towards the fairness of accommodations, possibly leading students to not use this accommodation that may be critical for success. Whether extra test time results in increased performance for students with disabilities is contested at the postsecondary level as some studies have found increased performance on tests when extra test time is provided to students with various diagnoses [121-123], whereas other studies have found no increase in performance [121,124]. However, none of these studies are specific to STEM, an important distinction in light of the increased processing time students need in STEM content areas [125]. A literature review on STEM accommodations by Ofiesh (2007) found little research investigating the effectiveness of accommodations in STEM, but the research which has been done has shown extra test time benefits students diagnosed with learning disabilities [125].

Recommendations for instructors.

We view extra test time as a fair and necessary accommodation. The participants in this study expressed benefits from extra test time accommodations beyond improved performance on their exams, such as significant reduction in anxiety.
We recommend that instructors encourage and support students with disabilities in using extra test time accommodations.

_Disabling course structures have a greater effect on student learning in physics courses_

Participants 1, 2, and 3 shared that they encountered barriers specific to STEM courses along with many barriers which were heightened versions of barriers experienced in other courses. Barriers were identified as “heightened” based on statements made by participants comparing the experiences in STEM courses to the experiences in non-STEM courses. Barriers specific to STEM were most often due to interactions between course features and diagnosis characteristics that increased the time required for tasks. Participants 4 and 5 also expressed supports and barriers in STEM courses, but they did not identify these barriers to be distinct from the barriers they experienced in other courses, as discussed in the preceding sections.

_More time needed for learning and expressing conceptual understanding_

To succeed in physics courses, participants recognized that memorization was insufficient and that they also needed to know how to apply the learned concepts. Participants 1, 2, and 3 identified that the time needed to understand physics concepts significantly added to the increased time required for tasks due to participants’ diagnosis characteristics. For example, Participant 2 expressed a diagnosis characteristic of being easily distracted that resulted in increased processing time. They shared how physics courses exacerbated this increased processing time due to the time required to think through a problem and that, when insufficient time was given, they had to rely on
memorization: "...for physics 1 my first test I did really badly and it was because I like knew the information, but the way I learn I had to like go through step by step, this is how this goes, this is how this goes and we didn't have enough time for that so I was like really downtrodden and then I found out basically ... I found out you just kind of have to do that thing three times, go over the questions three times and then you'll do well on the test, and I did that, and I was really happy I did well, but I hated it. It was all memorization."

The interaction between diagnosis characteristics and time for processing was especially evident when participants discussed physics assessments. Participants 1 and 2 expressed that the extra test time accommodation was even more critical for success in physics compared to other classes, with one of the biggest benefits being reduced stress and anxiety. For example, Participant 2 identified that extra test time was especially important in their physics course since it reduced the stress they experienced from requiring time to effectively engage with the content: "...things like math and physics, they [extra test time and reduced distraction environment] can be pretty damn important just 'cause like having, knowing I have that extra time makes me, makes my anxiety go down because I'm always that type of person that I'm up there 'till like the last minutes for the thing 'cause it just takes me a while."

Connections to literature.

The time requirement for conceptual understanding being higher than for rote memorization is a well-known characteristic of physics content [68,126,127], but for our
participants this compounded on the increased time they already took to complete tasks compared to their peers.

Recommendations for instructors.

Instructors can support students’ time management by providing class resources in an organized and consolidated format in an online location, such as the course learning management system. Since insufficient time to complete tests was found as a significant barrier, we also encourage teachers to provide ample time for all students to complete assessments, as being able to complete a test or show mastery of a topic in a set amount of time is rarely the learning objective. As testing accommodations are commonly used to address this barrier, we recommend that instructors make statements in class supporting students to use accommodations and collaborate with their institution’s disability services office to provide an equivalent testing experience for all students [128].

Barriers to staying on pace and determining how to study

Participants 1 and 3 expressed that physics courses were uniquely challenging in identifying useful study strategies. For example, Participant 3 identified that the study strategies they employed in other courses were not working in their SCALE-UP physics course and that they needed to develop new methods: “So, I'm like on the second or third week before I'm like, hey, this seems like this is going to be like this... you know like I need to rework my game plan [how they study].” Participants were able to identify the textbook and lecture slides as resources to study from but reported difficulties with
how to make use of these resources. As the course progressed, they began to pick up effective study strategies, such as using an iterative note taking strategy with the textbook or learning how to effectively preview the PowerPoint slides before class. However, these strategies were self-taught and often learned after they had already taken a test or two. When Participant 1 was asked if they came into the class knowing how to engage with the physics textbook, they expressed that they had encountered challenges initially engaging with the textbook, but eventually developed a strategy of reading the text iteratively: "Oh man, I mean at first no. At first when I would read the chapters it was, it was hard because um some of the concepts are … they're not intuitive, you can't really see them happen and that was the biggest challenge at first, but um I think repetition was a key for me, just reading it again."

The interaction between the time needed to develop study strategies and the additional time required to engage with the course material due to diagnosis characteristics resulted in participants falling behind the pace of class. The consequence of this for Participant 3 was that they were not able to fully prepare for the first exam and ended up performing poorly: "...and so the test was for um... chapters one through four, but I had only gotten up to chapter one. So, I did get a low grade on a test, but I knew everything of chapter one and I knew like half...on chapter two."

Participant 3 expressed that instructors could support students with such barriers by spending time at the beginning of the course to give students guidance about engaging with the content: "So having a foundational week would be the most amazing thing, I think, not just for people with focus issues, but students in general just because if you're
having focus issues and attention issues, most likely you probably don't have the best study skills … but if you have a foundation week, the teacher is like … telling you the first week, ‘Hey! we’re not going to jump into the material right now, but I really want you to understand how this class is setup, how you can be successful in this class’…”

**Connections to literature.**

Previous studies have also found that students with disabilities may need more time than their peers to complete tasks [50,129], and we find that physics courses can exacerbate this through a lack of sufficient course-level supports. Instructors can support students to use their time effectively by highlighting cognitive strategies that support learning physics content, such as metacognition [130-132] and critical thinking [133,134].

**Recommendations for instructors.**

Though we may assume students naturally learn study skills in physics courses by engaging with course content, our findings reveal that more intentional practices need to be implemented to scaffold students in developing study skills. Additionally, instructors should recognize that students may be confused about how to interact with their physics textbook. Students may feel that the layout of the textbooks in other STEM courses, such as biology, follows closely along with the course content to be memorized and understood for the exams. On the other hand, in a physics course, students must understand the concepts and be able to apply this understanding to solve problems. Thus, instructors should be explicit about the extent to which reviewing the textbook is
likely to prepare students to demonstrate their understanding of the content and alert students to other study strategies they should be using, such as working out new problems.

**SCALE-UP course supports and barriers**

Participants 2, 3, and 5 enrolled in SCALE-UP-style physics courses, and they expressed that they had never had a course like SCALE-UP before and needed to approach it differently than their other courses.

Participant 2 reported that a benefit to the SCALE-UP-style course was that the emphasis on student engagement allowed the participant autonomy in how they learned the material, which helped with diagnosis characteristics related to difficulties with sustained focus: “But like when I'm in Studio [SCALE-UP], I can space out and come back. They’re still working on the same problem or a little farther, I just kind of figure it out, and I go back and I get like, it happens a lot. Yeah, I'll just be like this is what you're getting confused about. It’s really nice I don’t have to worry about getting distracted.”

However, Participant 5 reported that the unique layout of the classroom combined with students engaging with content had the potential to increase difficulties with attention:

Participant 5: …occasionally like zoning out or being distracted in class…

Interviewer: *Is there anything in class that makes it easier to get distracted?*
Participant 5: ...Um, maybe potentially the way the class is arranged. We're just kind of around circular tables so like everywhere you look there might be like hands waving or things...But, um, and we have the two like, uh, boards on either side, so as long as I like focus on one of those and try to control myself, I'll be fine…”

From Participant 2, we identify that the logistical structure of a SCALE-UP course supports students with ADHD by providing autonomy and allowing space for being distracted. However, Participant 5 reports that the physical layout of a SCALE-UP course can result in barriers to learning due to increased distractions.

As discussed previously, Participant 3 expressed barriers to staying on pace with the class due to not knowing how to effectively engage with physics content. These barriers were compounded by the unique structure of the SCALE-UP course. Participant 3 shared how they had never been in a SCALE-UP course before and that they had to not only learn the content, but also how to learn the content in a SCALE-UP-style course: "...but I think the hardest part was like not knowing how to prepare for the class and like not knowing how to study...I've never been in a class like this [SCALE-UP class], so it was kind of different…[explanation of SCALE-UP structure]...you have to like kind of learn first and then when you go to the class like if you have questions and stuff, this is where you need to get those straightened out. Um... So I wish I would've known how to prepare for the class before..."
Connections to literature.

Significant work has been done to show that SCALE-UP courses provide increased learning when averaging across a whole class [102]. However, we find that SCALE-UP courses introduce barriers for students with ADHD, which builds evidence for the importance of considering the variability of learners in a course and not defaulting to supporting the “average” student. It is important for researchers to pay attention to variation, or lack of variation, across the learners we include in our research. For example, a recent review of physics education research found a lack of diversity in the populations of students included in research and a disproportionate amount of students included who have a higher than average math preparation [135].

Recommendations for instructors.

Though the barriers which emerge from learning in the new context of SCALE-UP may be heightened for students with disabilities, SCALE-UP is likely a new way to learn for many students. Therefore, we can support all students in SCALE-UP courses by implementing practices that teach students how to effectively engage with SCALE-UP courses, such as practices students can use to prepare outside of class and how to effectively engage with content in class. An example of how instructors can support students is given by Participant 3 who expressed an interest in a “preparation week” at the beginning of the course focused on developing skills for effectively engaging with both the SCALE-UP course and the physics content.
Summary

In this study, we found that students with ADHD reported both challenging and beneficial diagnosis characteristics. By understanding their diagnosis, participants were able to identify what they needed to succeed, but this understanding could also lead to negative self-perceptions. Some students shifted from negative to positive self-perceptions regarding their diagnosis characteristics by learning more about their diagnosis characteristics and implementing practices and strategies in response. Participants’ implemented strategies could be ineffective when courses did not support their use, and time for tests was reported as a significant course barrier. Extra test time could alleviate time constraints, but this accommodation could also be viewed by participants and peers as giving an “unfair” advantage. Participants reported that they were unable to use existing study strategies in physics courses due to the requirement for conceptual understanding. Participants’ physics courses did not support students in developing these skills at the beginning of the course, so participants reported barriers to staying on pace with the course. Tests in physics courses were also a challenge due to the increased time needed to critically reason through problems, and participants reported that the allotted time for tests was insufficient and therefore a barrier to participants expressing their understanding. SCALE-UP courses benefitted students through the autonomy given but could also introduce barriers from increased distractions.

By using a social relational perspective of disability, we found how diagnosis characteristics interacted with course structures to result in participants being prevented
from effectively learning and expressing understanding of course content. This contrasts with a medical model aligned analysis which would instead focus on how students need to individually improve to succeed. Physics courses presented similar, but heightened barriers compared to non-STEM courses, specifically in the areas of developing study skills, keeping pace with the course, completing tests in the allotted time, and knowing how to prepare and engage with the SCALE-UP course style. As represented in Fig 1, students found that understanding their diagnosis characteristics contextualized their experiences and empowered the students to select and implement useful study strategies. However, the usefulness of the study strategies varied both between physics and non-physics courses and could be supported or disabled by instructor-level practices.

Instructors make a choice, either examined and intentional or unexamined and unintentional, about where they situate disability: as a deficit within the individual (aligned with the medical model of disability) or as an interaction between an individual and social structures (aligned with the social model of disability). We argue that students are better supported by instructors who intentionally choose to conceptualize disability as situated in the interaction between the individual and instructional structures and actively work to remove barriers and add supports for all students [118]. The goal of proactively designing a course with accessible practices moves us away from the idea that instructors need to know their student’s diagnoses to support them [136]. Instead of saying it is the students who need to change, instructors can focus on what they can do to make their course more inclusive and supportive for all students. This shift not only
makes learning more inclusive, but it also moves us away from a perspective where
disability is seen as a source of inadequacy or personal fault. We have provided some
recommendations in this paper for inclusive practices and strategies, and further STEM
specific recommendations can be found in the following citations [19,137-140].

Limitations and recommendations for future research

Due to the significant lack of research, it is critical that researchers continue to
investigate the experiences of students with disabilities in STEM courses. Our findings
reveal that students with disabilities experience disabling course barriers, however this
work only investigates the experiences of students with ADHD at one specific four-year
public university. Future research should investigate the experiences of students with
varied diagnoses who are enrolled at other institutions. Some specific research
questions which can be investigated include the effects of accommodation use on
student’s stress and knowledge retention, positive qualities individuals associate with
their disability, and the experiences of students with disabilities in interactive learning
courses including but not limited to SCALE-UP courses.

To support the dissemination of accessible practices and strategies to instructors
and departments, we recommend researchers investigate ableism in physics
departments and effective strategies for combating it. This research is critical as
instructors and departments may not be willing to adopt accessible or inclusive
practices. Previous research has identified that some postsecondary instructors are
resistant to providing accommodations [52,56,59], but we are unaware of any published
work which has investigated the culture of the physics community towards accessibility and disability.
CHAPTER 6: DISABLING BARRIERS EXPERIENCED BY STUDENTS WITH DIAGNOSES CHARACTERIZED BY VARIATION IN EXECUTIVE FUNCTIONS IN POSTSECONDARY STEM COURSES

Introduction

Students with disabilities are enrolling in postsecondary institutions and choosing STEM majors at equivalent rates to students without disabilities [2,38,39]. However, recent work has begun to identify disabling barriers for students with disabilities in postsecondary STEM courses [65,94,95,139,140] and a lack of instructor knowledge across all disciplines regarding how to support students with disabilities [3-5]. We define disabling barriers as course structures which prevent students with disabilities from equal access to and participation with the course. As educators, we have the responsibility to support all students in our courses. Disabling course structures create barriers to participation for some students. Furthermore, disabling barriers can be in potential violation of legislation which prohibits intentional or unintentional discrimination on the basis of disability [6-10].

By using a social relational perspective of disability as our lens, we acknowledge the differences across individuals, and emphasize that students can have disabling experiences due to malleable course structures negatively interacting with the variations in learners’ needs, interests, and abilities [21]. By identifying disabling barriers, instructors can proactively design their courses in a way which supports future students with disabilities, without needing specific knowledge of the students’ disability diagnoses. However, there is a lack of research investigating the disabling barriers present in postsecondary STEM contexts.
In this study, we address this lack of research by interviewing students with disabilities to explore the disabling and supportive experiences participants had in postsecondary STEM contexts at a single institution. We specifically recruited students who identified with diagnoses which were characterized by variations in executive functions (i.e., cognitive processes such as planning, strategy development, and memory) as these diagnoses are often non-apparent and can be under-supported in STEM contexts. We used interpretative phenomenological analysis to identify participants’ diagnosis characteristics and how course structures interacted with diagnosis characteristics to result in positive or negative experiences. Based on these interactions, we contextualize the findings within previous research and provide recommendations for practices instructors can implement in STEM courses to support students with diagnoses characterized by variations in executive functions.

Frameworks utilized

The design of this study is very similar to study 1 and therefore utilizes the same framework, i.e., social relational perspective, for the same reasons. We do not reference UDL in the methods or findings but do refer to UDL in the summary and implications section to provide additional framing for how to identify and implement inclusive practices.

Research questions

Due to the lack of research regarding the experiences of students with disabilities in postsecondary STEM courses, we investigated the supportive and disabling course
features experienced by students who identified with diagnoses associated with variations in executive function in introductory physics courses and introductory chemistry labs. Our first research question is motivated by the social relational perspective's definition of disability as the interaction between diagnosis characteristics and course structures.

1. How do diagnosis characteristics experienced by students who identify with diagnoses associated with variations in executive function interact with STEM and non-STEM postsecondary courses to result in students being supported or disabled?

Our second research question investigates how the community around students with diagnoses characterized by variations in executive functions results in positive or negative experiences. This investigation is motivated by the social relational perspective's recognition that impairments are understood socially and that individuals are a part of social structures.

2. How do others respond when students who identify with diagnoses associated with variations in executive function disclose their diagnosis or accommodation use, and how does others' response affect these students' course experiences?
Methods

Analytical Framework: Interpretative Phenomenological Analysis

We chose to use interviews as our data source because we needed rich data to identify diagnosis characteristics and how they interacted with course structures. We analyzed the verbatim transcripts of these interviews using interpretative phenomenological analysis (IPA), a framework which is used to investigate the lived experiences an individual has regarding some phenomenon [96]. In this case, we employed IPA to investigate students with disabilities’ experiences in physics and chemistry courses. The investigation was done by interpreting the words participants shared about these experiences [97]. This interpretation consists of two levels: first, the participant is making sense of their experiences; second, the researcher is making sense of how the participant made sense of their experience. The researcher also has a role in making connections across participants’ statements and in relation to previous research [96]. To support the in-depth investigation done via the IPA process, Smith and Osborn (2003) recommend small sample sizes; a recommendation for new users of IPA is six individuals [96].

We chose IPA because it aligns with our goals of investigating the lived experiences of students with disabilities in college, specifically in STEM courses. In alignment with the IPA framework, we acknowledge our role as active interpreters of participants’ words. Our research questions and framework also necessitate an analysis which supports making connections within a participant’s transcript, namely participants’ identified diagnosis characteristics and the course structures participants experienced.
We also recognize that significant work has been done regarding the experiences of students with disabilities, and the IPA framework supports the generation of connections between our findings and previous research.

Recruitment, participants, and context

Participants were recruited from introductory chemistry and physics courses at a large southeastern research-intensive university in the United States. To recruit students with disabilities, emails were sent on our behalf by the university’s disability services office and by instructors currently teaching the target courses. Recruited participants took part in a one-hour semi-structured interview at the beginning and end of that semester, except for two participants who only chose to participate in the interview at the beginning of the semester. Our interview protocol included questions about the participant’s experiences in college courses as a student with a disability, with some questions focusing specifically on their current introductory physics or chemistry course. A limitation of the interview protocol is that it was not initially designed to identify a participants’ diagnosis characteristics. Consequently, only two questions had specific prompts regarding the participant’s diagnosis(es) and how it interacted with their courses. The pre and post interview protocol used can be found in Appendix A and Appendix B respectively. The entire transcript was still analyzed as participants described experiences relevant to our research questions throughout the interview.

A total of thirty-one participants were recruited and participated in pre and post interviews. In alignment with IPA framework recommendations, we chose a subset of
our participants to support depth versus generalization. We narrowed our sample for analysis by first removing participants who identified solely with ADHD, since we included these participants in a separate study [65]. Next, we removed participants who did not identify with a diagnosis that is characterized by variations in executive functions. Examples of some of the diagnoses not included in this analysis are diabetes and a visual impairment. Diagnoses and the age diagnosed were documented through an optional survey given to participants, and we report the exact wording participants provided. Participant 6 and 7 did not complete this survey and so information from the interview was used to document their diagnosis and age diagnosed. Participant 6 did not disclose their diagnosis age during the interview, so we report their age diagnosed as “N/A”.

As mentioned previously, participants were recruited from introductory physics and chemistry courses. A unique characteristic of the physics courses is that students have a choice between traditional lecture and SCALE-UP courses. The physical structure of the SCALE-UP course includes eleven round tables which can each seat nine students. This layout is chosen in alignment with the SCALE-UP model’s goal of having a combined lecture/lab course where the majority of class time is spent on students engaging with course content in a group setting [102]. Previous research has found the SCALE-UP model to support students from underrepresented ethnic or gendered populations [102], however these investigations did not consider students with disabilities. Our sample for analysis included seven participants, as described in Table 4.
Table 4: Participants’ diagnosis(es), age diagnosed, and the STEM course they were enrolled in at the time of the interview

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Diagnosis (in participant's words)</th>
<th>Age Diagnosed</th>
<th>STEM course enrolled in during data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant 1</td>
<td>Specific learning disability (dyslexia)</td>
<td>8</td>
<td>Second semester physics (calculus-based, lecture)</td>
</tr>
<tr>
<td>Participant 2</td>
<td>Bipolar disorder, anxiety, clinical depression</td>
<td>12</td>
<td>Second semester general chemistry (lecture)</td>
</tr>
<tr>
<td>Participant 3</td>
<td>Asperger’s, depression, migraines, sleep apnea, driving anxiety</td>
<td>12</td>
<td>First semester physics (calculus-based, lecture)</td>
</tr>
<tr>
<td>Participant 4</td>
<td>ADHD (inattentive type) and processing disorder</td>
<td>15</td>
<td>First semester physics (algebra-based, SCALE-UP)</td>
</tr>
<tr>
<td>Participant 5</td>
<td>Dysthymia and generalized anxiety</td>
<td>15</td>
<td>Second semester general chemistry (lecture)</td>
</tr>
<tr>
<td>Participant 6</td>
<td>Autism</td>
<td>N/A</td>
<td>Second semester general chemistry (lecture)</td>
</tr>
<tr>
<td>Participant 7</td>
<td>Severe anxiety</td>
<td>During college</td>
<td>Second semester general chemistry (lab)</td>
</tr>
</tbody>
</table>

*Analysis process, positionality, and building trustworthy interpretations*

Analyses and findings are influenced not only by the selected methods, but also by the people involved in the analysis process. Because we are researchers trying to make sense of others’ experiences, there is some level of interpretation involved, and our interpretations will be affected by our backgrounds and previous knowledge.

Researchers can also hold varying levels of power, and the variance in power can lead...
to some researcher’s interpretations being more highly valued than other researchers’ interpretations. In this section we describe some of the positionality of the researchers who conducted the analysis, how analysis was performed, how we chose to account for our prior knowledge and experiences, and how we sought to account for power differentials within the analysis team.

The interviews were conducted solely by the lead researcher, but the analysis of the interviews was conducted by three researchers. The three researchers involved in analysis included a spectrum of dis/ability identities, including non-disabled, diagnosed with a disability, and undiagnosed but identifying with characteristics of a disability. Two of the three researchers were undergraduate students and one was a graduate student. Our fields of study varied as well and included physics and biomedical sciences. We highly valued having researchers who identified as students with disabilities as we believe their experiences with having a disability in a postsecondary setting supported identifying and interpreting participants’ statements. However, we did not assume that these researchers’ experiences would be the same as the participants, and so increased weight was not given to these researchers’ interpretations. We sought to give every researcher’s perspectives equal weight by having all researchers give their input after any interpretation was presented.

Our analysis followed the procedures recommended by Smith and Osborn (2004) for using IPA [141]. First, researchers independently read through a participants’ pre and post transcript to build familiarity with the ideas and experiences of the participant. We then met to go through the participant’s transcripts (pre and post) line by line,
identifying where the participant discussed their diagnosis characteristics or how their diagnosis characteristics interacted with their college courses. To identify these statements, each researcher read through the transcript at their own pace and notified the other researchers when they identified a relevant statement. We then discussed the statement to co-generate a “comment” which summarized the participant’s diagnosis characteristic or how a diagnosis characteristic interacted with course structures. After the pre and post interviews for the participant were analyzed for these statements, we went through the comments to generate themes, which is succinct wording for the comments which aims “… to capture the essential quality of what was found in the text” (p. 68) [141]. Following this, we worked independently to generate a paragraph which summarized the main ideas and experiences expressed within a participant’s themes. We then met to discuss our summaries and reach consensus on the most salient ideas and experiences expressed by each participant. These salient ideas and experiences were organized into a list referred to as the participants’ superordinate themes.

Because each participant has unique experiences and interactions, we chose to analyze each participant’s transcripts independently, without using the findings from one participant to motivate findings for another participant.

The last step involved us meeting to generate a final list of superordinate themes which encapsulated the main points shared across all participants and identified which participant expressed which themes. Though we recognize that the experiences will vary across students with different diagnoses, our goal in this analysis was to identify common challenges and successes for students with diagnoses characterized by
variations in executive functions. This aligns with Smiths (1999) recommendations that IPA findings should “…enable us to see patterns across case studies while still recognizing the particularities of the individual lives from which those patterns emerge” (p. 424) [142]. In alignment with recommendations given by Smith (1999), each participant was represented in at least one of these superordinate themes and multiple participants were represented within each superordinate theme [143].

I trained the other two researchers in using IPA. We practiced implementing the IPA process on a transcript for a participant not included in this analysis; training emphasized identifying statements relevant to our research questions, paraphrasing relevant statements, and bracketing our assumptions about a participant’s experiences concerning a diagnosis.

We recognize that our positionalities had an effect on our interpretations, however by acknowledging these aspects of our identity we enacted practices to support adhering to our frameworks and methodology [98,99]. One key methodological decision was that we desired to center the participants’ experiences and not assume that our experiences were the same as participants. Therefore, we intentionally aimed to set aside our own experiences and perspectives when interpreting participants’ statements. This process of avoiding our own assumptions is referred to as “bracketing” and is recommended by the IPA framework as it supports a participant oriented analysis [96]. The variety of researchers involved in analysis supported bracketing as the variety of perspectives and experiences encouraged different interpretations.
We also recognized the power dynamics which occurred between graduate and undergraduate students could result in the graduate student’s interpretations being more highly valued. The consequences of this power dynamic oppose the goal of all researchers’ interpretations being equally valued and so we enacted practices which sought to reduce the increased value given to the graduate students’ interpretations. Throughout the analysis process, repeated statements and encouragement were given regarding the desire to hear every researcher’s interpretations. Repeated requests for researchers to defend and advocate for their interpretations were also given. Differing interpretations occurred often and when disagreements occurred, we discussed the interpretation to seek consensus among all researchers, with the understanding that we could report multiple interpretations if we were unable to reach consensus; however, the team reached consensus for the findings presented in this paper. To support undergraduate researchers’ comfort in defending their interpretations, the graduate student engaged in many discussions about topics unrelated to the research as this helped to build a healthy rapport among the researchers and established a more casual culture. We recognize that even with these practices in place, power imbalances can still exist and have meaningful effects [103]. Within the context of this study, this means that the graduate student’s interpretations may have been more accepted.
Findings and discussion

In our analysis we found five superordinate themes across participants: 1) students recognize supportive course practices, 2) accommodations were highly valued and frequently used, 3) STEM courses introduced barriers to keeping pace, 4) STEM courses cause increased anxiety, and 5) positive and negative interactions with others regarding disability. The first four superordinate themes address research question 1, which focuses on the interactions between diagnosis characteristics and STEM and non-STEM course structures. The fifth superordinate theme addresses research question 2, which focuses on the interactions students with disabilities have with peers, instructors, and disability services officials. The superordinate themes along with the participants who expressed alignment with the themes are shown in table 5.
Table 5. Superordinate themes identified along with which participants expressed alignment with the themes. Superordinate themes are organized under the research questions they address.

<table>
<thead>
<tr>
<th>Superordinate themes</th>
<th>Participant</th>
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<td>Research question 1: How do diagnosis characteristics experienced by students who identify with diagnoses associated with variations in executive function interact with STEM and non-STEM postsecondary courses to result in students being supported or disabled?</td>
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<td>1. Students recognize supportive course practices</td>
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<td>2. Accommodations were highly valued and frequently used</td>
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<td>3. STEM courses introduced barriers to keeping pace</td>
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<td>4. STEM courses cause increased anxiety</td>
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<td>Research question 2: How do others respond when students who identify with diagnoses associated with variations in executive function disclose their diagnosis or accommodation use, and how does others’ response affect these students’ course experiences?</td>
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<td>5. Positive and negative interactions with others</td>
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These superordinate themes are connected, with themes 1) and 2) highlighting supportive practices, themes 3) and 4) identifying how the lack of these supports result in disabling experiences, and theme 5) revealing how participants interactions with others influence whether experiences are positive or negative. Figure 2 gives a visual of the interaction between these themes.
Findings will be presented by first expressing how students interpreted their experiences and then framing students’ experiences using a social relational lens. We then contextualize participants experiences with findings from previous research, including our study investigating the experiences of students with ADHD, and provide recommendations for how instructors can support students with diagnoses associated with variations in executive function. By first presenting participants experiences, we aim to center their experiences. The latter interpretive piece is done in alignment with IPA, specifically that researchers are active interpreters who have context outside of what participants may be aware of, such as the literature base and the experiences of other participants.
Students recognize supportive course practices

Participant 1, 3, 4, and 5 reported experiences which, when viewed through a social relational perspective, revealed course structures that supported or disabled participants from using practices which were developed in response to participants’ diagnosis characteristics. The experiences reported in this section were not all specific to STEM courses, though when these supports were not provided it often resulted in more negative consequences in STEM courses. Other participants also identified beneficial practices, but these were not explicitly tied to diagnosis characteristics.

Participant 1 identified with having dyslexia, and they shared that one diagnosis characteristic they experienced was a challenge reading long sections of text. Often the participant worked around this challenge by self-identifying more succinct resources: “Yeah, also it's [online resource] usually no more than, like, two to three lines explaining the individual concept and looking for it rather than searching through a chapter and a half to find one little, the one little bit of information I need to understand it.” Participant 1 shared how their physics instructor supported the use of this study technique by providing a formula sheet in advance, allowing Participant 1 to easily identify the information they needed to know: “So, I'll look at the formula sheet and 'yup I know what that's doing, I know what it's for and how to use it. Alright. I know that one, I know that one, I know that one. Hey Google, what does that mean? I know that one. I know that one.'” Through a social relational perspective, we see that the instructional practice of providing a succinct presentation of information supported the student’s avoidance of large blocks of text.
Participant 3 identified with multiple diagnoses (i.e., Asperger’s and depression) which resulted in diagnosis characteristics including challenges with keeping track of tasks. In response to this, they relied heavily on the learning management system (LMS) because it allowed them to monitor assignments and due dates for all their courses and to access course content. Participant 3 shared how they were best supported in managing tasks when course content and assignment information were all posted at the beginning of the semester: “...like just having, just having everything collapsed into a single place, like where if I take care of that one thing I have everything I need and I’m just good to go...” When this information was not provided in the LMS one course, it could affect Participant 4’s other courses. Participant 3 gave an example where not having access to content in their calculus course resulted in a rush to study, causing them to miss one of their physics classes: “I missed today’s class. I missed Wednesday’s class because of the calculus class, of the calculus exam. I was scrambling to study for it the last week because I didn’t have access to everything.” The lack of course content outside of class disabled Participant 3 from effective engagement since Participant 3 relied on organized information to stay up to date with tasks.

Participant 4 and Participant 5 reported significantly different diagnosis characteristics, but both participants reported how their diagnosis characteristics interacted with instructors’ group formation strategies to result in varying levels of comfort. For Participant 4, their diagnosis characteristic of requiring increased time to process content resulted in discomfort when working with others as they felt uncomfortable sharing this diagnosis characteristic with others: “…because of having
like, like slower processing—...Then I don't want to have someone that's like, rushing and I don't wanna feel I'm not helpful...but it's hard for, when I'm with people that I don't know...because like, I don't wanna explain to a stranger...” Participant 4 was supported in their chemistry lab when they could work in a group with a supportive friend: “...last semester for Chem lab, my friend and I were together, like, we were lab partners the whole time- And like, she knows how I am. And like, but she was able to work with me...” Participant 5 shared how their diagnosis characteristic of having anxiety in social settings could result in them not having peers to work with inside or outside of class. Participant 5 shared how their AP chemistry instructor in high school supported them by placing them in a study group with other peers in their class who also didn't have a study group: “I think that one year, AP Chemistry, ... after my teacher found out how much I was freaking out, she kind of, like, arranged a study group with me and, like, three other girls that didn't have a study group yet so I had them, but most of the time, in science classes, I don't really have somebody to go to, so I got lucky.” We find that how instructors formed groups could result in increased or decreased comfort and support, due to interactions with diagnosis characteristics that could result in social anxiety or requiring more time to process information than peers.

Summary and connections to literature.

Instructors lack awareness of how to make their courses more inclusive [3-5,75-77] and the lack of research on inclusivity in STEM courses leaves instructors with few resources for how to implement more inclusive practices [23,137]. However, we find that
students with disabilities know the course structures necessary for their success and therefore the students in an instructor’s course can support the identification of how to make courses more inclusive. Though diagnosis characteristics vary across individuals with disabilities, we find the participants in this study and our study focused on students with ADHD [65] implemented practices which hinge on specific course structures including access to course content outside of class and supports for forming effective groups. Examples of practices from our study on students with ADHD include using organizers and study breaks, and the course structures which disabled students from these practices include a lack of organization regarding course content and a lack of breaks within class sessions respectively [65]. The specific course structures which disabled or supported students varies across this study and the study about students with ADHD, revealing that students with differing diagnoses may need differing course structures to be supported.

**Recommendations to instructors.**

Since students can identify course aspects that are beneficial or detrimental for their learning, we recommend that instructors survey students in their classes to identify supportive or detrimental course-level practices that the instructor could implement. While it will not be possible to implement everything students suggest, this feedback can provide instructors with some ideas for how their course can be made more inclusive.
Accommodations were highly valued and frequently used

Every participant reported the use of accommodations provided by the university’s disability service office in response to course features which were not fully inclusive and/or accessible. Individual participants discussed using a variety of accommodations (e.g., extra test time, reduced distraction environments, note taking services, audio recording software, the ability to retake missed exams), which they described as critical to their success, especially in STEM courses.

Different accommodations were used by participants due to course structures not accommodating challenges which arose from specific diagnosis characteristics. For example, Participant 5 reported a diagnosis characteristic of being prone to episodes of severe anxiety which could result in being unable to leave their home and therefore missing an in-class test: “'cause it doesn't happen often that I miss a test... but there's always a worst case scenario that I start spiraling and I might not be able to, like, leave my hou- like my dorm.” Since the courses taken by this individual didn’t have built-in flexibility regarding when tests could be taken, Participant 5 had access to an accommodation which allowed them to retake a test should one of these episodes of severe anxiety occur. Participant 5 shared that courses could trigger these episodes of severe anxiety and that their high school chemistry course was a significant source of anxiety: “I took one chemistry class in high school...I took the AP one-... That's actually how I got diagnosed with anxiety. (laughs) Because I was freaking out so much about that class, my mom finally got worried. (laughs).” These findings show that course
structures lead to disabling experiences which participants seek to remedy through accommodations.

Multiple participants (1, 3, 4, 6 and 7) reported using the extra test time accommodation, though the interactions between diagnosis characteristics and course structures that resulted in the need for extra test time varied across participants. Some participants (1, 6, and 7) explicitly reported primarily needing extra test time accommodations in STEM courses, whereas others (Participants 3 and 4) made use of the extra test time in every course. Participant 6 reported the diagnosis characteristic of slower processing speed that interacted with timed in-class exams and resulted in their need to use the extra test time accommodation in their postsecondary chemistry course: “Like, I know when to use it [extra test time accommodation]….something about the combination of um, math in there [introductory chemistry] and um, just the topics that were in question I just, I needed to be able to slow down.”

Participant 4 reported diagnosis characteristics such as challenges with attention and social anxiety and that these were exacerbated by course structures which required that students take tests in crowded lecture halls. The interaction between these diagnosis characteristics and crowded lecture halls resulted in a disabling barrier to effectively engaging with the test. In response, Participant 4 sought the extra test time and separate testing environment accommodations for every course and reported that these accommodations allowed them to effectively engage with the test: “…I don’t feel rushed, I don’t have a million, like, eyes near me, like people walking around.”
Participants 2 and 5 did not use the extra test time accommodation, but for different reasons. Participant 5 was given access to the extra test time accommodation but did not use it because they did not think it was necessary for their success. However, Participant 2 did not use extra test time because they were not given access to it by the disability services office, even though Participant 2 expressly desired the extra test time accommodation due to a diagnosis characteristic of being prone to episodes of severe anxiety: "I went to [the disability services office] and the person I talked to really didn't help me at all, um... all that he said he would give me was being allowed to take my test in a different space...but what I was really hoping was that he was going to allow me to have extended time. Because that's like my main issue and it's not like I'm not studying...it has a lot to do with my ...

[removed] anxiety issues that I deal with just regularly..." Participant 2 later reported that this desire for extra test time was especially critical for their success in their chemistry course. The discussion between Participant 2 and the disability services official will be further explored in the “Interactions with others” section due to its significant negative consequence for Participant 2.

Connections to literature.

Many previous studies have identified the benefits that accommodations have for students with disabilities [50-52,59], and our findings corroborate this. A literature review

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3 We have chosen to replace a participant word because the word is generally considered ableist. We have found the reference at https://www.autistichoya.com/p/ableist-words-and-terms-to-avoid.html useful to our thinking about abelist terms and references.
by Ofiesh (2007) found that accommodations supported students with learning disabilities in STEM contexts [144]. Our results build on this finding by suggesting that accommodations are even more important in STEM courses than non-STEM courses for students from a variety of additional executive function-related diagnoses other than learning disabilities. The increased requirement for accommodations in STEM courses is due to interactions between a variety of diagnosis characteristics and a variety of qualities associated with STEM courses, including insufficient provided time on assessments and the requirement to take assessments in crowded areas. In our analysis of the experiences of students with ADHD in STEM [65], we also found that extra test time was more important in STEM courses, and our current findings extend this experience beyond students with ADHD.

**Recommendations for instructors.**

Due to students’ increased need for accommodations in STEM courses, we recommend two practices for instructors. In the short term, instructors should encourage students to make use of the accommodations that support students’ success. Instructors’ statements supporting accommodation use are important because previous studies have found that students may perceive instructors to be anti-accommodations, which can lead students to choose not to use accommodations [52,58,145]. Examples of positive practices include making whole class announcements which encourage students to use accommodations and/or responding to accommodation request emails with both affirmation and asking if there are any other ways the student would like to be
supported. In all cases, instructors should be careful to conduct communication in a way which does not jeopardize students’ confidentiality regarding accommodation use. For example, if students ask to discuss their accommodations, instructors should offer to have the conversation in a private setting, such as through email or in the instructor’s office.

In the longer term, we encourage instructors to critically reflect on the amount of time they provide to all students to complete tests. By reducing the time constraint for all students (e.g., offering longer time for the test or creating shorter assessments), instructors can provide a testing environment where students who need extra test time are supported within existing course structures, versus students needing to pursue external supports which can result in the disclosure of the student’s disability identity and feelings of being othered [52,56].

**STEM courses introduced barriers to keeping pace**

Several participants (3, 4, 6 and 7) reported barriers to keeping pace in their STEM courses due to the requirement to listen and write notes simultaneously and the lack of guidance for how to engage with content outside of class.

One main challenge participants discussed about STEM courses was receiving too much information at once during lecture. This challenge became a barrier for Participants 3, 4, and 6 when they were expected to write down everything they needed in class while the instructor was simultaneously talking. For example, Participant 4 reported a diagnosis characteristic of requiring an increased time to process
information, and the requirement to write and listen simultaneously disabled the participant from having sufficient time to process information: “…I have a processing disorder, so it takes me longer to understand certain things- And like, writing stuff down, like it's hard for me, I know some people get it right away, I'm like, I'm like ugh.” For Participant 4, the course barriers of having to write and listen simultaneously disabled them from being prepared for their first biology test: “…what are we supposed to be writing, because you had so much coverage for one test… biology last semester, Bio Two, it was nine chapters for one test and I'm like, I don't even know what to study.” Participants expressed that having access to course content outside of class could alleviate this barrier as the resources reduced the amount of writing which need to be done.

Participants 3, 4, 6, and 7 reported that courses did not provide access to resources which supported their learning outside of class. As identified in the previous section, this disabled students such that they had to write and listen simultaneously in class. This also disabled students from effectively studying outside of class and staying on pace with the course. Participant 6 identified with a diagnosis characteristic of having challenges processing auditory information (i.e., increased time needed to process auditory information compared to peers) and they expressed how lecture slides online allowed them to learn outside of class: “I've only now just started trying to keep up more with the PowerPoints on my own because I was just trying to go straight from what he was doing. But I just couldn't keep up that way.” Participant 7 identified with severe anxiety, and reported that the lack of access to course content outside of their chemistry
class compounded with a lack of in course support to result in barriers effectively studying for the course. Participant 7 shared how they were unable to effectively study using the recommended book or notes due to a lack of examples from the instructor about how to work through problems: “…we would go to the back of the book, there was no process⁴ [worked out solution]. So, we had no idea how someone would get there… he [the instructor] wouldn't give us an explanation at all, how he got there. And he wouldn't provide like, there was no similar examples in the, in the classroom either. And he doesn't even have PowerPoints. He would just write on the, like on the doc cam.” Participant 7 reported that the instructor started providing more practice problems in class and uploading lecture slides online, but these practices occurred after Participant 7 had already experienced severe anxiety due to these barriers.

Connections to literature.

Traditional lecture style classes have been shown to result in challenges for students to identify and process important information in class [146]. STEM courses compound this challenge due to increased challenges arising from the requirement for conceptual understanding versus rote memorization [68,147]. We find that the challenges of identifying and processing important conceptual information resulted in barriers for students with diagnoses association with variations in executive function in STEM courses when students were expected to learn and record all necessary content

⁴ STEM textbooks traditionally include solutions to practice problems at the end of the book. Solutions are usually just numerical answers and do not include the worked out process.
while in class and/or when students were not provided resources to effectively study outside of class. Students with ADHD also reported challenges keeping pace with physics courses, although the barriers arose due to interactions with different diagnosis characteristics, specifically requiring increased time to study and not being supported in using this time effectively [65].

**Recommendations for instructors.**

In response to barriers to taking notes in class, we recommend instructors provide digital access to content presented in class via, for example, their learning management system or webpage. Providing this content online before class is ideal as it allows students to preview content before class or download/print the slides for note-taking purposes. Note that not all digital content is equally accessible, and considerations should be made for whether visuals have alternative text and whether the provided file lets students edit formatting such as font size and color.

Another support which instructors could provide is study guides which outline the main concepts and examples of problems to practice the main concepts. Participant 5 reported that study guides were helpful when they highlighted beneficial practice problems: “*My chemistry teacher gives us, like, these study guides. They’re basically just questions that we can do in the textbook, which definitely helped because last semester I just had to figure out which [questions] would be best to study- for the class. So, things like that work ’cause if you’re gonna assign us a textbook, you might as well show us how to use it.*”
To stay on pace in a course, students need to have supports which allow them to identify if they are achieving expected learning goals at the appropriate times. To support students in monitoring their pacing and to identify areas where they are encountering challenges, Participant 4 recommends that instructors provide smaller, more frequent assessments: “…so having more frequent kind of... I'm gonna use the word ‘assessments’, but just something. Yeah, something that let you try it out and be like, ‘Yep, got it.’ Or, ‘Nope, don't got it.’” This can be seen as a form of instructional scaffolding, a practice which supports students in problem-centered instruction [148].

**STEM courses cause increased anxiety**

Participants 2, 3, 5, 6, and 7 all reported that aspects of their STEM courses resulted in episodes of severe anxiety which could lead to barriers effectively preparing for or engaging with course assessments. Some of these participants reported how course structures could exacerbate or alleviate participants’ social anxiety.

Participants 5 and 7 were both diagnosed with anxiety following severe episodes of anxiety experienced in chemistry courses, either in high school or university. Participant 7 shared an experience in their postsecondary chemistry class which resulted in pursuing a diagnosis, specifically how preparing for their chemistry test resulted in a debilitating anxiety attack: "It was traumatizing…Before one exam, I had such, like I had never ... I've had like anxiety attacks, but I usually calm myself down. But that was the first time that I got an anxiety attack so bad that I just had to go to bed. Like, I just, I was crying, bawling. And a ton of anxiety, and I just had to go to bed
because I wasn't getting anything.” Participant 7 later explained that the source of their anxiety in this case was due to the participant being unable to effectively study and prepare for assessments: “…in chem 2, he [the instructor] would tell us like, he told us like first day like this is how you need to study, which I did, but it did not work out…” As mentioned in the section “Accommodations were highly valued and used”, Participant 5 experienced increased episodes of anxiety in their high school chemistry course and this led to Participant 5 being diagnosed with anxiety. Participant 5 expressed that the episodes of anxiety often occurred before assessments, but did not explicitly state what it was about the assessments or course that triggered the anxiety: “I mean, it wasn’t the class structure …I was very worried about that test…I didn't sleep very well for, like, a week- and I felt, like, that night, I studied way longer than I should have and, like, it was all just coming together and then, like, exploded.”

Like Participant 7, every participant who reported episodes of severe anxiety reported that these occurred most often before or during assessments. Also, like Participant 7, the reasons for the anxiety were feelings of not being prepared and/or not knowing how to prepare for the assessment. Course structures we previously discussed in this paper, such as a lack of access to course content online and the requirement to take notes and listen simultaneously, also interacted with students’ anxiety to create barriers. Participant 3 shared that the consequences of these barriers were extremely debilitating for them, and that barriers which would cause anxiety for someone else could cause severe anxiety for Participant 3: “Everything that would give someone else anxiety is like maybe four times greater. Greater not just four times of…If I have a lot of
anxiety I'm pretty much on autopilot and I'm just like, I'm not really able to function.”

Students have the same diagnosis characteristic of severe anxiety in all course settings, but this diagnosis characteristic interacted with the lack of supports for assessment preparation in STEM courses, triggering the episodes of anxiety and disabling students from effectively engaging with assessments.

Participants 2, 5, and 7 reported a diagnosis characteristic of being prone to social anxiety and large courses were a barrier for these participants as the large numbers of people could trigger their social anxiety. Participant 5 identified that a specific challenge in these settings was developing networks with peers: "With my stats class, I also didn't know anybody, so I couldn't borrow notes from anybody." When asked whether courses making groups helped, Participant 5 gave an example of their theater survey class where being placed in groups helped them begin building relationships with peers: “…in my theater survey class, she [instructor] put us into groups pretty early on and that definitely did help 'cause then we all started talking to each other.”

Connections to literature.

Anxiety is a common challenge for college students, with 26% of undergraduate students reporting that their course performance is affected by anxiety [149]. Within STEM contexts, Cooper et al. (2020) found that various aspects of STEM courses, such as the hostile environments within courses or the use of introductory courses as “weed-out” courses, can lead to increased levels of anxiety [150]. From participants’
experiences, we find that STEM courses can be a source of heightened anxiety for students with diagnoses that are characterized by variations in executive functions. This anxiety can lead to debilitating experiences which affect not just their course performance, but also their mental health. We also corroborate Cooper et al.’s (2018) finding that group work can be implemented positively to decrease anxiety [151]. Students with ADHD in physics courses did not report any interactions which resulted in increased anxiety [65].

**Recommendations for instructors.**

In addition to our previous recommendations about how to support students in preparing for assessments, we encourage instructors to think of other ways they can support students’ studying, such as providing practice assessments and/or a schedule for when students should be confident in applying specific concepts. Building on this, we recommend instructors encourage the use of mental health counseling services as a support for any student experiencing anxiety, as these services are often unused due to negative stigmas associated with the services [152]. A key piece of this encouragement is normalizing the use of mental health services as a support, rather than portraying it as a way to fix something in the student [153]. Regarding social anxiety, we see that supporting the development of peer networks is a helpful strategy. Some specific ways to do this include facilitating the development of an optional group chat outside of class for students or providing opportunities for students to meet the students around them at the beginning of a course. Our recommendations for instructors are specific to either
course structures (e.g., studying, group work) or encouraging students to utilize existing campus resources. Topics which fall outside these areas, such as diagnosing students or making treatment suggestions, are outside instructor’s disciplinary knowledge or roles, and we discourage instructors from prompting discussions about these topics with students.

**Interactions with others**

Every participant reported experiences concerning interactions about how others reacted to their diagnosis. We found that the “others” could be separated into three major groups: peers, instructors, and disability services officials. The majority of the participants reported positive or neutral interactions with all of these groups at this institution, but two participants reported negative experiences specifically with disability services officials.

**Peers**

No participant reported that peers at this institution caused negative experiences due to knowledge of participant’s diagnosis, diagnosis characteristics, or accommodation use. However, Participants 2, 3, 4, 5, and 6 described that peers did not know of their diagnosis and that the participants preferred to keep their diagnosis and accommodation use hidden and confidential. For example, Participant 5 reported that while extra test time wasn’t necessary for them, they also didn’t use the accommodation due to the risk that their peers may notice their absence, thereby risking confidentiality of their disability and accommodation use: “…it would be hard
getting there [testing location] 'Cause I'd know that they'd know. Yeah. And then they're like, ‘Oh, did you take the tests?’ And it's just like, ‘No, yeah. I took it.’ (Laughs)’ Though Participant 6 didn’t describe any negative experiences from peers in postsecondary education, however they did report negative experiences in high school, specifically due to people being surprised that the participant identified as autistic: “…some people will respond in like a way that's like, ‘Well, you don't seem like you're autistic.’ And like-Well, I am, so. (laughs). Yeah. It gets very uncomfortable sometimes. But that was like, high school when I dealt with more of that.” Disability stigma, whether explicit or implicit, was identified by participants and resulted in participants taking actions to hide their diagnosis or accommodation use.

Instructors

At this institution, instructors receive email notifications of which students in their courses have requested specific accommodations and therefore know that these students identify with a disability. Every participant in this study reported positive or neutral interactions with instructors at this institution (though one reported a negative incident at a different incident, discussed below) regarding the participant's diagnosis, diagnosis characteristics, or accommodation use. Participant 4 shared that while they knew disability stigma existed, they only had positive experiences with instructors with whom they had shared their accommodation use: “And I know like that's a big thing about like people judging other people and stuff, but I haven’t really felt unwelcome, professors are always like... I tell them, like hey, I'm registered with this [extra test time],
so-I’ll take my tests here… and they’ve always been very accommodating of that.”

Participant 3 was the only participant to report a negative experience with instructors regarding their disability or accommodation use, but this was at a different university. Participant 3 reported that at this other university they would not make use of the extra test time accommodation due to the knowledge that some instructors would be unwilling to provide it: “I actually went through much of my time at, uh, [different university], uh, feeling like I couldn't really take extra time on my tests because if my professors … well, even if- if I asked that of my professors-... there was always going to be that one who would say, ‘No, you aren't getting this.’” Instructors play a critical role in providing and supporting accommodations, and participants in this study did not report instructors introducing barriers to using accommodations at the institution investigated in this study. One participant did report negative experiences with instructors at a different institution, revealing there are still instructors who are disabling students from using accommodations.

**Disability services officials**

The disability services office at this institution has enacted a variety of differing strategies from other disability services offices due to an adoption of a social model of disability. Some of the enacted strategies include not always requiring documentation of a disability diagnosis to receive accommodation services, encouraging staff to build a rapport with students, empowering staff to make accommodation decisions without the need for a committee meeting, and encouraging conversations about accessibility
throughout campus. While many participants reported positive experiences interacting with the disability services office, Participants 2 and 6 reported negative experiences. Positive experiences stemmed from easily receiving the accommodations which participants felt were necessary for their success. Subsequently, negative experiences arose due to interactions which resulted in either not receiving accommodations or not wanting to make use of them. As mentioned previously, Participant 2 desired the extra test time accommodation, but was denied it by the disability services official. Participant 2 reported that the disability services official made this decision based on the official’s personal experience not needing extra test time: “He had such a personal bias against giving me any extra time because he said that he struggled with it and…uh, but he said he wasn’t given any extra time and he just spent all of his time in the library, which I already do.” This had a severe negative effect on Participant 2 as it was a challenge for them to reach out for help, and being denied this help was very demotivating and depressing: “…for me to reach out for extra help to recognize that and then for him [disability services official] to be like, ‘no, we don't have- I'm not going to give you the help that you're asking for.’ You know, like that was very upsetting.” Participant 6 was able to receive extra test time and reduced distraction test environment accommodations, but they reported that they initially did not make use of them because they felt talked down to by the disability services officials: “I had just a couple of weird experiences. It felt like, kind of like I was being talked down to some of the times. And I don't think they [disability service officials] meant it that way, it just came across that way to me, so I just kind of avoided it for a bit.” However, once they encountered the
need for accommodations in their chemistry course, they did make use of the services and found the accommodations to be beneficial:

Interviewer: “But then for chemistry, what caused you to [use accommodations]?”

Participant 6: “I think the necessity. Like knowing that I was like, I can't do this in the auditorium setting and I know that if students are finishing at different times and leaving, I would just, it wouldn't work out. So I'm glad I did.”

Disability services offices should be a safe place for students with disabilities to receive the supports that courses aren’t providing; however, we find that how disability services officials engage with students can disable and/or dishearten students from receiving accommodations. To ensure that accommodations are reaching the intended populations, disability services officials do have to play the role of determining who receives accommodations. However, the risk of denying accommodations for a student who needs them provides more support for the importance of courses enacting inclusive practices which are available for all students.

Connections to literature.

Previous studies have documented many cases where students with disabilities have encountered negative interactions with peers or instructors [50,51,63]. The consequences of these culminate in negative self-views towards one’s disability
diagnosis [63] and/or not making use of accommodations [50,52,59,77,145]. In contrast to these negative interactions, we find mostly positive or neutral interactions with others at the institution in our study. One potential reason for this lack of negative experiences with others at this institution is the university’s emphasis on inclusion and diversity. For example, Participant 2 identified with experiencing severe social anxiety, and shared how the diverse culture at this university reduced feelings of social anxiety by reflecting a welcoming culture where they felt a sense of belonging: “…just seeing so many different kinds of people at these events makes it feel more welcoming, um... just, I mean, I don’t know it’s something about [this university], that the amount of diversity that you see everywhere is so... welcoming. Um, it’s so- it’s like it feels more like you- like you’ll be accepted somewhere within all of those people.”

Recommendations for instructors.

We recommend that instructors make intentional statements encouraging the use of accommodations as this clarifies to students with disabilities that the instructor welcomes their use [139]. Furthermore, encouraging statements about accommodations can help challenge the ideas that using accommodations is shameful and looked down on. As shared in the quote by Participant 2 in the previous section, we find that having diverse student populations can increase feelings of inclusivity and so we encourage universities to pursue a student population from diverse backgrounds and identities. By surrounding students with other students from a variety of backgrounds and identities, we support students in recognizing that diversity is a natural part of humanity.
Summary and implications

In this study, we find that students with diagnoses characterized by variations in executive functions reported how STEM course practices could result in supportive or disabling experiences due to interactions with self-identified diagnosis characteristics. These experiences were contextualized by the positive or negative interactions participants had with peers, instructors, and disability services officials.

Examples of supportive course practices included having course content available online before class in an organized format and supports for developing social networks with peers. Regarding accommodations, extra test time and reduced distraction environments were the most commonly used due to increased time given for processing and the reduction in social anxiety due to being surrounded by less people. All accommodations were reported to be critical for participants’ success in STEM courses.

Participants also reported negative consequences when there was a lack of supportive course practices or when accommodations were not provided. These challenges interacted with a variety of diagnosis characteristics to result in barriers keeping pace with their STEM courses and experiencing episodes of severe anxiety in STEM courses. Both outcomes resulted in challenges succeeding in STEM courses and negative consequences for participants’ mental health.

Interactions with others influenced almost every experience participants had in their STEM courses. “Others” were broken down into three categories: peers, instructors, and disability services officials. We found that most interactions participants
had with all three parties at thus institution were either positive or neutral, though participants did still prefer to keep their diagnosis confidential from peers who they did not know well. Participants expressed that interactions were positive or neutral due to an inclusive and diverse culture at this university along with not encountering any instructors who opposed the use of accommodations. Two participants reported negative interactions with disability services officials that resulted in not being able to or not wanting to use accommodations which participants identified as beneficial.

All our findings were identified using a social-relational lens, allowing us to determine how course structures resulted in supportive or disabling experiences for students with diagnoses characterized by variations in executive functions in STEM courses. These experiences reveal that disabling practices can result in heightened barriers in STEM courses versus non-STEM courses. This finding is echoed in the results of our investigation of the experiences of students with ADHD in physics courses [65], and so we build further evidence regarding the need for inclusive teaching practices in STEM contexts.

One support for identifying inclusive practices is the Universal Design for Learning (UDL) framework [30]. UDL recognizes that learners vary in their needs, interests, and abilities and therefore courses should be designed in a way which supports this variability. Recommendations center around the ideas that courses should provide options and supports for how students receive, engage with, and express understanding of content. Many of the recommendations we provide in this study align with the UDL framework. For example, our recommendation to provide study guides
aligns with UDL recommendations to support students in managing information and resources. At the end of the limitations section we provide links to a variety of studies which provide further examples of STEM specific practices and strategies motivated by the UDL framework.

While the participants in this study recognized the existence of disability stigma, participants reported few interactions with others where they felt disability stigma was present. Students’ experiences with disability stigma were severely negative and resulted in significant negative consequences, highlighting the harm this perspective can cause for students with disabilities. The fact that the participants reported few experiences of disability stigma indicates that disability stigma can be combatted through practices such as instructors encouraging the use of accommodation services and universities pursuing and supporting a diverse student population.

Overall, we encourage the adoption of a social-relational lens of disability since it promotes an individual to transition from the commonly held perspective that students with disabilities are the source of deficit to a perspective that course structures are responsible for disabling experiences. This allows individuals to identify how courses can be changed to be more supportive, as opposed to saying that students carry flaws which are the source of failure. This latter view is especially harmful when considering students with disabilities, as the idea that students with disabilities carry flaws which make them less capable than others is a foundational assumption of disability stigma.
Limitations and recommendations for future research

One significant limitation of this study is that participants were only recruited from one institution located in the US, thereby limiting the breadth of experiences we investigated. How disability is viewed varies significantly across cultures, and we find that interactions with others provide important context for the experiences of students with disabilities. Therefore, we encourage researchers to continue investigating the experiences of students with disabilities at a variety of institutions across the world. We found similarities and differences across the experiences of students with different diagnoses and so future studies should continue exploring whether students of varying diagnoses benefit from different course structures.

We also find that students can identify what they need to succeed, but in this study we only provide a few recommendations for how STEM courses can be made more inclusive. Therefore, instructors and researchers should continue asking students how STEM courses can be made more inclusive along with identifying if these inclusive practices vary across instructional styles. Some examples of recommendations for STEM specific inclusive practices and strategies can be seen in the following citations [19,137-140].

Further research should also investigate disability stigma in varying cultures and teaching environments, along with identifying ways to effectively combat disability stigma in these contexts.
CHAPTER 7: USING UNIVERSAL DESIGN FOR LEARNING TO INVESTIGATE AND IMPROVE THE INCLUSIVENESS OF STEM COURSES

Introduction

Students with disabilities make up a significant portion of the students in postsecondary STEM courses [1,2,38], however little research has investigated if STEM instructors implement practices and strategies that support students with disabilities [23]. Previous studies have shown that course design can result in disabling or supportive experiences for students with disabilities [50,63,65], yet STEM instructors lack knowledge about how to support students with disabilities in their courses [77,80-83]. We define disabling to mean that the individual with a disability is prevented from access to and participation in the course due to how a course is designed.

This study describes our work with physics faculty and chemistry teaching assistants (TAs) to identify how inclusive their courses were and to implement new practices which would support students in accessing, engaging with, and expressing their understanding of course content. We define inclusive practices to be practices which support the variability of learners’ needs, interests, and abilities. We used the Universal Design for Learning framework to operationalize how courses can be made more inclusive, and instructors were provided professional development regarding UDL and the experiences of students with disabilities [30]. Observations conducted before the professional development were used as feedback for instructors to support their choice of new practices which addressed gaps in inclusive practices.
Through course observations conducted before professional development, we provide an evaluation of the enactment of UDL checkpoints in STEM courses, including areas of strengths and weaknesses across courses, differences across instructors, and differences between the physics courses and chemistry labs.

Using course observations, instructor interviews, and student interviews, we present the practices instructors chose to implement after professional development. We evaluate the extent to which these practices were enacted and whether students evaluated the practices as beneficial, detrimental, or neutral.

Frameworks utilized

We use the social model of disability to identify that STEM course structures are the source of disablement for students with disabilities and therefore course structures are the target for change. The Cognitive-Affective Model of Conceptual Change (CAMCC) is used to motivate how our professional development and instructor support is designed. We finally use Universal Design for Learning (UDL) as the content for professional development and as a tool for determining how course practices align with recommendations for increasing inclusion.

Research questions

In response to the need for instructor support in implementing inclusive practices, we worked with instructors to identify disabling barriers within their courses and to implement new practices which could reduce these barriers by increasing inclusivity. However, we recognize that STEM courses are not “blank slates” regarding inclusivity,
and so first we evaluated the extent to which existing course practices in STEM courses were inclusive. Thus, our first research question was:

1. To what extent do STEM instructors enact UDL checkpoints during in-class sessions before professional development on UDL?

To evaluate the extent to which UDL professional development and support resulted in new, inclusive teaching practices, we investigated the following research questions:

2. What is the effect of providing UDL professional development and supporting STEM instructors in implementing new UDL aligned practices and strategies?
   a. What new teaching practices and strategies do instructors choose to implement?
   b. To what extent are the new practices implemented, and how do these practices increase inclusivity?
   c. How do students rate the effectiveness of implemented practices and strategies?

Since previous research has investigated the enactment of UDL checkpoints in physics and chemistry written curricular materials, we also seek to compare our findings
and determine how UDL enactment compares in written curricular materials versus in-class sessions.

3. How do the areas of high and low enactment of UDL checkpoints during in-class STEM sessions compare to findings from previous studies which investigated the enactment of UDL checkpoints in STEM written curricular materials?

Methods

Recruitment & intervention design

Instructor recruitment

Instructors were recruited from a very large, research-intensive, university in the southeastern United States through emails sent by the chemistry and physics department chairs on our behalf to instructors who would be teaching student-centered courses over the next several semesters. In alignment with the CAMCC tenet that instructors need to believe that the proposed pedagogy is effective, we specifically sought to recruit instructors who had an interest in increasing the inclusivity of their courses.

Specifically, we recruited physics instructors who would be teaching SCALE-UP courses, which combine the traditionally separate lecture, laboratory, and recitation components into one, flexible classroom setting [102]. The physical classroom for the SCALE-UP physics courses featured large round tables with built in computers to
facilitate group work, allowing the instructor to decrease didactic lecture in favor of group activities. The SCALE-UP courses at the institution in our study enrolled up to 99 students per section, and the instructor was supported by a graduate and undergraduate teaching assistant.

We recruited chemistry instructors (graduate teaching assistants) from the general chemistry lab, which were taught using guided inquiry. Each class session starts with a key question that students work collaboratively to address, often identifying a procedure for answering the question and then enacting the process to reach a solution. Instructors guide and support students to achieve these goals by asking students guiding questions, as opposed to giving direct answers [71]. The maximum class size for the general chemistry labs at this university is 24 students, and the lab is taught by one chemistry graduate teaching assistant (GTA).

We recruited two cohorts of instructors. Cohort 1 included two physics faculty and two chemistry GTAs, while Cohort 2 consisted of one physics faculty and one chemistry GTA. Cohort 2 began participation during the last semester of Cohort 1’s participation. All the physics faculty had taught their course several times, but the chemistry TAs’ baseline semester was either their first or second semester teaching the general chemistry lab.

**Design of data collection and instructor intervention**

We aimed to support instructors in identifying course barriers and implementing UDL-aligned practices to address these barriers. Instructors participated in the study
over a minimum of two semesters. In the first (baseline) semester, we conducted an instructor interview and approximately three baseline course observations throughout the semester\textsuperscript{5}.

After the baseline semester, participants attended workshops led by the research team about students with disabilities, UDL, and how to implement UDL in STEM contexts. Components of these workshops were developed using preliminary findings from our interviews with students with disabilities, reported in other studies \cite{55,65}. In alignment with the CAMCC tenant that proposed pedagogy should be seen as effective, workshops highlighted that practices which support students with disabilities consequently support all students (e.g. putting resources online allows all students to access the resources). As mentioned above, this choice is an example of interest convergence.

During professional development, participants also received feedback about the baseline observation data collected from their course. To enact the CAMCC tenant that existing practices should be shown to be ineffective, researchers worked with participants to highlight how specific UDL checkpoints had low or no enactment their course. Instructors then chose practices they wanted to implement to address UDL checkpoints with low or no enactment.

Instructors implemented the chosen practices in the semester(s) following training. During this implementation semester, the research team conducted five

\textsuperscript{5} Instructor C1b was observed three times, but two of these observations had to be collapsed into one data point since the lesson being taught covered both observations. We were unable to perform a fourth observation due to the instructor’s lab being cancelled on the final available week. Due to significant variations in how one course was taught, one instructor (A2) was observed five times.
observations of each instructor’s course\textsuperscript{6}. Stains et al. (2018) recommends at least four observations are needed to characterize the instructional practices used in a course \cite{154}. Instructors from cohort 1 taught the same course for an additional semester, so we observed their courses for this semester as well.

In alignment with condition 3 of the CAMCC (i.e., instructors need sufficient time and resources to implement pedagogical changes) ongoing support was provided during the implementation semester(s) in the form of monthly meetings between the research team and instructors. In these meetings, instructors were prompted to identify challenges and/or successes they experienced with enacting UDL-aligned practices, and the research team provided recommendations and encouragement. Each instructor participated in an interview at the end of the final implementation semester.

**Student recruitment**

To evaluate the perceived effectiveness of implemented practices, we recruited students from the participating instructors’ courses to participate in focus groups at the end of the instructors’ final implementation semester. Each focus group included one to three students. We initially planned to recruit only students with disabilities, but no students with disabilities chose to participate. Thus, we widened our recruitment to all students in the instructors’ courses. While the expansion of our recruitment criteria does not allow us to investigate whether the implemented practices supported students with disabilities, it does still align with the idea that UDL enactment should support all

\textsuperscript{6} Two instructors (C1a and C1b) were only able to be observed four times during their first implementation semester, but they were observed five times in their second implementation semester.
students. The result of this change is that student perspectives represent "all" students and do not specifically provide evidence for how practices supported students with disabilities.

Table 6 provides the pseudonyms for each instructor, the course they taught, their cohort, and the number of students recruited from their course for focus group interviews. Figure 3 gives a timeline of the data collection and professional development activities.

Table 6: Instructor pseudonyms along with their course, cohort, and how many students were recruited for focus groups from their course.

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Course</th>
<th>Cohort</th>
<th>Students interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1a</td>
<td>College Physics 1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>P1b</td>
<td>College Physics 1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>P2a</td>
<td>College Physics 2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>C1a</td>
<td>Chemistry 2 lab</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>C1b</td>
<td>Chemistry 2 lab</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C2a</td>
<td>Chemistry 2 lab</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 3. Timeline of data collection and professional development activities. Note that some instructors had two implementation semesters, which each had five observations. Student interviews were only conducted at the end of the final implementation semester. Monthly meetings are not shown in the figure for brevity.
Data sources and analysis process

We collected three types of data: observations of courses, instructor interviews, and student focus groups. Observations conducted before professional development are used to answer our first research question, whereas observations during implementation semesters, instructor interviews, and student focus groups are used to answer our second and third research questions. The use of multiple sources of data to support a claim (i.e., triangulation) is recommended to increase the trustworthiness of interpretations [155,156].

The observations and interview protocols allowed us to generate a more comprehensive view of the enactment of UDL checkpoints in and out of class, and each instrument had strengths and weaknesses in differing areas. The observation instrument was able to capture course practices that occurred within a single course session; however, it could not capture out-of-class practices. The interview instrument could capture out-of-class practices, but relied on self-report, and due to the limitations of a one hour interview, it was unable to record the extensive catalog of practices and strategies the instructor used in their courses. Because of these strengths and weaknesses, we primarily rely on the observation data to discuss the extent to which a course enacts UDL checkpoints in class. We use interview data to evaluate the extent to which practices were enacted outside of class and whether students reported new practices to be effective.
Course Observations: Universal Design for Learning Observation Measurement Tool (UDL-OMT)

Course observations were conducted using the Universal Design for Learning Observation Measurement Tool (UDL-OMT) [157]. The purpose of the UDL-OMT is to assess the extent of enactment of the UDL framework during in-class sessions [157].

The UDL-OMT is a semi-structured observation instrument which scores 31 items for the presence and levels of enactment of the items throughout the class period. The 31 items are designed to operationalize the UDL checkpoints by “… identifying places where particular checkpoints would more likely be observed based on their relevance to instructional events” [p. 4] [157]. Each item is rated by the observers on a scale from 0 to 3, where 0 indicates no evidence of UDL, 1 indicates incomplete evidence of UDL in environment, 2 indicates UDL is occurring, and 3 indicates dynamic, interactive UDL. Basham et. al further define the scoring levels by the number of practices implemented, whether students engaged with the practices, whether the practices were “static and/or traditional” in nature, the levels of interactivity and flexibility afforded by the practices, and the extent students relied on teachers for effective use of the practice. Due to the high subjectivity of many of these scoring criteria, we encountered challenges reaching agreement between the two observers. Therefore, we reduced our operationalization of the scores to the number of practices implemented and the extent to which practices were enacted. In our rating system, a 0 denotes no practices observed aligned with a specific item, a 1 denotes one practice occurred, a 2 denotes two practices occurred sparingly, and a 3 denotes that either two practices occurred extensively or more than two practices were used that aligned with an item.
For practices to be counted, they had to occur for longer than a few seconds over an entire class period as students are likely to miss something which occurs only once for a few seconds. For example, a single short instructor statement was not sufficient for us to consider unless the same statement was made several times. Observation items are organized under four categories: introducing and framing new materials (six items); content representation and delivery (nine items); expression and understanding (seven items); and activity and student engagement (nine items).

To build the trustworthiness of our interpretations, observations were conducted by two researchers (W.J. and J.S.) who had different backgrounds and experiences. W.J. was pursuing a PhD in physics, with a focus on physics education research, while J.S. was pursuing a PhD in exceptional education, with a focus on supporting individuals with disabilities. The variation in the researchers’ backgrounds was important as they provided multiple perspectives on classroom practices, with J.S. providing expertise in UDL and W.J. providing expertise in STEM contexts. As W.J. gained experience utilizing the protocol and using UDL in their research, they also gained expertise in applying UDL. Knowledge of UDL and its applications was important due to the subjectivity of determining what practices were aligned with which observation items. To promote consistency across observations, W.J. was present for every observation conducted. J.S. co-observed half of the total observations, and after every co-observation, both researchers discussed their observations to reach agreement. These discussions provide an on-going form of peer review, a technique which Creswell and Poth (2018) recommend as a means of building trustworthiness [105].
Though Basham et. al (2020) have since provided the alignment of the UDL checkpoints to the observation items, we did not have access to this alignment information or their operationalizations of the observation items at the time of our data collection. Therefore, we generated our own operationalizations of the items and alignment with the UDL checkpoints. To support the operationalization of observation items, the two researchers involved in observations generated definitions and examples of STEM course practices which represented enactment of the observation items (e.g., allowing students to present lab results in differing mediums was a practice which constituted C1: Allows options for learners to express understandings in a variety of ways). These definitions and examples are provided in Appendix A. UDL-OMT items were aligned to the UDL checkpoints by two of the researchers in our study (W.J. and E.S.). Both researchers had experience applying the UDL checkpoints in STEM contexts due to their involvement in a study investigating the extent to which popular physics curriculum enact UDL checkpoints [95]. In Appendix B we provide a comparison of our UDL-OMT and UDL alignments to those provided by Basham et.al [157].

In Table 7 we provide our alignments for the observation items to UDL checkpoints. Note that a limitation of our operationalization of the observation instrument is that some observation items do not align with any UDL checkpoints and not all UDL checkpoints are represented. Basham et. al’s (2020) does have alignment to checkpoints for every observation item they list, however not all checkpoints are represented in their alignment as well. Differences in our alignment and Basham et. al’s (2020) alignment of observation items to UDL checkpoints is likely based on differences
in how we operationalized/defined the observation items. Basham et. al (2020) do not provide operationalizations or definitions for their observation items, so we are unable to provide the specific reasons why our alignments to UDL checkpoints differ [157].
<table>
<thead>
<tr>
<th>Principles</th>
<th>Guidelines</th>
<th>UDL Checkpoint</th>
<th>Observation Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide options for perception</td>
<td>1.1: Offer ways of customizing the display of information</td>
<td></td>
<td>B2: Presentation of information allows for customization.</td>
</tr>
<tr>
<td></td>
<td>1.2: Offer alternatives for auditory information</td>
<td></td>
<td>B4: Instruction allows alternatives for auditory information.</td>
</tr>
<tr>
<td></td>
<td>1.3: Offer alternatives for visual information</td>
<td></td>
<td>B3: Instruction allows alternatives for visual display of information.</td>
</tr>
<tr>
<td>Provide options for language &amp; symbols</td>
<td>2.1: Clarify vocabulary and symbols</td>
<td>B7: Clarifies content specific vocabulary, symbols, and jargon.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.2: Clarify syntax and structure</td>
<td>B8: Clarifies content-based syntax and structure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.3: Support decoding of text, mathematical notation, and symbols</td>
<td>B9: Highlights options for self-directed clarification of vocabulary and symbols.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.4: Promote understanding across languages</td>
<td>B5: Supports options for multiple languages.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5: Illustrate through multiple media</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Multiple means of representation</td>
<td>3.1: Activate or supply background knowledge</td>
<td>A1: Assesses background knowledge prior to introducing new knowledge.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.2: Highlight patterns, critical features, big ideas, and relationships</td>
<td>A3: Highlights what is important for students to learn.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.3: Guide information processing, visualization, and manipulation</td>
<td>D9: Provides closure that reiterates big ideas and instructional purposes.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.4: Maximize transfer and generalization</td>
<td>A4: Supports understanding of big ideas and critical concepts.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A2: Supports linking background knowledge to new knowledge.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B6: Supports understanding of relationships across disciplines, settings, or concepts.</td>
<td></td>
</tr>
<tr>
<td>Provide options for physical action</td>
<td>4.1: Vary the methods for response and navigation</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.2: Optimize access to tools and assistive technologies</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Provide options for expression &amp; communication</td>
<td>5.1: Use multiple media for communication</td>
<td>C1: Allows options for learners to express understandings in a variety of ways.</td>
<td></td>
</tr>
<tr>
<td>Principles</td>
<td>Guidelines</td>
<td>UDL Checkpoint</td>
<td>Observation Code</td>
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<tr>
<td>5.2: Use multiple tools for construction and composition</td>
<td>C3: Use multiple media for communication&lt;br&gt; C2: Provides access to a variety of tools and/or technologies that allow students to express their understanding.</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>5.3: Build fluencies with graduated levels of support for practice and performance</td>
<td>C4: Provides options that guide students to plan, develop strategies, and/or goal-setting that promotes expression of understanding. D4: Encourages learners’ use of strategic planning to complete instructional tasks.</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>6.1: Guide appropriate goal setting</td>
<td>C5: The environment facilitates management of information and resources to achieve desired learning outcomes. A6: Identifies potential misunderstandings/misconceptions.</td>
<td>Provide options for executive functions</td>
<td></td>
</tr>
<tr>
<td>6.3: Facilitate managing information and resources</td>
<td></td>
<td></td>
<td>B1: Supports multiple levels of content understanding (e.g., novice, intermediate, expert).</td>
</tr>
<tr>
<td>6.4: Enhance capacity for monitoring progress</td>
<td></td>
<td></td>
<td>D2: Provides a variety of activities relevant to all learners. D3: Promotes sustained effort and focus.</td>
</tr>
<tr>
<td>7.1: Optimize individual choice and autonomy</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7.2: Optimize relevance, value, and authenticity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.3: Minimize threats and distractions</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Principles</td>
<td>Guidelines</td>
<td>UDL Checkpoint</td>
<td>Observation Code</td>
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<tr>
<td>Provide options for sustaining</td>
<td>8.1: Heighten salience of goals and</td>
<td>*D3: Promotes sustained effort and focus.</td>
<td></td>
</tr>
<tr>
<td>effort &amp; persistence</td>
<td>objectives</td>
<td>D9: Provides closure that reiterates big ideas and instructional purposes.</td>
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<tr>
<td></td>
<td></td>
<td>B1: Supports multiple levels of content understanding (e.g., novice, intermediate, expert).</td>
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<tr>
<td></td>
<td></td>
<td>D6: Supports multiple levels of challenge.</td>
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<td></td>
<td>8.2: Vary demands and resources to</td>
<td>D5: Encourages collaboration and communication among learners.</td>
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<tr>
<td></td>
<td>optimize challenge</td>
<td>D8: Provides formative progress monitoring and content checks.</td>
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<tr>
<td></td>
<td>8.3: Foster collaboration and</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>community</td>
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<td></td>
<td>8.4: Increase mastery-oriented</td>
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<td></td>
<td>feedback</td>
<td></td>
<td></td>
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<tr>
<td>Provide options for self-regulation</td>
<td>9.1: Promote expectations and</td>
<td>N/A</td>
<td></td>
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<tr>
<td></td>
<td>beliefs that optimize motivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.2: Facilitate personal coping</td>
<td>N/A</td>
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<tr>
<td></td>
<td>skills and strategies</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>reflection</td>
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<tr>
<td></td>
<td>Not aligned to a checkpoint</td>
<td>A5: Uses questions that support understanding or inquiry</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C6: Intentionally provides supports for students’ problem solving and critical thinking skills</td>
<td></td>
</tr>
<tr>
<td>* We did not code D3 when the</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>instructor heightened the salience</td>
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<tr>
<td>of goals and objectives, but upon</td>
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<tr>
<td>reflection we agree this observation</td>
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<tr>
<td>item should map to checkpoint 8.1.</td>
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<tr>
<td>Observation scores for 8.1</td>
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<tr>
<td>therefore do not include scores</td>
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<td></td>
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<tr>
<td>from observation item D3.</td>
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</tbody>
</table>

To analyze the observation data, we used the observation scores to generate scores for the aligned checkpoints. For example, if an instructor had a score of 2 on observation item B3, then they received a score of 2 for checkpoint 1.2. In cases where multiple observation items aligned to the same checkpoint, the average value of the observation items was taken. For example, if observation item A3 had a score of 3 and observation item D9 had a score of 2, then checkpoint 3.2 received a score of 2.5 since checkpoint 3.2 aligned with A3 and D9.
We averaged the observation data across observations within each instructor to provide a measure of how much the UDL checkpoints were enacted across an entire semester within one instructor’s course. We recognize there is variation across observations, and in Appendix E we provide the averaged pre and post professional development checkpoint scores for each instructor along with a measure of consistency for each checkpoint.

Our process for collecting and analyzing the observation data follows a quasi-mixed, monostrand, conversion design as we collected and organized numerical data (i.e., quantitative), but we analyze the data using qualitative means since our sample size is not large enough for quantitative analysis [158].

**Instructor interviews**

Instructors were interviewed twice during our study, once before the baseline observations (pre-interview) and once after all the observations were complete (post-interview). Interviews used a semi-structured interview protocol, lasted a maximum of one hour, and were conducted by W.J.

The pre-interview investigated the existing practices and strategies instructors used in their courses. We aligned our questions with the three UDL principles (multiple means of representation, engagement, and expression) resulting in questions which asked how instructors presented information to students, had students engage with information, and had students express understanding of information. The interviews concluded with questions about the instructor’s familiarity with UDL and, after a brief
description of our definition of UDL, whether they believed the UDL framework could be helpful in designing inclusive practices. The instructor pre-interview protocol can be found in Appendix F.

The post-interviews focused on investigating the new UDL-aligned practices and strategies the instructors chose to implement. Like with the pre-interview, questions were aligned to the three UDL principles, but focused on the new practices instructors chose to implement to support students in receiving, engaging with, and expressing understanding of information. The instructor post-interview protocol can be found in Appendix G.

All interviews were transcribed verbatim and were analyzed using a mix of structural and magnitude coding. Structural coding is a technique where researchers provide a topic or phrase which identifies how a segment of data answers a research question [159,160]. Structural coding is used when analysis seeks to answer how often some event occurs across participants [159]. We used structural coding to identify which practices instructors implemented in their courses and how many instructors implemented these practices. Magnitude coding is used to provide an evaluative interpretation of existing codes by using sub codes to denote intensity, frequency, or evaluative content [159]. In our study, we used magnitude coding to evaluate whether coded instructor practices were implemented before or after professional development, and to evaluate how coded instructor practices enacted UDL checkpoints. This data is used as supporting evidence for research questions 1 and 2.
Coding was done in two independent iterations, with the first iteration focusing on identifying practices (structural coding) and whether they were pre-professional development or post-professional development practices (magnitude coding), and the second iteration aligning identified practices to UDL checkpoints (magnitude coding).

Our initial structural coding produced a long list of phrases describing practices which varied across instructors. To consolidate within and across instructor lists, we organized the coded phrases into more consistent phrases called “unique practices” based on the similarity of the action, the intended goal of the practice, and whether the practices had the exact same alignment to UDL checkpoints. For example, we originally coded “PowerPoints uploaded online” and “Notes uploaded online” separately; then we collapsed these codes into “Uploading course content online” since both practices provided content online in customizable formats (UDL checkpoint 1.1).

To promote the trustworthiness of findings, analysis of the instructors’ interview transcripts was done by two researchers (W.J. and S.C), with W.J. being the primary coder, and S.C. being the secondary coder. Both researchers had some expertise in the UDL framework. S.C. is an expert in exceptional education who is currently pursuing a PhD in exceptional education. W.J. coded the entire data set (12 interviews), and S.C. coded 33% of the data set (4 interviews). After each iteration of coding, W.J. and S.C. discussed their independent coding with the goals of reaching alignment. After this discussion, the primary coder reviewed the coding of the full data set to make edits based on changes agreed upon during the discussion. W.J. generated the “unique practices” list, and S.C. reviewed the full data set of collapsed practices.
Like the observation data, the process of having another researcher conduct and review portions of data collection and analysis is a form of peer-review which Creswell and Poth (2018) recommend as a means of building trustworthiness of interpretations [105]. Since this process is specifically analysis and not data collection, we can also consider our process as a form of peer examination, which Krefting (1991) also argues builds trustworthiness [161]. In the case of peer examination, access to the original transcripts is critical for confirmation of findings, and this was modeled in our process since W.J. and S.C. relied on the transcripts as the source for every step of the analysis [161]. Krefting (1991) also recommends triangulation as a means of supporting any claim, and we utilize triangulation with the instructor data by also providing data and interpretations from observations and student evaluations of implemented practices [161]. Similar strategies were used to build the trustworthiness of our interpretations of the student focus group interviews.

The data collection and analysis for the instructor interview data follows a traditional, qualitative, monostrand design [158].

**Student focus groups**

Student focus groups were conducted at the end of the last implementation semester for each instructor participant. Due to scheduling constraints, the focus groups included between one and three students. Each focus group used a semi-structured interview protocol, lasted for a maximum of one hour, and was conducted by W.J.
Student focus group questions were aligned with the three UDL principles and asked how the students’ instructor represented information, evaluated the students’ understanding of content, and motivated the students to engage with content. These three questions do not cover the entirety of the UDL principles, but since the interview protocol was semi-structured they provided starting places to probe instructor practices. Questions about instructor practices included follow-up questions about whether and why students found the practices beneficial or detrimental. The student focus group interview protocol can be found in Appendix H.

Interviews were transcribed verbatim and coded similarly to the instructor interviews, using structural and magnitude coding. For structural coding, we used the “unique practices” developed from the instructor interview analysis as our codebook. For magnitude coding, sub-codes were used on the same student statements to classify whether students evaluated the practices as positive, neutral, or negative (RQ 2a). Practices were coded as “positive” when students identified a practice as having a positive byproduct, such as supporting their learning or reducing stress. Practices were coded as “negative” when students identified a practice as having a negative byproduct, such as hindering their learning or increasing stress. If no evaluative wording was used in the student statement, the practice was coded as neutral.

The same two researchers coded the student interviews. W.J. coded all the interviews (12 interviews) and S.C. co-coded 25% of the interviews (3 interviews). The researchers met to discuss the co-coded interviews, and W.J. made edits to the other coding based on these discussions.
The data collection and analysis for the student interview data follows a traditional, qualitative, monostrand design [158].

**Findings**

The first section of the findings will answer research question 1 by presenting our analysis of the observation data before professional development. To answer research question 2, the second main section will follow a case-study format where we explore the practices each instructor chose to implement, whether the enactment occurred, how the enactment aligned to UDL checkpoints, and whether the enactment was judged to be effective by the instructor and students. Observation and interview data will be used as the evidence for making claims.

*Enactment of UDL-aligned practices before UDL professional development*

We rely heavily on the observation data to document how in-class practices enacted UDL checkpoints because the observations captured a wider range of practices than the instructor interviews. Figure 4 displays the baseline observation UDL checkpoint scores for each instructor. In Appendix I we provide the entire list of identified unique practices coded from the interviews along with which UDL checkpoints they align to. We believe this list of practices is a helpful tool for operationalizing what UDL checkpoints can look like in STEM courses.
Figure 4 cont.
Figure 4. Average baseline semester UDL enactment scores by instructor and checkpoint. (A) Checkpoints related to multiple means of representation. (B) Checkpoints related to multiple means of action and expression, (C) Checkpoints related to multiple means of engagement. Error bars are standard error (error bars are larger for C1b, who had fewer observations). * denotes checkpoints with high enactment and † denotes checkpoints with low enactment. ‡ denotes checkpoints with meaningful differences across type of course and § denotes checkpoints with meaningful differences across instructors.

We analyzed differences in enactment of UDL-aligned instructional practices in three ways: 1) checkpoints with high and low enactment across all instructors; 2) differences between course type; and 3) differences between individual instructors.

We operationalized a checkpoint as having “high enactment across instructors” if 4 or more instructors (out of 6) had an average score of 2 (i.e., two or more practices frequently observed) or more for that checkpoint. Similarly, we operationalized a checkpoint as having “low enactment across instructors” if 4 or more instructors had an average score of 1 (i.e., at most one practice observed) or lower for that checkpoint. Additionally, we investigated differences across courses (i.e., physics SCALE-UP
versus chemistry lab) and operationalized a practice as having meaningfully different enactment across course-type if the average scores across course-types differed by more than 1 point. A difference of 1 meant that we observed at least one additional practice and/or saw the practices occurring more frequently. Finally, we investigated differences across instructors and operationalized a practice as having meaningfully different enactment across instructors if an individual instructor’s score differed by more than 0.5 from every other instructor. A cutoff of 0.5 was chosen since only a few checkpoints had instructors who varied from all other instructors, and the variations are limited by a scale which only goes from 0 to 3. We use a larger cutoff for the course level differences to reduce the likelihood of variations across individual instructors being the reason for differences across course types. These criteria do not denote statistically different values, rather cut-offs were chosen based on our knowledge of the data and evaluation of noteworthy results. Table 8 shows the checkpoints which correspond to each of these sections and the data we will be analyzing to make these claims is shown in Figure 4.
Table 8: Checkpoints with high enactment, low enactment, different enactment across course, and different enactment across instructors

<table>
<thead>
<tr>
<th>Criteria</th>
<th>UDL Checkpoints which meet criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>High enactment across instructors</td>
<td>2.1 - Clarify vocabulary and symbols</td>
</tr>
<tr>
<td></td>
<td>2.2 - Clarify syntax and structure</td>
</tr>
<tr>
<td></td>
<td>3.3 - Guide information processing, visualization, and manipulation</td>
</tr>
<tr>
<td></td>
<td>6.3 - Facilitate managing information and resources</td>
</tr>
<tr>
<td></td>
<td>8.3 - Foster collaboration and community</td>
</tr>
<tr>
<td>Low enactment across instructors</td>
<td>1.2 - Offer alternatives for auditory information</td>
</tr>
<tr>
<td></td>
<td>1.3 - Offer alternatives for visual information</td>
</tr>
<tr>
<td></td>
<td>2.3 - Support decoding of text, mathematical notation, and symbols</td>
</tr>
<tr>
<td></td>
<td>2.4 - Promote understanding across languages</td>
</tr>
<tr>
<td></td>
<td>6.1 - Guide appropriate goal-setting</td>
</tr>
<tr>
<td>Differences across courses</td>
<td>1.1 - Offer ways of customizing the display of information</td>
</tr>
<tr>
<td></td>
<td>8.1 - Heighten salience of goals and objectives</td>
</tr>
<tr>
<td>Differences across instructors</td>
<td>2.3 - Support decoding of text, mathematical notation, and symbols</td>
</tr>
<tr>
<td></td>
<td>5.1 - Use multiple media for communication</td>
</tr>
<tr>
<td></td>
<td>5.2 - Use multiple tools for construction and composition</td>
</tr>
<tr>
<td></td>
<td>6.1 - Guide appropriate goal-setting</td>
</tr>
<tr>
<td></td>
<td>7.3 - Minimize threats and distractions</td>
</tr>
<tr>
<td></td>
<td>8.1 - Heighten salience of goals and objectives</td>
</tr>
<tr>
<td></td>
<td>8.3 - Foster collaboration and community</td>
</tr>
</tbody>
</table>

Checkpoints with high and low scores across all instructors

Five checkpoints (2.1, 2.2, 3.3, 6.3, and 8.3) had high enactment in our baseline observations.

Checkpoints 2.1 (clarify vocabulary and symbols) and 2.2 (clarify syntax and structure) are checkpoints we would expect to occur often in STEM contexts where new equations and variables are frequently introduced. During our observations we saw instructors enact checkpoint 2.1 when they consistently defined new symbols and vocabulary (e.g., defining “force” or “stoichiometry”). We saw instructors enact
checkpoint 2.2 when the instructors implemented practices such as frequent explanations about the structure of new formulas and the variables which were included in the formulas (e.g. explaining how \( F_{\text{net}} = ma \) represents that force is equivalent to the mass multiplied by acceleration of some object).

Checkpoint 3.3 (guide information processing, visualization, and manipulation) had high enactment because instructors often provided steps for solving new kinds of problems and provided opportunities to practice new content, for example using clicker questions that emphasize focused aspects of newly presented content.

Checkpoint 6.3 (facilitate managing information and resources) had high enactment because instructors often provided worksheets which included tables and organizers for working through problems or labs. Additionally, chemistry lab instructors often reminded students how to organize their lab notebook and manage the data they were collecting.

Checkpoint 8.3 (foster collaboration and community) had high enactment because the SCALE-UP and inquiry-based chemistry labs had students work with peers during most of each class session. Instructors frequently encouraged students to work with their peers, even for tasks where group work was not required. Practices which could support a richer and stronger enactment of checkpoint 8.3 include recommendations by instructors for how students can effectively engage in group work, such as providing group roles or having class discussions about norms that promote healthy group discussions.
Five checkpoints (1.2, 1.3, 2.3, 2.4, and 6.1) had low enactment in our baseline observations.

Checkpoints 1.2 (offer alternatives for auditory information) and 1.3 (offer alternatives for visual information) emphasize options in modality for receiving content. Checkpoint 1.2 and 1.3 had low enactment because we rarely observed written information having an auditory complement or verbal information having a written complement. For example, when graphs were presented, we rarely heard instructors provide a verbal description of the graph that would allow someone to replicate the meaningful graph features purely by the verbal description; often instructors did not verbally describe the units used on the axis or the overall trend of the graph. The occasions where we observed Checkpoint 1.2 typically involved providing a complete verbal description of every step as they worked out solutions to problems.

Though checkpoint 2.3 (support decoding of text, mathematical notation, and symbols) sounds similar to checkpoints 2.1 and 2.2, checkpoint 2.3 emphasizes providing access to resources that support understanding new equations and variables, and we rarely observed instructors providing these resources. Examples of practices which would constitute enactment of checkpoint 2.3 include instructors recommending specific websites or course resources (e.g., book or PowerPoint slides) as places to review vocabulary or equations.

Checkpoint 2.4 (promote understanding across languages) had low enactment since we rarely saw instructors provide recommendations or resources that supported students in understanding content in languages other than English. An example of a
practice that would enact checkpoint 2.4 is to recommend or provide resources that allow students to view STEM vocabulary in their preferred language or allowing students to discuss in their preferred language.

Checkpoint 6.1 (guide appropriate goal-setting) had low enactment since we rarely saw instructors implement practices that supported students in identifying goals for what the student wanted to accomplish in the course nor the practices students could use to reach their goals. Instructors could enact checkpoint 6.1 by providing a list of course level goals (i.e., learning objectives) accompanied by specific recommendations for what students need to do to achieve the goals (e.g., breaking the large goal into smaller tasks with a suggested timeline). We recognize that these statements often occur during the beginning of the course and thus, we may not have observed enactment of this checkpoint during our observations. However, instructors should continue to support students in setting and reaching their goals throughout the semester to remind students of how they can be successful in the course. A few key times to make these statements are before and after assignments that have a significant impact on student grades because this supports students in identifying how to prepare for assessments and/or how to make changes if students find that their existing study practices are ineffective.

While we explored the data at the principle and guideline levels of the UDL framework, we did not identify any principle or guideline-level trends in the areas of high or low enactment. The variations in checkpoint scores at the principle and guideline
levels reveals the importance of investigating inclusiveness at the checkpoint level, as otherwise areas of concern may be hidden by areas of strengths.

**Differences across courses**

Checkpoints 1.1 and 8.1 had an average score across course types which differed by more than 1, the threshold we selected for meaningful difference.

Checkpoint 1.1 (offer ways of customizing the display of information) had average enactment scores ranging from 1.2 to 2 in physics courses, whereas this checkpoint was not observed (all scores were 0) in the chemistry labs. Checkpoint 1.1 is often enacted by providing content in a digital format, as digital content allows students to change color or font size. In the physics courses, students had access to desktop computers or their own laptops, and we often saw students referring to digital versions of presented slides during class. In the chemistry labs, students were unable to bring laptops or use their cellphones as their use in the presence of chemicals used in the lab was considered a safety hazard.

Checkpoint 8.1 (heighten salience of goals and objectives) had scores ranging from 0 to 0.8 in physics courses, whereas the scores ranged from 1.5 to 2.6 in the chemistry labs. The chemistry courses had a higher enactment of checkpoint 8.1 because they used a key question in each lab to emphasize the purpose of the lab; GTAs referred to the key question to contextualize what students were doing and to evaluate if results accomplished the intended objective. We rarely observed physics
courses having learning objectives listed, though we sometimes observed instructors verbally emphasizing what students were expected to learn and why.

**Differences across instructors**

When comparing across instructors, we see that various instructors had notably higher or lower scores than other instructors in checkpoints 2.3, 5.1, 5.2, 6.1, 7.3, 8.1, and 8.3.

Instructor P1a had notably lower scores in checkpoints 5.1 and 8.3. Instructor P1a predominantly had students responding on worksheets, so we rarely observed students using other tools such as whiteboards, plotting programs, or data collection utilities (e.g., Logger Pro), which resulted in a low score on checkpoint 5.1 (use multiple media for communication). For checkpoint 8.3 (foster collaboration and community), we observed that instructor P1a rarely encouraged students to work with their peers. In general, instructor P1a had lower scores on most checkpoints compared to other the physics instructors because they devoted a large portion of the class to lecture and provided students with little flexibility in how they accomplished tasks.

Instructor P2a had notably higher scores in checkpoints 7.3 and lower scores in checkpoint 8.1. Checkpoint 7.3 (minimize threats and distractions) had high enactment due to the instructor providing breaks during every class which allowed students to disengage with the content for a few minutes. The instructor also restricted the extraneous use of cell phones in their class but allowed students to leave the classroom if they needed to use their devices. Checkpoint 8.1 was lower since we never observed
Instructor P2a make statements about the learning objectives for the class session or provide recommendations for how students could effectively engage with content. The lack of statements about learning objectives contrasted with other physics instructors who made these statements in at least one observation. Instructor P2a had higher scores in most of the checkpoints compared to the other physics instructors. In the pre-interview we identified that this instructor already had a mindset of recognizing the variability of learners. For example, instructor P2a stated “And we know, we all know, that, uh, understanding and learning is different from one person to another. It's no common thing. So, you may have some average (and the word "average," we have to define it) way of understanding, but the tails [on the bell curve] are so large of other people...” The variability of learners mindset led instructor P2a to implement practices that supported variation in how students developed mastery of the course material, such as having students explain new concepts to their peers or providing opportunities for students to re-earn lost points on exams.

Instructor C1a had notably higher scores in checkpoints 2.3, 5.2, and 6.1. Instructor C1a was the exception to low instructor scores in 2.3 (support decoding of text, mathematical notation, and symbols) and 6.1 (guide appropriate goal-setting). Instructor C1a scored higher on checkpoint 2.3 because they recommended resources for students to review vocabulary outside of class and scored higher on Checkpoint 6.1 because they supported goal setting by spending extensive time guiding students in developing the lab procedures which would be used to answer the key question. Students had flexibility in choosing how to perform the lab, and the instructor facilitated
this choice by asking critical questions about how chosen procedures would accomplish the intended goal. Instructor C1a received higher scores on Checkpoint 5.2 (use multiple tools for construction and composition) because they required students to use whiteboards and their lab notebooks as tools to brainstorm and finalize their lab procedure. Once finalized, the students would record the information in their lab notebooks.

**New UDL-aligned practices implemented after professional development and student evaluation of their enactment and effectiveness**

At the end of the professional development, instructors chose practices they wanted to implement to increase the inclusivity of their courses. The chosen practices for each instructor are presented in Table 5 along with the corresponding UDL checkpoints. Practices were aligned to the UDL checkpoints by the lead researcher (W.J.) based on the UDL checkpoint alignment generated previously for the instructor “unique practices” codes. Most of the chosen practices were either identical or very similar to “unique practices” codes.
Table 9: Instructor choices of implemented practices and which checkpoints they enacted. (I) denotes that the practice occurred in class, (O) denotes that the practice occurred outside of class, and (B) denotes the practice occurred in and out of class.

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Implementation choices</th>
<th>Checkpoints</th>
</tr>
</thead>
</table>
| P1a        | - Increased reminders for students to stay on task and asking students to put away phones (I)  
- Using sign-in sheet for attendance (I) | 7.3 – Minimize threats and distractions  
No alignment |
| P1b        | - Uploading all course content online (B)  
- Providing overview slide which learning objectives and structure of class (B) | 1.1 – Offer ways of customizing the display of information  
7.3 - Minimize threats and distractions  
3.2 – Highlight patterns, critical features, big ideas, and relationships  
8.1 – Heighten salience of goals and objectives |
| P2a        | - Having students explain new concepts to peers (I)  
- Having students write down summary of main points at end of each chapter (I) | 3.4 – Maximize transfer and generalization  
6.4 – Enhance capacity for monitoring progress  
8.4 – Increase mastery-oriented feedback  
6.4 - Enhance capacity for monitoring progress |
| C1a        | - Providing closure at end of lab on main points covered (I)  
- Allowing students to submit assignments online (O)  
- Rubrics for assignments (O) | 8.1 - Heighten salience of goals and objectives  
4.1 – Vary the methods for response and navigation  
6.4 - Enhance capacity for monitoring progress |
| C1b        | - Generating a website with an overview of course topics (O) | 1.1 – Offer ways of customizing the display of information  
2.5 – Illustrate through multiple media |
Instructor | Implementation choices | Checkpoints
--- | --- | ---
C2a | - Generating worksheets which have guided inquiry in writing (I) | 3.2 - Highlight patterns, critical features, big ideas, and relationships
 | - Generating widgets to practice content before class (O) | 3.3 – Guide information processing and visualization
 | | | 6.2 – Support planning and strategy development
 | | | 6.3 – Facilitate managing information and resources
 | | | 6.4 – Enhance capacity for monitoring progress
 | | | 1.1 – Offer ways of customizing the display of information
 | | | 3.1 – Activate or supply background knowledge
 | | | 5.1 – Use multiple media for communication

Figure 5 shows the averaged baseline and implementation observation scores for the checkpoints which aligned with the in-class practices chosen by each instructor. Only practices which occurred in class have scores since out-of-class practices cannot be observed with the observation protocol. In the following sections, we will discuss these results and provide instructor and student quotes to characterize the effectiveness of in- and out-of-class practices.
Figure 5: Scores for checkpoints aligned with in-class implemented practices chosen by each instructor. Error bars are standard error.

Table 10 provides our findings related to students’ perceptions of the instructor-selected practices. Students could report the same practice as any combination of positive, negative, and/or neutral since one practice could have facets that students found beneficial and others that they did not find beneficial. For example, one student made statements that “having students explain new concepts to peers” was both beneficial and neutral. Because students could potentially evaluate the same practice in multiple ways, the sum of student evaluations may be greater than the total number of students.
Table 10: Practices implemented by instructors and student evaluations of practices. Student evaluation columns denote the number of students who evaluated the practice as positive, negative, neutral, or N/A (did not discuss the practice). Values of 0 mean that no student evaluated the practice in the way denoted by the respective column. The last column gives the total students interviewed from each instructors’ course.

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Implementation choice</th>
<th>Positive</th>
<th>Negative</th>
<th>Neutral</th>
<th>N/A</th>
<th>Total # of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1a</td>
<td>Increased reminders for students to stay on task</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Using sign-in sheet for attendance</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>P1b</td>
<td>Uploading all course content online</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Providing overview slide which learning objectives and</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>structure of class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2a</td>
<td>Having students explain new concepts to peers</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Having students write down summary of main points at end</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>of each chapter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1a</td>
<td>Providing closure at end of lab on main points covered</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Allowing students to submit assignments online</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Rubrics for assignments</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>C1b</td>
<td>Generating a website with an overview of course topics</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>C2a</td>
<td>Generating worksheets which have guided inquiry in writing</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Generating widgets to practice content before class</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Instructor P1a chose to implement increased reminders for students to stay on task, including asking students to put away phones. Instructor P1a also began using a sign-in sheet to record attendance as part of student grades. We interpret the use of increased reminders and asking students to not engage with their phones to weakly align with checkpoint 7.3 (minimize threats and distractions) as it supports students in maintaining attention to the task at hand, but it does so in reaction to students who are already distracted. A practice which would have a stronger alignment with checkpoint 7.3 would be to identify sources of distractions for students and proactively design the course to support students to eliminate or mitigate these distractions, thereby supporting students to stay attentive during class (e.g., providing breaks or decreasing ambient noise in the classroom). We interpreted using a sign-in sheet to record attendance to not align with any UDL checkpoints since it does not support students receiving, engaging with, or expressing understanding of course information.

In the post-interview, instructor P1a reported that neither of these practices increased student engagement with tasks. Regarding the increased reminders for students to stay on task, Instructor P1a explained that a significant majority of the students ignored the instructors’ statements: “I just remind them [students], ‘please, be with me, practice, uh, in class,… Please don't do unrelated stuff’… but some, the bottom 10%, 15%, they just ignore you. They just pretend you are air.” Instructor P1a reported that the physical sign-in sheet increased attendance, but that many students just attended class for the attendance points and would not be engaged with the course:
“Uh, at least attendance sheet physically worked. Um, I’m able to keep most of them physically in class…Some of them just be there because they had to be there... they watch their basketball...they watch their Facebook.”

In line with instructor P1a’s assessment of the course, we did not notice a change in observation scores from baseline to implementation semester for checkpoint 7.3 (minimize threats and distractions) because we had already observed the instructor make statements reminding students to stay on task during the baseline semester. We also, anecdotally, observed that the reminders were ineffective at keeping students on task and therefore did not accomplish the intended goal.

No students in the focus group interviews talked about the instructor reminding students to stay on task. Three out of the seven students discussed the use of a physical sign-in sheet, and all three students reported this practice to be negative because they felt the physical sign-in sheet resulted in other students only showing up for attendance points, introducing distractions due to talking throughout the class about things not related to course content:

P1a_student1: “So more people are showing up for class way more, which is a good thing, I guess. But also, a lot, a lot of people that show are, like, I guess, not really doing anything, just kinda sitting there”

P1a_student2: “I sit right next to where he lectures and there are people at my table that talk the whole time, and I just have to tune it out…”
In summary, the practices P1A chose to implement had weak or no alignment to UDL checkpoints and that the instructor, researchers and students agreed that the practices were ineffective in keeping students on task.

P1b

Instructor P1b chose to upload all material presented in class in a digital format online. Previously Instructor P1b only had PowerPoints online, but in the implementation semesters the instructor began uploading videos of demonstrations and pictures of worked out solutions that the instructor performed on a document camera during class. This practice aligns with checkpoint 1.1 (offer ways of customizing the display of information) as digital documents provide customization options such as zooming into content, increasing font size, and increasing the volume of videos. Not all digital content is equally accessible, and we recommend the following references for readers interested in learning how to make digital content of varying types accessible [29,162]. Instructor P1b also chose to add an introductory slide at the beginning of each PowerPoint which provided the main topics that would be covered and how that class period would be structured. The use of this slide aligned with checkpoints 7.3 (minimize threats and distractions), 3.2 (highlight patterns, critical features, big ideas, and relationships), and 8.1 (heighten salience of goals and objectives) since it helped students identify the main points covered during each class session and helped increase the predictability of the course activities.
In the post-interview, instructor P1b reported that they were not as consistent with uploading course content online as they wanted to be: “I did not do as good a job this semester as I did the past semester…I wanna make sure that … if I do solve a problem- or make random notes on the overhead projector, that I scan those or take a picture of those and post those on, uh, [Learning Management System, LMS] and well. And I did that but sporadically, rather than every single time.” The reason instructor P1b wanted to increase the consistency of uploading content was so that students who were unable to attend class could access it and so that students who had challenges tracking information in class could engage with the content outside of class: “But if you do miss class, if you’re sick or something, you have all of the information that was in class, is on there [LMS]. Also… if you have some kind of executive function disorder and …you were having trouble following something that I was doing in class, you can go back to it and all of the notes are there, and everything is there.” Instructor P1b did not discuss the introductory slide in the post interview or comment about whether it accomplished the intended goals.

In the classroom observations, researchers documented a decrease from baseline to implementation semesters for Instructor P1b’s in-class enactment of checkpoint 1.1 (offer ways of customizing the display of information) (from 1.2 to 0.5). We likely saw a decrease in checkpoint 1.1 as we did not observe students accessing PowerPoints during class and we saw a decrease in use of the instructional technology that allowed the instructor to broadcast their screen to the computers located in front of students. However, we did observe the instructor ask the TA to take pictures of worked
out solutions ask students to record in-class demos for later upload. These latter practices constituted out of class enactment of checkpoint 1.1, so they are not accounted for in the observation scores.

During the classroom observations, researchers documented an increase in scores for checkpoints 3.2 (highlight patterns, critical features, big ideas, and relationships) (from 0.9 to 1.4) and 7.3 (minimize threats and distractions) (from 2 to 2.6) and roughly equivalent scores for 8.1 (heighten salience of goals and objectives).

While these three checkpoints related to the use of the introductory slide, we see variations in the baseline to implementation semester changes for these checkpoints because the use of the introductory slides was not consistent, and they often contained minimal information. Since checkpoint 8.1 is aligned with providing the introductory slide, the scores for 8.1 did not change because the slides were used infrequently and the slides often did not include enough information to warrant alignment with 8.1. Checkpoint 3.2 increased by 0.5 points because we noticed the instructor making more verbal statements about which topics were of key import and why. Checkpoint 7.3 increased not because of the use of the introductory slides, but because the instructor started to provide breaks throughout the three-hour class sessions.

During focus groups, three out of the four students responded positively to the additional course content being provided online (the fourth student did not discuss the practice during their interview). Students positively remarked that they used the online resources to study:
P1b_student1: “But I mean he posts, everything he does on the whiteboard, he posts on Webcourses...I look at it before the tests. That's how I study.”

One student reported that having the videos of demos online was not very important since students would not need them if they already saw the demo in class.

P1b_student2: “I watched a few of them [videos of demos]- But if you're in class and you've seen it, then it kinda sticks with you…”

Recommendations for accessible science content state that videos should have closed captioning and verbal descriptions of what is occurring [163]. The videos provided by instructor P1b did not have captioning, which may have been a barrier to access for some students, such as those who are Deaf or Hard of Hearing, but they did have verbal descriptions, which may have supported access for some students, such as those with visual or executive function impairments.

The four students interviewed from Instructor P1b’s course all responded positively to the use of introductory slides, saying that the slides helped students to identify what would be covered during the class and what activities would be included:

P1b_Student1: “Yeah, it definitely helps out. Like, um, it shows you what the day's objective is, is so then you can somewhat prepare yourself of like…”

P1b_Student 2: “You know what's gonna be going on.”
Instructor P1b was observed to have minimal enactment of their chosen practices due to limitations in the observation instrument, low frequency of enactment, and weak alignment of implemented practices to intended checkpoints. However, the students and instructor both reported that the practices occurred and that the practices were effective in supporting students. The instructor also expressed that in the future they wanted to increase the consistency of the implemented practices.

P2a

Instructor P2a chose to implement intentional time for students to explain new concepts to peers throughout each lesson and for students to write down the main points covered by each chapter. Providing opportunities for students to explain new concepts to peers aligns with checkpoints 3.4 (maximize transfer and generalization), 6.4 (enhance capacity for monitoring progress), and 8.3 (increase mastery-oriented feedback) since it supports students in monitoring whether they understand the topics. If students do not understand the topics, it allows peers to provide timely feedback and support as opposed to having to wait for instructor feedback during later activities. Instructor P2a also chose to provide an activity at the end of each chapter where students worked with their peers to document the main concepts covered in the chapter. This practice aligns with checkpoints 6.4 (enhance capacity for monitoring progress) since it gives students an opportunity to reflect on what they have learned. Instructor
P2a already implemented these practices in the baseline semester, but Instructor P2a chose to implement both practices more frequently in the implementation semesters.

In the post-interview, instructor P2a reported that the practice of having students explain concepts to their peers was effective and resulted in students conversing with their peers about the new topics covered. Instructor P2a shared that they used this practice when substitute teaching for another instructor, and that even students who weren’t used to the practice still engaged with it: “…this method [students explaining concepts to peers] really increases the participation…and even last week, I covered for a colleague…at least half of the class was, was engaged. They, they were surprised, but they were, they were engaged.” Instructor P2a did not talk about the effectiveness of having students write down the main points during each chapter.

During the classroom observations, researchers documented an increase in checkpoint 6.4 (from 1.6 to 2.3) from baseline to implementation and no change in scores for checkpoints 3.4 and 8.3. We observed an increase in the instructor prompting students to discuss new topics with peers, however the instructor already had high scores in checkpoints 3.4 and 8.3, so this increase in use did not warrant an increase in scores (since an increase in use of a practice does not result in an increased score unless that practice was rarely occurring previously). Checkpoint 6.4 increased since the second practice the instructor implemented, having students write down main points covered, rarely occurred in the baseline semester.

All four students who participated in the focus group interviews responded positively to the practice of having students explain new concepts to their peers. One of
these students also responded neutrally to the practice. The extent to which this practice was valued depended on the engagement of their peers and how much their peers understood the concept discussed. If their peers were engaged and able to contribute to the discussion, it was positive; if their peers were unengaged or unable to contribute to the discussion, then it was not seen as helpful.

P2a_student1: “…it [discussing concepts with peers] depends on like the people you’re around. ‘Cause there’s some people that just either just don’t understand the concept or don’t really care. And then like for, I would say for this class I was surrounded by people that were very like readily engaged, like, uh, active learners. So like I... we were both able to actually like understand concept. But I know there’s some like groups behind me that are just kind of like chilling.”

The same student reported how they wished this practice had been used more, especially when more complex topics were covered.

P2a_student1: “…if it [discussing with peers] was maybe something a little later in the chapter where it gets like adding stuff in together, it would be more helpful.”

All four students responded negatively to the practice of writing the main points at the end of each chapter since no feedback was provided for this assignment, leading students to feel like it was busy work.
P2a_student2: “…’cause also like at the end of each chapter, he would make our groups do a summary of everything we learned. I felt like to me that was busy work… I assume it's just a way to record attendance or something…”

From observations we found that instructor P2a’s chosen practices were enacted consistently and did align with the intended checkpoints. Since both practices were already occurring, we either saw no change (for checkpoints that high baseline scores) or an increase in scores. The instructor and students both reported that having opportunities for students to explain new concepts to their peers was effective as it engaged the students with the content and supported students in monitoring their learning and addressing areas of confusion. Having students write the main points was negatively by students due to a lack of feedback.

C1a

Instructor C1a chose to implement a discussion at the end of each class where students would discuss their lab results and Instructor C1a would highlight the main points students learned from the lab. This discussion aligns with checkpoint 8.1 (heighten salience of goals and objectives) since the discussion highlights the goals and objectives of each course. Instructor C1a also allowed students to submit assignments done outside of class online, whereas previously these assignments could only be submitted on paper. Allowing students the option to submit assignments online aligns
with checkpoint 4.1 (vary the methods for response and navigation) since this practice provides options for how students provide completed assignments. Lastly, instructor C1a provided rubrics for assignments detailing how students earned points on assignments which were done outside of class. Providing these rubrics aligns with checkpoint 6.4 (enhance capacity for monitoring progress) since a rubric supports students in determining if completed work meets expectations.

In the post-interview, instructor C1a reported that students reported that the option to submit assignments online was beneficial since it allowed them to receive feedback before future quizzes which were based on the graded assignments: “I know that they [students] liked getting their grades back online. Um, I did have a couple of students who expressed concern because they weren't getting their grades back before the quiz. Um, but there is not much I can do about that when you don't submit your assignment until two hours before lab starts.”

Instructor C1a also shared that they perceived the rubrics to be effective since they supported students in determining why they received a specific score on an assignment: “the rubrics were designed to let them know like, what I was looking for to get full points on a question, so the rubrics are just like, full marks, comments with partial credit and no marks … at least they [students] knew like, where they were missing points. Like, if they didn't do a problem, they knew exactly how many points they were gonna miss.” Instructor C1a did not comment about the increased discussions at the end of each class.
The researchers did not document a change in enactment of checkpoint 8.1, which we aligned to the end-of-class discussion; however, instructor C1a’s scores were already near the maximum score possible for this checkpoint. We did observe the instructor spending significantly more time at the end of class discussing the lab results and their significance with the class. Instructor C1a also implemented new practices to facilitate the discussions, such as having each group explain their results or having students be the ones to explain what the findings represent. The changes in how discussions occurred lead to a slight increase in scores, and we would have seen a higher change in scores had the baseline scores not already been near the maximum. The practices instructor C1a chose to implement that were aligned to checkpoints 4.1 and 6.4 mostly occurred outside of class, so we are unable to see the effects in the observation data.

All four students who participated in the focus group interviews responded positively to the discussions at the end of class. Students expressed how the discussions helped them identify the main points and what will be needed for future assignments and assessments:

C1a_student1: “So she kind of gives us, like, a heads up. Okay, you need to know this, this is important.”

C1a_student2: “I think that helps more with, like, studying because you can, like, know exactly what you have to look for. And that, like, helps you remember it in the long run. I like when teachers do that, like when they just tell you what they want.”
Only one student made a statement about the rubrics and no students made statements about the option to submit assignments online. Regarding the rubrics, the one student expressed a neutral response about how the rubrics had insufficient information to help students identify what needed to be included in the assignment. The rubrics did not result in any detriment, but it also didn’t support the student.

C1a_student1: “We do have a rubric, but it's usually, like, each title was there…It's not, like, this is what we’re expecting or anything.”

Instructor C1a implemented the highest number of practices out of all instructors, and we did observe a high enactment of the one practice which occurred in class (i.e., providing closure at the end of lab on main points covered). Instructor C1a reported in the interviews that the out of class practices were occurring, but only one student commented on one of the two out of class practices (i.e., rubrics for assignments). All students reported that the end of class discussions were effective for reasons which matched the aligned checkpoint (8.1), but the one student who commented on the rubrics reported that the rubrics were not useful.

C1b

Instructor C1b developed a website which presented an overview of the topics covered in the course, including specific pages for each lab with the relevant concepts
and equations, a guide about how to write their lab report, and miscellaneous pages which covered items such as how to cite sources, and how to structure a lab notebook. Providing the website enacted checkpoints 1.1 (offer ways of customizing the display of information), 2.5 (illustrate through multiple media), and 3.2 (highlight patterns, critical features, big ideas, and relationships) since the information was in a customizable digital format, included a mixture of visuals and wording, and highlighted the main concepts students needed to know.

In the post-semester interview, instructor C1b reported that most students did not make use of the website, which the instructor believed was because the website was separate from the LMS for the course: “people didn't utilize that [website] as much. And I thought that would have mainly to do with the fact that, when it's on [LMS], everything is very centralized so it's easier for them to access than it is for them to go to an offsite- I've seen a couple people were citing it [website], so I know some people use, utilized it in in their lab reports and things like that.”

Since students were not allowed to use computers in the chemistry lab, they would only have access to the website outside of class. Thus, our observation protocol did not capture this practice.

Only one student was interviewed from Instructor C1b’s course and this student reported that they did not ever make use of the website, even though they knew it existed. They reported that this was because they were more comfortable with using Google to answer their questions:
C1b_student1: “I’ve never used it [website]…I just usually just go to Google…Google’s just what I’m used to.”

When the student was asked if they knew how to access the website, they reported uncertainties about how to access the website:

Interviewer: “Okay. Um, and would you even know how to get to this website?”
C1b_student1: “Weebly [name of website host] in the Google Search Engine? (laughs) I don’t know.”

Instructor C1b only chose one practice and it occurred outside of class so we were unable to observe it; however, we were able to visit the website and confirm that it existed and included the course content as described. Instructor C1b and the one student interviewed both reported that students knew of the website, but that it was mostly unused.

C2a
Instructor C2a worked with the lab coordinator to develop worksheets that to scaffold the guided inquiry process in written form (i.e., the worksheets included open-ended questions that guided students in developing a lab procedure and recording data). For example, the worksheets would prompt students to determine what variable they needed to calculate to answer the key question, what variables they could actually
measure with the given lab equipment, and what equations would allow the students to convert the measured variables to the desired variable. The use of written guided inquiry questions and data organizers in the worksheets aligns with checkpoints 3.3 (guide information processing and visualization), 6.2 (support planning and strategy development), 6.3 (facilitate managing information and resources), and 6.4 (enhance capacity for monitoring progress) since the worksheets helped students monitor their planning and progress and record data.

Instructor C2a also generated widgets (i.e., online graphical interfaces) on the online LMS that allowed students to check their understanding of prerequisite knowledge and practice areas of difficulty. The use of these widgets aligns with checkpoints 1.1 (offer ways of customizing the display of information), 3.1 (activate or supply background knowledge), and 5.1 (use multiple media for communication) since the widgets were available in a customizable digital format, supported students in checking their prerequisite knowledge, and were in an interactive graphical format, which provided an alternative to the traditional written information.

In the post-interview, instructor C2a reported that the worksheets were beneficial since they reduced student confusion and reduced the time other groups needed to wait to talk to the instructor, “it [helped] the instructor to not have to be, spend five minutes here, and then the other people have to wait…. I think with the worksheet it did work pretty well, because, you know, they [students] get in, they got in their groups, and they didn’t really have to be after me.” There were some initial challenges with the worksheet, but Instructor C2a reported that they were able to identify how the worksheet
needed to be improved as the semester proceeded, “But, after a while, I think I even started catching what we should start changing and not changing…I would notice the same pattern in every, every lab, and then I would be like, "I think this has to be changed."

Instructor C2a also reported that they asked the students if they found the widgets to be helpful, and received mostly positive and some mixed feedback: “I, asked in class, ‘Did you find them [widgets] interesting, or helpful?’ Some people said, ‘yes,’ a lot of people said, ‘yes,’ and a lot of people say, ‘no, I don’t even know they existed.’… ‘I didn’t even know they were there.’ or some people say, ‘no, we don’t like them.’”

During observations, researchers documented an increase from baseline to implementation in the checkpoints aligned with the guided worksheets; checkpoints 3.3, 6.3 and 6.4 were scored as 2 or higher in the implementation semesters and checkpoint 6.2 was scored above 1.5. This was partly due to the implementation of guided worksheets and partly due to the TA increasing their use of verbal guided inquiry. The increase in verbal guided inquiry was likely due to the TA developing improved skill for applying guided inquiry, especially since their baseline semester was the first semester they taught the lab. From the baseline to the implementation semesters, checkpoint 3.3 increased from 1.4 to 2.9, checkpoint 6.2 increased from 0.75 to 1.6, checkpoint 6.3 increased from 2.5 to 2.75, and checkpoint 6.4 increased from 1.5 to 2. The second practice implemented by the instructor, generating widgets to practice content before class, occurred outside of class and therefore could not be scored using the observation instrument.
Only one student was interviewed from Instructor C2a’s course. This student reported that the worksheets were beneficial as they supported students in understanding the purpose of the experiment and designing procedures to accomplish intended goals.

C2a_student1: “Those [worksheets] actually helped you, like, guide through how to get through the experiment… It guided us towards like how to understand the experiment and get to … the experiment done.”

The student reported that they noticed the widgets, but that widgets were not available for every lab. The student shared that the widgets were useful, but it was not a concern if the widgets were unavailable.

C2a_student1: “I think I did them [widgets], the two times I saw them…I remember there was one where I was naming the glassware and I didn't know which one was which, so, it was helpful in class the next day… but like if there was a widget and I didn't see it then I didn't really care (laughs) if I did it or not.”

The use of the guided worksheets by C2a occurred frequently and we observed the worksheets to be aligned with the intended goals. C2a and the students reported that the worksheets were beneficial for reasons which also aligned with intended goals, specifically that the worksheets supported students in planning and monitoring their
progress. We were unable to observe the widgets, and C2a and students reported mixed use of the widgets. The one student participant reported the widgets were either beneficial or neutral for supporting students in monitoring their learning.

Summary and take-aways

Enactment of UDL checkpoints before professional development

Before professional development, only a few checkpoints (2.1, 2.2, 3.3, 6.3, 8.3) were observed to have a high enactment in the physics courses and chemistry labs. These included checkpoints which we would expect in all STEM courses, such as defining vocabulary, symbols, and equations (2.1 and 2.2). Additionally, some of the highly enacted checkpoints align with recommendations for research-based active-learning instructional strategies, such as group work (8.3) and supporting students in actively reasoning through problems (3.3) [164]. However, we do not see high enactment of checkpoints that align with other recommendations for research-based active-learning instructional methods, such as posing questions in a wide variety of contexts and representations (7.2). Thus, there are some pre-existing areas of UDL enactment in postsecondary STEM courses, and these areas typically align with previous research-based recommendations.

While we see higher scores in checkpoints related to providing supports, we see lower or medium scores in checkpoints related to providing options, autonomy and flexibility. Many UDL checkpoints are not represented in recommendations for research-based curriculum [164], especially in areas related to providing options for how students
can engage with a course. This could be the reason for low enactments in areas such as customization of digital information and a lack of options for students engaging with and expressing their understanding.

When comparing across disciplines, we find that physics courses and chemistry courses had differing enactment of checkpoints 1.1 and 8.1. These findings reveal that there can be logistical and safety barriers to UDL implementation, and that inclusive practices are supported in implementation through consistent enactment. The logistical and safety barriers were outside of instructors’ control, lending evidence to the claim that inclusive practices also rely on other instructional stakeholders, such as department and university administration. We argue that these should not be seen as insurmountable barriers, but rather administrators and instructors should collaborate to develop creative solutions that maintain safety while providing a setting where all students can be included and supported.

The differences across instructors reveal that even within the same courses, instructors have the autonomy to implement practices that increase or decrease inclusivity. The lower scores for the instructor who provided extensive lectures reveals that lecture can limit the options and supports necessary for inclusivity. The higher scores for the instructor with a variability of learner’s mindset reveal that having the variability of learners’ mindset leads to considerations and implementations of practices which support students who fall outside the “average” student. Teacher beliefs affect the practices implemented in a course [165], and we argue that instructors who adopt a variability of learners mindset are better equipped to identify how to reduce disabling
course practices and increase supportive course practices. We expect instructors will further be supported in creating inclusive courses if they adopt the social model of disability, which positions course structures (rather than students) as the source of disability.

Previous studies which investigated the alignment of UDL checkpoints to physics [95] and chemistry [94] research-based written curricular materials show varying agreement with our results. For example, we see that checkpoint 2.1 was highly enacted in our investigation and in physics and chemistry curriculum since vocabulary and syntax was well defined in all contexts. However, checkpoint 6.3 is highly enacted in our investigation, somewhat enacted in the chemistry curricular materials, and not enacted in the physics curricular materials [94,95]. The differences in the enactment of checkpoint 6.3 are due to differences in the extent to which data organizers were provided for students in the varied contexts. The courses we observed constituted all the dynamic complexities found in a classroom, including how students are presented different types of new content, the variety of activities students engaged with to practice content, feedback provided throughout presentation and engagement, and how students interacted with peers and instructors. The flexibility of in-class sessions contrasts with written curricular materials which is more static and typically does not include feedback or interactions with others. The differences in content accounts for some of the variation in our findings, with the remainder likely being due to variations in how instructors choose to teach their courses. With these differences in mind, we argue that every aspect of a course doesn’t need to align with every UDL checkpoint, rather
the concerted course structure, resources, and design should together consider and strive to be accessible and inclusive.

*Effectiveness of implemented practices after UDL professional development*

The practices instructors chose to implement were unique for each instructor and were chosen based on instructors’ interest and what they felt was accomplishable. Implemented practices were chosen to support students in staying engaged with tasks, identifying the goals and objectives of each class, accessing content before and after class, monitoring learning, and planning how to engage with tasks. Only checkpoint 6.4 (enhance capacity for monitoring progress) was enacted by practices selected by three separate instructors. This variation in practices chosen reveals that instructors have differing ideas and values for which inclusive practices should be implemented first. One facet of the difference in practices is the level of effort required, revealing that it is important to consider effort and time when working with instructors to make their courses more inclusive [88]. We also see that some instructors chose to implement practices that aligned with checkpoints that already had high enactment before professional development. One potential reason for this is that instructors may encounter challenges in identifying and/or implementing practices that align with checkpoints that aren’t already being enacted in their courses. Researchers should continue investigating which UDL checkpoints have low enactment in STEM courses and develop examples of practices that address checkpoints with low enactment.
We found varied levels of enactment and reports of effectiveness of the implemented practices. Various factors influenced the levels of enactment measured by our observations, including how aligned the practices were with the UDL checkpoints, the consistency of implementation, and the breadth of implementation. The effectiveness of implementation, measured by instructor and student interviews, also varied and was influenced by the levels of enactment of practices, whether students individually needed supports in the areas targeted, and whether students were able to identify the purpose of the implemented practice.

While we appeared to meet the conditions for the CAMCC (intervention framework), we see that believing in a pedagogical framework does not necessarily lead to effective implementation of the framework. In Ebert and Crippen’s (2010) paper about the CAMCC, they recommend providing instructor reflection, but this reflection is to “…achieve conceptual change” [p. 386] in instructors, not to evaluate if practices are achieving the intended goals [166]. We agree that believing in a framework is the first step necessary for successful implementation, but we also find that effective implementation of new inclusive practices requires consistency of implementation and reflections and evaluation regarding whether the enacted practices are accomplishing the intended goal. A literature review by Henderson et. al about the necessary components for effective pedagogical change in postsecondary STEM also found that reflection on the effectiveness of implemented practices is a critical component of achieving intended goals [167] and though we sought to implement these kinds of reflection in our monthly meetings with instructors, we find that our meetings were
insufficient in supporting the necessary reflection. One reason for this may be that we did not perform the analysis of the observation data from implementation semesters until after implementation ended, and therefore we were unable to provide this data for instructor’s consideration. Future professional development should seek to provide data-based feedback throughout implementation to support instructors in monitoring their pedagogical changes.

Recommendations for instructors

Implementing inclusive practices based on the UDL framework is a challenging endeavor in part due to the lack of operationalization of UDL checkpoints within specific contexts (e.g., postsecondary STEM) and in part due to a lack of awareness about what aspects of courses disable students from equivalent access. We recommend readers who are interested in implementing UDL in STEM contexts review Appendix A and Appendix D as we provide examples of instructional practices and how they align to our observation items and to UDL checkpoints. We do not consider this an exhaustive list, but as a starting point for ideas about how courses can be made more inclusive. For further recommendations and examples of STEM specific practices and strategies, we encourage readers to review the following references [19,137-140].

We also recommend readers begin the process by choosing only a few areas to start with. Designing a course to be inclusive can be a time intensive task and, as seen in our findings, not every implemented practice will result in success. An iterative process is necessary to refine practices, and this process takes time and intentionality. To identify
a starting point, some options include reflecting on the design of courses using the UDL checkpoints and our provided operationalizations, or referring to our observation data in this paper and choosing checkpoints that we observed to have low enactment [168].

Limitations and future research

One limitation of this study is that the observation instrument did not have alignment to every UDL checkpoint. Future research should refine existing tools, such as the UDL-OMT, to include every checkpoint or develop new tools which cover every checkpoint. In the latter case, we believe tools for measuring UDL implementation should be content-specific since the operationalization of UDL varies within different content areas (such as STEM versus social sciences).

Our study also predominantly investigated the enactment of UDL checkpoints in class. Future research should investigate the entirety of practices instructors implement outside of class and how the practices align to UDL checkpoints. This could be done through some combination of surveys, interviews, and/or document analysis. A key component of these investigations should be where content is provided to students (e.g. learning management systems) and if it is in an organized and accessible format [169].

Because we were unable to recruit students with disabilities for our interviews, we were unable to evaluate if the implemented practices supported students with disabilities. Future research which seeks to investigate the implementation of UDL should prioritize feedback from students with disabilities to ensure that any course changes are supporting the intended population.
Another limitation is that the analysis assumes that all checkpoints should be observable in each class. This is not the case as some checkpoints may more commonly occur in course structures which occur across multiple courses or outside of the class. Future work which seeks to use the UDL framework to investigate the inclusiveness of a course should keep this in mind and use data sources which capture course structures which extend across individual classes.
CHAPTER 8: CONCLUSION

Research question 1

Research Question 1 sought to investigate the supportive or disabling experiences students with disabilities had in postsecondary STEM courses. We also proposed a sub-question about whether students of differing diagnoses encountered differing supports or barriers. Since the supports and barriers are so strongly tied to the varying diagnoses, we present our findings and discussion for both Research Question 1 and the sub-question for Research Question 1 together.

In our first and second study, we interviewed students with disabilities to investigate students’ diagnosis characteristics and how course structures disabled or supported students due to interactions with students’ diagnosis characteristics. The first study specifically investigated the experiences of students with ADHD, and this allowed us to investigate whether students with the same diagnosis reported similar diagnosis characteristics and supportive or disabling experiences. The second study included students from a variety of diagnoses, and this allowed us to investigate whether students from differing diagnosis reported similar supportive or disabling experiences, and if these experiences arose for the same or differing reasons.

From the first study, we did find that there were consistencies in how students understood their diagnosis of ADHD and that organization was highly valued but could be hindered by lack of course organization. However, from our second study we found that students with varying diagnoses reported varying diagnosis characteristics and varying course practices which were important for their success. such as access to
course content in succinct formatting, access to course content at beginning of course, and supports for forming study groups. The first study also revealed that students with disabilities understand their diagnosis characteristics through comparisons to others.

Since disabling barriers arise from courses not being designed in a way to support students’ diagnosis characteristics, differing diagnosis characteristics resulted in differing interactions with course structures. For students with ADHD, the most common barrier was a lack of course organization, which disabled students from using organizational strategies. In our second study, we identified a multitude of barriers including the requirement to listen and write notes simultaneously and a lack of access to course information outside of class. The barriers in both studies resulted in students being disabled from effectively learning content and could result in students having to withdraw from courses. Students also reported that anxiety was a common result of these disabling experiences.

Students reported that disabling barriers were often heightened in STEM courses compared to non-STEM courses. Barriers were identified as “heightened” based on students reporting more severe consequences in STEM courses versus non-STEM courses. The most noted barriers across both studies were a lack of sufficient time on assessments and a lack of resources and guidance for how to effectively engage with course content in and out of class. Across both studies, students reported that the extra test time accommodation largely alleviated concerns from insufficient time on assessments, however the use of the extra test time accommodation could risk the students losing confidentiality regarding their diagnosis and accommodation use. The
loss of confidentiality was feared due to disability stigma which students either perceived to exist or had experienced from peers or instructors. Barriers effectively engaging with course content arose from a lack of access to content outside of class and a lack of guidance concerning how to effectively engage with STEM course content. The consequence of these barriers was the same as the consequences in non-STEM courses, however because the barriers were heightened, the consequences also increased in severity (e.g. higher anxiety and lower scores).

Research question 2

Research Question 2 aimed to describe the practices and strategies used in STEM courses and labs and the alignment between those practices and UDL recommendations for inclusive practices.

We found some UDL checkpoints with high enactment, specifically in areas of defining vocabulary, supporting students in processing information, and group work. Checkpoints with low enactment were often with regards to providing options, autonomy, and flexibility regarding how to engage with the course. This reveals that STEM courses are enacting some UDL checkpoints, but there are also many areas where STEM courses can do a better job of being inclusive.

When comparing across courses, we see differences in areas regarding access to customizable information and heightening the salience of goals and objectives. The difference in access to customizable information was due to logistical and safety constraints of chemistry courses restricting the use of technology, whereas the second
difference was due to the chemistry courses utilizing a key question for each lab which emphasized the purpose of the day’s activities. These findings reveal that there can be logistical and safety barriers to UDL implementation, and that inclusive practices are supported in implementation through consistent enactment. The logistical and safety barriers were outside of instructors’ control, and so this lends evidence to the claim that inclusive practices also rely on other instructional stakeholders such as departments and university administration. These barriers should not be seen as insurmountable barriers, rather administrators and instructors should collaborate to determine creative solutions which maintain safety, but also provide a setting where all students can be included and supported.

Difference across instructors emerged across a variety of checkpoints, with no clear trends appearing for the types of checkpoints that differed. The reason for the differences occurred due to differences in teaching styles and mindsets. One instructor had particularly low scores across UDL checkpoints due to a teaching style which consisted of extensive lecturing. Alternatively, one instructor had particularly high scores due to the mindset that there are a variability of learners and course practices should support this variability. We find that lecturing can potentially introduce barriers to inclusive practices since it limits the scope of options and supports which can be provided. A variability of learners mindset however can support the implementation of inclusive practices.
Cohort’s enactment of UDL compared to experiences reported by students with disabilities

A sub-question of Research Question 2 was how areas of low enactment of UDL compared to the barriers identified from the interviews of students with disabilities. As a reminder, students with disabilities reported that STEM courses introduced barriers including insufficient time on tests, the requirement for students to listen and take notes simultaneously, a lack of access to course information outside of class, a lack of course organization, and a lack of resources and guidance for how to effectively engage with course content in and out of class.

The barrier of insufficient time on tests emerged due to a lack of flexibility in timing or type of assessments offered. UDL checkpoint 4.1 (vary the methods for response and navigation) provides recommendations which address the barrier of having timed restrictions on tests, however this checkpoint is not aligned with any items in the observation protocol due to how we operationalized observation item C2 (provides access to a variety of tools and/or technologies that allow students to express their understanding). Observation C2 is the most closely related to checkpoint 4.1, but we operationalized C2 to mean that instructors had students present understanding using a variety of mediums (e.g. whiteboards, lab notebooks, excel spreadsheets) and therefore we aligned C2 to checkpoint 5.2 (use multiple tools for construction and communication). Anecdotally we did observe that timed tests were the main source of assessment for every physics course, whereas the chemistry labs mostly relied on in-class participation and outside of class lab reports for grading. Based on the anecdotal findings, we do see that timed tests are commonly used as a main source of
assessment, but that this introduce barriers. However, the lack of tests in chemistry labs reveal that timed tests are not the only way to assess understanding.

The requirement for students to listen and take notes simultaneously, the lack of course information outside of class, and the lack of course organization can be collapsed into the barrier that course content was not being provided outside of class in an organized fashion. These practices most align with checkpoint 1.1 (offer ways of customizing the display of information). Providing content online in an organized format is a course structure which occurs outside of class, and since our observations were limited to in class practices, we are limited in our capability to make comparisons to our observation data. However, we were able to observe whether students could access course content on digital devices, and this provided some measure of checkpoint 1.1. From our observations, we saw that physics instructors had low to medium low enactment of checkpoint 1.1, with content such as in-class worked out solutions often being in a format (e.g., writing on whiteboard or a piece of paper) which was not converted to a digital version. Limitations from the observation instrument do not allow us to measure how organized course content was nor is there a UDL checkpoint which has a strong alignment to the practice of providing course content in an organized fashion. The combination of these findings reveals that course content is not always provided in a digital format to students and that this can introduce barriers to students learning outside of class.

The lack of resources and guidance for how to effectively engage with content in and out of class is a more complex barrier than the others identified. Recommendations
which would address this barrier are represented in checkpoints 3.3 (guide information processing and visualization), 5.1 (use multiple media for communication), 5.3 (build fluencies with graduated levels of support for practice and performance), and 6.2 (support planning and strategy development) since all of these checkpoints are about supports and options for how to work with course content. We see a high enactment of checkpoint 3.3 and medium to medium-low enactment of checkpoints 5.1 and 6.2. Checkpoint 5.3 is not covered by the observation protocol due to this checkpoint including practices and strategies which occur across multiple class sessions. These findings reveal that while courses may implement some practices which support students in engaging with content, these supports are potentially not extensive enough to provide necessary support for students. Alternatively, the students interviewed may have had instructors who had less enactment of these checkpoints than the instructors we observed.

*Enactment of UDL checkpoints in-class versus in written curriculum*

The last sub-question for Research Question 2 investigated how the enactment of UDL measured by our in-course observations compared to previous studies about the enactment of UDL in research based physics [95] and chemistry [94] written curriculum. One of the limitations documented in these previous studies were that written curriculum doesn’t include all of the facets of teaching in-person. Since we analyzed the enactment of UDL checkpoints for in class sessions of STEM courses, we believe it’s useful to compare our findings to the curriculum studies to generate a more
complete evaluation of whether STEM courses are enacting UDL checkpoints. We separate our findings into physics and chemistry as we observed physics and chemistry courses, and the previous studies about written curriculum were also separated into physics and chemistry curriculum. The exception to this is we found that there were consistent areas of low enactment of a few checkpoints in physics and chemistry across the in-class observations and the analysis of written curriculum. We present these low enactment checkpoints in a final subsection.

Because we split our dataset into physics and chemistry, we define “high enactment” of checkpoints as two out of three instructors having scores in the checkpoint of 2 or higher. Similarly, we define “low enactment” of checkpoints as two out of three instructors having scores in the checkpoints of 1 or lower. For high and low enactment in the written curriculum papers, we consider classifications of “high” or “some” as high enactment and classifications of “low” or “none” as low enactment.

In Appendix J we provide a table which identifies how every checkpoint was ranked (i.e., high, low, or neither) in the physics and chemistry observations and written curriculum analysis.

**Physics**

Checkpoints 2.1 (clarify vocabulary and symbols) and 8.3 (foster collaboration and community) had high enactment in our physics observations and in the written physics curricular materials. This suggests that the practices of defining vocabulary and
encouraging students in group work are prevalent in postsecondary introductory physics education.

Many checkpoints had low enactment in both the physics observations and written curricular materials; these checkpoints also had low enactment in both the chemistry observations and written curricular materials, so we will discuss them in section 6.3.3.

Checkpoints 2.2 (clarify syntax and structure), 3.3 (guide information processing, visualization, and manipulation), 3.4 (maximize transfer and generalization), and 6.3 (facilitate managing information and resources) had high enactment during in-class observations and low enactment in written curricular materials. One potential reason why checkpoints 2.2, 3.3, and 3.4 are higher during in-class observations is that instructors can observe student difficulties in real time during class and make modifications to course-level barriers to make the course more inclusive. Once barriers are identified, instructors have the flexibility to make dynamic changes, whereas written curricular materials are in a static form. Examples of how instructors responded to these barriers include providing additional information such as how variables connect in formulas (2.2), providing specific guidance and instructor for how to engage with problems on a group or individual level (3.3), and providing connections to other course content or real-world applications of concepts (3.4). These practices could also occur in written curricular materials, but the previous analyses found that they did not occur in the physics curriculum analysis. We believe checkpoint 6.3 varied in part because our in-class observations also included an operationalization of instructors supporting
students receiving physical equipment, and this operationalization was not included nor applicable to written curricular materials. However, we also observed instructors providing data organizers, whereas the written curricular materials had low enactment of 6.3 due to a lack of data organizers. Only checkpoint 3.2 (highlight patterns, critical features, big ideas, and relationships) had high enactment in written curricular materials and low enactment in during in-class observations. We rarely observed instructors spending class time detailing what the main purpose of the lesson was, whereas written curricular materials had the main goals and learning objectives in writing at the beginning of each activity. Instructors may believe that presenting and engaging with the lesson's content is sufficient for students to identify the main ideas and critical features, but we argue that explicit identification of the main points better supports students with disabilities.

Chemistry

Checkpoints 2.1 (clarify vocabulary and symbols), 3.2 (highlight patterns, critical features, big ideas, and relationships), and 6.3 (facilitate managing information and resources) had high enactment in both the chemistry observations and written curricular materials. This suggests that practices such as defining vocabulary (2.1), highlighting critical features (3.2), and providing data organizers (6.3) are common in postsecondary introductory chemistry education. Checkpoint 3.2 was enacted highly in different logistical ways; specifically, during the in-class observations, we observed instructors providing a key question to highlight the main ideas, whereas the written curricular
materials used formatting such as bolding and underlining font to highlight key wording and vocabulary. Checkpoint 6.3 also had differences in enactment. In-class observations and written curricular materials both provided data organizers, and in-class observations additionally supported students by providing guidance for where to locate physical items (labels for cupboards and drawers and instructor directing students to where to find equipment).

Checkpoints with low enactment in both the chemistry observations and written curricular materials will be discussed in section 6.3.3.

Only checkpoint 8.1 (heighten salience of goals and objectives) had high enactment during in-class observations and low enactment in written curricular materials. Checkpoint 8.1 was high in in-class observations due to a wrap-up activity at end of each laboratory session, whereas the written curricular materials did not have the goals in writing, nor did they have opportunities for students to determine if goals were achieved. Two checkpoints, 1.3 (offer alternatives for visual information) and 6.2 (support planning and strategy development), had high enactment in written curricular materials and low enactment during in-class observations. Checkpoint 1.3 had low enactment during in-class labs since instructors rarely provided visual information and when visual information was provided verbal descriptions were minimal. Checkpoint 6.2 was low for in-class labs since the instructors did not provide many options for how students could accomplish labs in the baseline semester; however, this changed in the implementation semesters and scores increased for checkpoint 6.2 to above or around 2. Overall, we do not see many variations between the checkpoints with high and low
enactment for in-class observations and written curricula, revealing strong alignment between the pedagogical principles enacted across these two modalities.

**Across physics and chemistry**

Checkpoint 2.1 (clarify vocabulary and symbols) had high enactment in both disciplines and both in-class observations and written curricular materials, indicating that postsecondary introductory physics and chemistry instruction emphasizes defining vocabulary.

Only checkpoints 2.3 (support decoding of text, mathematical notation, and symbols) and 2.4 (promote understanding across languages) had consistently low enactment during in-class observations, based on our criteria of two out of three instructors having scores below one. This low enactment suggests a need to increase the supports provided to students in postsecondary STEM courses to learn about vocabulary. Checkpoints 8.2 (vary demands and resources to optimize challenge) and 9.3 (develop self-assessment and reflection) were also low in almost every area, although physics instructors just barely had scores over 1. The low enactment of checkpoint 8.2 reveals that all students are often expected to accomplish the exact same task in the same way with the same resources. Instead, instructors should encourage options and flexibility for the process, goal, and resources related to activities. The low enactment of checkpoint 9.3 reveals that students are not being supported in monitoring their learning, and that STEM instructors and content should include prompts and activities which explicitly have students reflect on whether they are
achieving learning goals. If students are not achieving learning goals, STEM courses should have practices and strategies which support students in addressing areas of concern.

While there are some differences, physics and chemistry in-class observations and written curricular materials only have a few checkpoints with high enactment. The lack of enactment of UDL checkpoints reveals that there are substantial changes which must be made to increase the inclusiveness of STEM courses. The fact that there are differences in the enacted checkpoints across modalities reveal that in-class sessions and written curricular materials lack a unified framework for making learning inclusive. Neither our study nor the written curricular studies investigated accessibility in-depth and so we cannot make strong claims about the existing levels of accessibility. The lack of research about the accessibility of STEM courses or curricular materials and the lack of instructor knowledge about how to make materials accessible supports the argument that it is unlikely that existing materials are provided in an accessible format.

**Research question 3**

We proposed Research Question 3 to investigate the effect and effectiveness of working with instructors to implement new practices which align with UDL recommendations.

In our third study, we worked with physics and chemistry instructors to implement new inclusive practices after providing professional development in UDL and the experiences of students with disabilities. Instructors chose practices based on areas
they desired to improve in their courses, and we found that no two instructors chose the same practice to implement. Examples of practices implemented included ensuring all in-class course content was available online, providing online supports before class to review and practice content, and providing whole class discussions on the main topics covered during each class. From observations of the courses, we found variations in the enactment of the new practices and this led to the scores for UDL checkpoints not always increasing. From instructor and student interviews, we found variations in perceived effectiveness of the new practices. Effective practices were ones which were consistent and were evaluated to achieve the intended goal, whereas ineffective practices were inconsistent and did not achieve the intended goal.

*Implemented practices versus barriers identified by students*

A sub-question for Research Question 3 was whether the new practices instructor implemented addressed barriers identified by students with disabilities. As a reminder, the barriers identified by students include insufficient time on tests, a lack of access to course content in an organized fashion outside of class, and a lack of guidance for how to effectively engage with course content in and out of class.

No instructors implemented practices which addressed the barrier of insufficient time on tests. Example of practices which could have addressed this barrier would be providing a variety of alternative assessments to assess understanding or providing flexibility for the timing to complete tests.
Instructor P1b, C1b, and C2a all implemented practices which addressed the barrier of a lack of access to course content in an organized fashion outside of class. Instructor P1b began providing all in-class course content online and also provided this information in organized folders. Instructor C1b provided a website which included all of the topics covered in the course in pages in an organized format which had the relevant topics included in webpages for each week’s lab. Instructor C2a provided widgets to students in the courses learning management system which included practice problems for important information covered in each week’s lab. These differing practices reveal that instructors agreed that the lack of access to course content in an organized fashion outside of class was an important barrier to address and that there are multiple ways in the barrier can be addressed.

We did not observe any instructors implement practices which addressed the barrier of a lack of guidance for how to engage with content in and out of class. Examples of practices which could address this barrier include spending class time on how to effectively study provided resources (book, PowerPoint slides, worksheets) or emphasizing how in-class activities provide models for how students can effectively study outside of class.

**Limitations**

The first limitation of this dissertation is that all data was collected from one four-year research intensive, large, south-eastern USA institution. Therefore, we cannot say that the findings from our interviews with students with disabilities or our observations
and professional development of instructors are generalizable to all institutions. This is especially true for institutions which have drastically different structures and cultures, such as community colleges, institutions in other countries, or liberal arts institutions.

Another limitation is that our sample sizes are small, with only twelve students with disabilities and six instructors included across all studies. Therefore, our studies do not provide strong generalizations for the experiences of all students with disabilities in STEM courses, the enactment of UDL checkpoints in all STEM courses, or the breadth of practices STEM instructors may choose to implement after UDL professional development. Rather, our findings provide a starting place for considering what barriers may exist for students with disabilities in STEM courses and highlighting how UDL can provide a useful framework for both characterizing the inclusiveness of a course and supporting instructors in making their courses more inclusive.

A third limitation is that our third study was unable to measure the enactment of every UDL checkpoint for every aspect of a course (e.g. in and out of class course structures). This means that there could have been higher enactment of checkpoints than we observed, but we were unable to record this information since the enactment occurred outside of class or across class sessions.

Another limitation is that we did not specifically investigate accessibility of online content and whether the existing levels of accessibility supported students with disabilities. As mentioned previously, we define accessibility to mean whether content is physically usable by individuals. In studies 1 and 2, we found that having course content online is beneficial for students with disabilities, but not all online content is equally
accessible. The consequence is that even if course content is provided online, it may be provided in a way which isn’t accessible, i.e. physically usable, by students. Additionally, in study 3 we did find that some instructors implemented practices which resulted in content being online, however we did not investigate the accessibility of this uploaded content or whether all students were physically able to use the resources.

The last limitation we wish to highlight is that we only present a few barriers for students with disabilities and our list of recommended practices is by no means exhaustive. We only present a few barriers in part due to limitations from the IPA framework, which seeks to identify commonalities across participant findings, and in part due to our small sample size. While we provide extensive examples of STEM-specific practices which STEM instructors can implement to increase inclusivity in the manuscript and appendices, this list is not complete, nor will it ever be complete. We still highlight that our list is not exhaustive as encouragement for instructors and researchers to never stop exploring what new practices and strategies can be implemented to support students with disabilities.

**Future work**

In response to the limitations and findings identified, we provide the following recommendations for future research.

First, researchers should investigate the experiences of more students with disabilities in STEM courses from a variety of diagnoses at a variety of institutions. By expanding who we hear from, we can learn about more barriers that students with
disabilities may encounter in STEM courses. By identifying the problems, we can begin working towards solutions.

Next, we encourage researchers and instructors to use the UDL framework as a means of evaluating the inclusiveness of courses and developing new inclusive strategies. As mentioned in the literature review, STEM research and instructors lack awareness about the importance of supporting students with disabilities and UDL can serve as a helpful framework for beginning to address this neglect in our research and course design. To begin this process, workshops and research papers should continue highlighting the need for this research and how UDL can be used in STEM contexts to develop more inclusive courses.

Researchers and instructors should also seek to develop and implement practices which could reduce the barriers identified by students with disabilities in our studies. The barriers of insufficient time on tests and a lack of guidance for how to engage with content outside of class were not addressed by the practices instructors implemented in our third study and although we provide recommendations for practices which address these barriers, we have not evaluated if our recommendations achieve the intended goals.

Accessibility should be an important consideration when developing content and/or posting content in a digital format for students to access. We recommend that researchers investigate whether existing STEM content is in an accessible format and how STEM instructors can be supported in developing accessible content. Additionally,
we encourage instructors to contact their disability services office for recommendations about how to make digital content more accessible.

Lastly, we encourage the development or refinement of data collection tools which would allow an instructor and/or researcher to evaluate the enactment of all UDL checkpoints across every aspect of a course. This endeavor would likely require multiple tools since instruments such as observation protocols are by nature limited to just the in-class sessions. To accomplish this goal, researchers could modify existing tools, such as the UDL-OMT we used, or develop new tools which consider all the UDL checkpoints from the beginning of development.

**Take-Aways**

The goal of this dissertation was to identify how students with disabilities can be better supported through proactive course design and the studies conducted reveal that there are STEM-specific disabling barriers which need to be addressed. We also find that there are STEM-specific practices and strategies which can be implemented to reduce disabling barriers.

From student interviews we see that STEM courses do implement some inclusive practices, but that there is significant room for improving how STEM courses support the variations in needs, interests, and abilities of students. Students with disabilities have not been a consideration in most discipline-based research at the postsecondary level, and the consequences are that postsecondary STEM courses are not designed in a way which supports students with disabilities. We also see that disability stigma has
negative consequences for student self-views and whether students will use accommodations. Students with disabilities have experienced the disabling barriers and disability stigma, and therefore researchers and instructors should continue working with asking students with disabilities to identify how postsecondary culture and courses can be more supportive.

The social relational perspective provides a useful lens for investigating how course structures disable or support students while also recognizing the unique effects of diagnosis characteristics on the day-to-day lives of students with disabilities. We encourage researchers who seek to investigate the experiences of students with disabilities in postsecondary settings to use the social relational perspective as a framing for investigating which course structures are specifically disabling students with disabilities. We also encourage instructors to adopt either the social relational perspective or the social model of disability, as this shifts the mindset from “students are the ones who need to change” to “my course is the thing which needs to change to better support all students”. The shift in mindset moves instructors from an ableist/disablist mindset to a mindset which recognizes, celebrates, and supports the variability in learners needs, interests, and abilities.

Universal Design for Learning can serve as a holistic framework which helps identify how STEM courses can better support students in receiving, engaging with, and expressing understanding. By using UDL, we found that STEM courses are not supporting the variability of learners across all dimensions. Our findings reveal a specific need in areas related to resources for vocabulary and providing content in
alternative languages. We also find that there is a lack of options, flexibility, and autonomy in STEM courses. Researchers and instructors should think about what practices and strategies can address these areas of concern, with the caveat that students need to be supported in engagement with new resources and making effective choices when flexibility is provided.

We also found that professional development in UDL can support instructors in implementing more inclusive practices. However, successful implementation is a slow and steady process which requires reflection and evaluation of newly implemented practices. Since we found that instructors often chose practices in areas which already had high enactment, any future professional development should include many supports for identifying areas of low enactment and identifying practices and strategies which address the areas of low enactment and are seen as doable by instructors. We also see that the UDL guidelines include a multitude of checkpoints which can be challenging to operationalize into effective, STEM specific, practices and strategies. In response to the challenge of operationalizing UDL checkpoints, we provide a variety of STEM specific teaching practices and strategies in Appendix C and I. We encourage researchers and instructors to refer to these examples as a starting point for considering what it looks like to enact UDL recommendations and subsequently support the variability of learners.

This research has helped me as a teacher to identify ways in which I can better support students with disabilities and subsequently all students. I highly encourage any instructor who desires to improve their teaching to adopt the variability of learners
mindset, and never stop considering how they can provide more options and supports for how students receive, engage, and express understanding of content.
APPENDIX A: STUDENT WITH DISABILITY PRE-INTERVIEW PROTOCOL
Thank you for coming here and giving us your time. We are interested in understanding the college experiences of students who identify with a documented disability. With this in mind, I would like to ask questions about how your experiences may have been shaped by your diagnosis, and would like to use whatever language you are comfortable with. Do you have a preference for how you refer to your diagnosis? (ex. disability, specific diagnosis, disabled, etc.)

**Icebreaker:**

So what is your major and when did you decide to pursue that field of study?
- Could you tell me why you decided to pursue that field of study?

1. What has your experience been like in your current physics/chemistry course?
   a. Do you feel like your disability has shaped that experience? In what ways?
   b. In what ways does the teacher present the information or give you access to the information? (examples could be powerpoints, worksheets, group work, online lectures etc.)
      i. Which methods of presentation are most beneficial for you?
      ii. Which methods of presentation are most challenging for you?
   c. How is your understanding of the material evaluated? (For example, does the instructor rely only on tests or were there other methods of assessment such as group projects, presentations, worksheets, etc.?)
      i. Do you enjoy this diversity or would you have preferred just one means of evaluation? If just one, which one and why?
   d. Do you feel motivated to learn the information in this class, and if so why?
      i. Does the instructor do anything in particular that helps with this?
      ii. Does the instructor do anything in particular that hinders this?
   e. What strategies do you employ to be successful in your course work?

2. Have you ever had a teacher or a course at UCF where your disability did not impact your performance in the class? What things did the teacher do to make this so? [2]
   a. What aspects of this course were specifically helpful for you in learning the material?
   b. What aspects of this course were specifically helpful for you in demonstrating your understanding of the material?
   c. In what ways did the teacher present the information or give you access to the information? (examples could be powerpoints, worksheets, group work, online lectures etc.)
      i. Which methods of presentation were most beneficial for you?
d. How was your understanding of the material evaluated? (For example, did the instructor rely only on tests or were there other methods of assessment such as group projects, presentations, worksheets, etc.?)
   i. Did you enjoy this diversity or would you have preferred just one means of evaluation? If just one, which one and why?

e. Did you feel motivated to learn the information in this class, and if so why?
   i. Did the instructor do anything in particular that helped this?

f. Was there anything you did in a different class that you enjoyed, but that wasn’t in this class?

3. Have you experienced barriers or successes to learning in college because of your disability? [2]
   a. How frequently have these barriers occurred?
   b. Were any of these barriers with regards to how the information was presented? What are some examples?
   c. Was any form of evaluation particularly difficult for you? What forms?
   d. Did you ever feel demotivated in class, and if so was there anything in particular that made you feel this way?
   e. Was there a class at UCF where you felt your learning disability was especially an issue?
      i. What made it this way?
      ii. Was there anything that you felt was a significant barrier in this class specifically because of your disability?

4. In college, do you ever feel unwelcome in the class due to your disability? If so, has there been anything that has specifically caused this?
   a. Have you felt this more from students or professors?
   b. Is there any recommendations you would make to a professor to make the environment more welcoming and comfortable for students with disabilities?

5. Have you made use of any specific accommodations due to your disability and if so what were they? [3] Are you utilizing any accommodations in this class, if so what are they and how frequently are they needed?
   a. If no
   b. Was there any particular reason you didn’t?
   c. If yes
d. How comfortable are you when discussing with a professor the accommodation or needs you may have? If uncomfortable, why? [3]

e. Were you satisfied with these accommodations? Why or why not?
   i. How did these accommodations change your experience in the class if at all?

f. Do you feel you would have performed worse or even better without these accommodations?

6. Is there anything else you would like to share about your experiences as a student with disabilities in the classroom?
APPENDIX B: STUDENT WITH DISABILITY POST-INTERVIEW PROTOCOL
Thank you for coming here and giving us your time. We’re interested in understanding the experiences of people who may struggle with organization, making plans, attention, and completing tasks due to a documented disability.

Icebreaker:

So what is your major and when did you decide to pursue that field of study?
- Could you tell me why you decided to pursue that field of study?

What current physics/chemistry class are you in?

1. What has your experience been like in your current physics/chemistry course?
   a. Did you feel like your disability has shaped that experience? In what ways?
   b. In what ways did the teacher present the information or give you access to the information? (examples could be powerpoints, worksheets, group work, online lectures etc.)
      i. Which methods of presentation were most beneficial for you?
      ii. Which methods of presentation were the most challenging for you?
   c. How was your understanding of the material evaluated? (For example, does the instructor rely only on tests or were there other methods of assessment such as group projects, presentations, worksheets, etc.)
      i. Do you enjoy this diversity or would you have preferred just one means of evaluation? If just one, which one and why?
   d. Did you feel motivated to learn the information in this class, and if so why?
      i. Did the instructor do anything in particular that helped with this?
      ii. Did the instructor do anything in particular that hindered this?
   e. What strategies did you employ to be successful in your course work?

2. Have you experienced any barriers to learning in college this semester because of your disability? [2]
   a. How frequently did these barriers occurred?
   b. Were any of these barriers with regards to how the information was presented? What are some examples?
   c. Was any form of evaluation particularly difficult for you? What forms?
d. Did you ever feel demotivated in class, and if so was there anything in particular that made you feel this way?

e. Was there any class at UCF this semester where you felt your area of difficulties was especially an issue?
   i. What made it this way?
   ii. Was there anything that you felt was a significant barrier in this class specifically because of your disability?

3. This semester, did you ever feel unwelcome in the class due to your disability? If so, has there been anything that has specifically caused this?
   a. If so, did you feel this more from students or professors?
   b. Are there any recommendations you would make to a professor to make the environment more welcoming and comfortable for students with disabilities?

4. Have you made use of any specific accommodations due to your disability this semester and if so what were they? [3] Did you utilize any accommodations in your physics/chemistry class, if so what are they and how frequently were they needed?
   a. If no
   b. Was there any particular reason you didn’t?
   c. If yes
   d. How comfortable are you when discussing with a professor the accommodation or needs you may have? If uncomfortable, why? [3]
   e. Were you satisfied with these accommodations? Why or why not?
      i. How did these accommodations change your experience in the class if at all?
   f. Do you feel you would have performed worse or even better without these accommodations?

5. Is there anything else you would like to share about your experience this semester as a student with disabilities in the classroom/college?
Table 11: UDL-OMT observation items along with our definitions and examples we used as operationalizations

<table>
<thead>
<tr>
<th>Observation Item</th>
<th>Definition</th>
<th>Examples</th>
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<tbody>
<tr>
<td><strong>A. Introducing and Framing New Material</strong></td>
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</table>
| 1. Assesses background knowledge prior to introducing new knowledge. | Assessing background knowledge provides a baseline for instructors to know where to begin their content. | • Has quiz/worksheet that is then reviewed for areas of strength/weakness by teacher before proceeding to lesson  
• Clicker questions assessing previously learned knowledge (this includes knowledge gained outside of class).  
• Think/pair/share |
| 2. Supports linking background knowledge to new knowledge. | Linking background knowledge to new knowledge has been proven to increase a person’s ability to remember and generalize new material. | • Provides analogies linking known things to new things (ex. comparing a river to an electric current)  
• Shows real world situation where new content is phenomenologically taking place  
• Scaffolds new ideas, tying them to prior knowledge |
| 3. Highlights what is important for students to learn. | Highlighting what is important for students to learn allows them to focus in on what information is valuable and discard what is irrelevant or unimportant. | • Has outline of big concepts/ideas at beginning of class  
• Has key information bolded, underlined, etc. in slides  
• Writes objective of lesson on board  
• Using specific problems as an example of a broader type of problem |
| 4. Supports understanding of big ideas and critical concepts. | Scaffolding big ideas and critical concepts allows students to progress and adopt personal goals that are realistic. | • Class lab, activity, etc. focuses on a big idea (ex. energy conservation introduced in slide and then shown with demonstration/lab)  
• Clicker Questions asking questions about critical concept.  
• Frequent check-in to assess students’ grasp of concepts |
| 5. Uses questions that support understanding or inquiry. | Using questions to answer a question provides students with the ability to reflect on what they have done to answer the questions they may have. | • Clicker Questions on concepts  
• Worksheets that require critical thinking and conceptual knowledge to answer  
• Open questions presented to class to discuss/answer |
<table>
<thead>
<tr>
<th>Observation Item</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Identifies potential misunderstandings/ misconceptions.</td>
<td>By asking questions, instructors are able to identify potential misunderstandings and redirect student thinking and understanding.</td>
<td>• Uses higher-order thinking questions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Have students answer question and then test it through experiment/calculation.</td>
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<tr>
<td></td>
<td></td>
<td>• Exploring why Clicker Question wrong answers are wrong</td>
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<td></td>
<td></td>
<td>• Having class discussions on implication of if misconception/misunderstanding was actually correct</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Frequent monitoring of student comprehension</td>
</tr>
<tr>
<td><strong>B. Content Representation and Delivery</strong></td>
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<td></td>
</tr>
<tr>
<td>1. Supports multiple levels of content understanding (e.g. novice, intermediate, expert).</td>
<td>Providing multiple levels of content allows all students to participate in class work while learning at their own pace. They are able to observe students who work at higher levels and learn from their experiences while working at a level that is realistic for them.</td>
<td>• Groups allowed to have flexibility in how they carry out experiment (# of trials, which chemicals used, etc.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Projects/papers that are open and have few restrictions (ex. make a device based on something from this last chapter of material)</td>
</tr>
<tr>
<td>2. Presentation of information allows for customization.</td>
<td>Customization of materials can be for print or digital formats. Materials should be malleable to provide options for learners. Just because material is digital does not mean it is equally accessible.</td>
<td>• Oral, written, and visual presentation are available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Visual presentation may allow for customization (ex. Different color background, large font, no pictures or effects)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ppts/notes available for download</td>
</tr>
<tr>
<td>3. Instruction allows alternatives for visual display of information.</td>
<td>Visual information can be quite dense, particularly with visual art, which can have multiple complex meanings and interpretations depending on contextual factors and the viewer’s knowledge base. To ensure that all learners have equal access to information, it is essential to provide non-visual alternatives.</td>
<td>• Slides and text have text-to-speech option on computer</td>
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<tr>
<td></td>
<td></td>
<td>• Material is read out loud</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Allow extra time for students to write notes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Large print or braille when necessary</td>
</tr>
<tr>
<td>4. Instruction allows alternatives for auditory information.</td>
<td>Auditory teaching is the main staple in most postsecondary classrooms. Information solely relayed through</td>
<td>• Uses visual aids</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use a notetaker when possible to record information</td>
</tr>
<tr>
<td>Observation Item</td>
<td>Definition</td>
<td>Examples</td>
</tr>
<tr>
<td>------------------</td>
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</tbody>
</table>
| sound is not equally accessible to all students. To ensure that all learners have access to learning, options should be available for any information presented aurally. | - Slow down the pace of communication  
- Preferential seating for best communication  
- Provide new vocabulary in advance  
- Make sure the instructor has the students attention |
| 5. Supports options for multiple languages. | Most curriculum in the United States is printed monolingually, while not all learners in the US speak English as their first language. It is important to provide alternatives for key information or vocabulary for accessibility. | - Notes online in more than one language  
- Signer present if necessary |
| 6. Supports understanding of relationships across disciplines, settings, or concepts. | The ability to generalize information is key in showing student understanding. By providing opportunities to link information across disciplines, settings, or concepts, instructors allow students to store the information into long term memory. | - Discusses how concept is used in things students see/use everyday (ex. lightning clouds as capacitors)  
- Explains how answer can be solved two ways using old and new concept  
- Has project/lab that uses concept in light of a different field (Ex. Lab on acid/base neutralization and framing it in cleaning water for city) |
| 7. Clarifies content-specific vocabulary, symbols, and jargon. | The semantic elements through which information is presented – the words, symbols, numbers, and icons – are differentially accessible to learners with varying backgrounds, languages, and lexical knowledge. | - When a new symbol is presented in an equation, it is given a name and explanation  
- New symbols, their name, and short description written on board and left there for the whole class  
- Link key vocabulary, labels, icons, symbols to alternative representations of their meanings (i.e. definition, graphic, chart, etc.) |
| 8. Clarifies content-based syntax and structure. | Single elements of meaning (like words or numbers) can be combined to make new meanings. Those new meanings, however, depend upon understanding the rules or structures (like syntax in a sentence or the properties of equations) of how those elements are combined. | - Purpose of equation and how its parts interact is discussed (ex. deriving expression and seeing what happens if variable is increased in value)  
- Provide alternate representations that clarify the syntactic or structural relationships between elements of meaning |
<table>
<thead>
<tr>
<th>Observation Item</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Highlights options for self-directed clarification of vocabulary and symbols.</td>
<td>Allows students to find answers to their own questions before giving the answer to them. This process will provide students the opportunity to access prior knowledge and connect to new knowledge.</td>
<td>• Recommendations for resources to review new symbols (Ex. hyperphysics, wikipedia, etc.)</td>
</tr>
<tr>
<td><strong>C. Expression of Understanding</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Allows options for learners to express understandings in a variety of ways.</td>
<td>Learners differ widely in their capacity to navigate their physical environment. To reduce barriers to learning, provide alternative means for response, selection, and composition.</td>
<td>• Multiple ways that knowledge is evaluated (ex. Clicker Questions, presentations, papers, interviews, etc.)&lt;br&gt;• Options for how they present lab results (ex. PowerPoint, poster, etc.)</td>
</tr>
<tr>
<td>2. Provides access to a variety of tools and/or technologies that allow students to express their understanding.</td>
<td>While a significant number of students with disabilities have Assistive Technology, all students need access to tools that help them navigate both physical environment and curriculum and allow them to fully participate in all aspects of the class.</td>
<td>• Variety of lab equipment/materials that allow flexibility in performing experiment&lt;br&gt;• Options for computing/presenting class data (ex. calculator, SPSS, Excel, PowerPoint, paper/pencil)</td>
</tr>
<tr>
<td>3. Builds competencies in use of multiple options for expressing their understanding.</td>
<td>In a media-rich world, it is important for learners to have the freedom to express their understanding in multiple ways. Allowing students to build their competencies with multiple options provides them with opportunities to decide which options work best for their learning style.</td>
<td>• Variety of different means of evaluation (ex. presentations, worksheets, tests, research papers, etc.)&lt;br&gt;• Require new methods to show proficiency with new material (ex. plotting, PowerPoint, deriving equations)</td>
</tr>
<tr>
<td>4. Provides options that guide students to plan, develop strategies, and/or goal-setting that promotes expression of understanding.</td>
<td>By providing options for students, they have the ability to take control of their learning which promotes their self-determination and connection to the content being taught. It is not enough to provide options, but the right options to ensure maximum engagement.</td>
<td>• Must choose which chemicals/equipment to use to perform experiment&lt;br&gt;• Choice of question to answer on test/homework (ex. student given 3 questions and must answer one fully)&lt;br&gt;• Provide choices for class assignments</td>
</tr>
<tr>
<td>5. The environment facilitates management of information and</td>
<td>Both the physical and web environment can be shaped to align with course goals and priorities.</td>
<td>• If group work is key in class, then classroom designed such that group members can easily talk to each other</td>
</tr>
</tbody>
</table>
### Observation Item | Definition | Examples
--- | --- | ---
resources to achieve desired learning outcomes. | Using questions to answer a question provides students with the ability to problem solve to answer the questions they may have. | (Ex. circle tables, students standing and free to move around, etc.)

• Chemicals/equipment easy to access when needed

6. Intentionally provides supports for students’ problem-solving and critical-thinking abilities. | When students are able to self-monitor their progress, they are able to set personal goals that are attainable. Through instructor feedback and monitoring their own progress, students have more ownership of instruction and outcomes. | Extra material available for students to work through (ex. practice problems)

• Professor, TA, LA, etc. available and open during class to be asked questions about problems. Professor, TA, LA etc. should respond with open dialogue.

7. Facilitates student self-monitoring of progress | | Clicker questions on material

• Lab worksheet where students are asked if final results align with their hypothesis and if so why/why not.

• Clear deadlines and expectations given during class on material they are currently involved in

• Checkpoints during lab to assess progress

### D. Activity and Student Engagement

1. Promotes learner choice and self-determination while engaging with the content | Allows students to make choices based on their work. Students have more control and buy in of material. | Experiments/labs open to be performed in a multitude of ways

• Projects that are outside of class

2. Provides a variety of activities relevant to all learners. | Students do not learn in the same way as each other. Providing a variety of activities to students allows students to focus on their learning strengths and styles. | Collaborative learning

• Debates

• Student-led review

• Reflection papers

• Data analysis

• Worksheets to be done in pairs or groups

• Performing experiments

• Building a presentation

3. Promotes sustained effort and focus. | People in general require a brain break after seven to eight minutes of focus. By allowing for breaks in the schedule, students are able to concentrate for longer periods of time. | Clicker questions given at regular pace (Not too long such that most students are finished and waiting for an excessive time)

• Groups allowed to work on lab report once they finish experiment
<table>
<thead>
<tr>
<th>Observation Item</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
</table>
| 4. Encourages learners’ use of strategic planning to complete instructional tasks. | Systematic planning provides students step-by-step instructions that promote organizational skills and extended focus on complicated tasks. | • Problems given that require multiple steps in order to get the correct answer  
• Experiments where the groups must design how to actually perform the study. |
| 5. Encourages collaboration and communication among learners. | Collaboration and communication provide opportunities for students to practice social skills in a variety of environments. Students learn key team building skills that are necessary in the workplace. | • Group work that effectively involves all group members  
• Having students discuss results with students around them  
• Allowing collaboration in answering clicker questions |
| 6. Supports multiples levels of challenge. | Providing multiple levels of content allows all students to participate in class work while learning at their own pace. They are able to observe students who work at higher levels and learn from their experiences while working at a level that is realistic for them. | • Open experiment design  
• Complex problems given that are optional |
| 7. Provides for self-reflection and self-assessment. | Allowing students time for self-reflection and self-assessment provides them with the ability to monitor their emotions, reactivity, and progress toward personal goals. | • Rubric for assignments with a clear outline of how students will be graded  
• Questions on if results of lab/activity agree with what they believe should happen.  
• Self-evaluation rubric |
| 8. Provides formative progress monitoring and content checks. | Proper feedback and progress monitoring allows students to correct mistakes and change their learning. | • Project feedback given throughout the project itself, not just at the end.  
• Clicker questions  
• Reviewing previous week’s quiz and which questions students did good or bad on |
| 9. Provides closure that reiterates big ideas and instructional purposes | Closure reiterates the big ideas from the lesson and provides students an opportunity to show the instructor they are able to grasp the concepts taught during the lesson. | • Final overview of lesson given  
• Main points of experiment/lab discussed and written on board |
APPENDIX D: VARIATIONS IN ALIGNMENT OF UDL-OMT OBSERVATION ITEMS TO UDL CHECKPOINTS
Table 12: UDL-OMT items with our alignment and Basham et. al’s (2020) [157] alignment to UDL checkpoints. Underlined items denote checkpoints which were aligned differently.

<table>
<thead>
<tr>
<th>Observation code</th>
<th>UDL checkpoint alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A1:</strong> Assess background knowledge prior to introducing new knowledge.</td>
<td>3.1: Activate or supply background knowledge</td>
</tr>
<tr>
<td><strong>A2:</strong> Supports linking background knowledge to new knowledge.</td>
<td>3.4: Maximize transfer and generalization</td>
</tr>
<tr>
<td><strong>A3:</strong> Highlights what is important for students to learn.</td>
<td>3.2: Highlight patterns, critical features, big ideas, and relationships</td>
</tr>
<tr>
<td><strong>A4:</strong> Supports understanding of big ideas and critical concepts.</td>
<td>3.3: Guide information processing, visualization, and manipulation</td>
</tr>
<tr>
<td><strong>A5:</strong> Uses questions that support understanding or inquiry</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>A6:</strong> Identifies potential misunderstandings/misconceptions.</td>
<td>6.4: Enhance capacity for monitoring progress</td>
</tr>
<tr>
<td><strong>B1:</strong> Supports multiple levels of content understanding (e.g., novice, intermediate, expert).</td>
<td>7.1: Optimize individual choice and autonomy</td>
</tr>
<tr>
<td><strong>B2:</strong> Presentation of information allows for customization.</td>
<td>1.1: Offer ways of customizing the display of information</td>
</tr>
<tr>
<td><strong>B3:</strong> Instruction allows alternatives for visual display of information.</td>
<td>1.3: Offer alternatives for visual information</td>
</tr>
<tr>
<td><strong>B4:</strong> Instruction allows alternatives for auditory information.</td>
<td>1.2: Offer alternatives for auditory information</td>
</tr>
<tr>
<td><strong>B5:</strong> Supports options for multiple languages.</td>
<td>2.4: Promote understanding across languages</td>
</tr>
<tr>
<td><strong>B6:</strong> Supports understanding of relationships across disciplines, settings, or concepts.</td>
<td>3.4: Maximize transfer and generalization</td>
</tr>
<tr>
<td><strong>B7:</strong> Clarifies content specific vocabulary, symbols, and jargon.</td>
<td>2.1: Clarify vocabulary and symbols</td>
</tr>
<tr>
<td><strong>B8:</strong> Clarifies content-based syntax and structure.</td>
<td>2.2: Clarify syntax and structure</td>
</tr>
<tr>
<td><strong>B9:</strong> Highlights options for self-directed clarification of vocabulary and symbols.</td>
<td>2.3: Support decoding of text, mathematical notation, and symbols</td>
</tr>
</tbody>
</table>

218
<table>
<thead>
<tr>
<th>Observation code</th>
<th>Ours</th>
<th>Basham et. al</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Allows options for learners to express understandings in a variety of ways.</td>
<td>5.1: Use multiple media for communication</td>
<td>2.3: Support decoding of text, mathematical notation, and symbols</td>
</tr>
<tr>
<td>C2: Provides access to a variety of tools and/or technologies that allow students to express their understanding.</td>
<td>5.2: Use multiple tools for construction and composition</td>
<td>4.1: Vary the methods for response and navigation</td>
</tr>
<tr>
<td>C3: Builds competencies in use of multiple options for expressing their understanding.</td>
<td>5.1: Use multiple media for communication</td>
<td>4.2: Optimize access to tools and assistive technologies</td>
</tr>
<tr>
<td>C4: Provides options that guide students to plan, develop strategies, and/or goal-setting that promotes expression of understanding</td>
<td>6.1: Guide appropriate goal setting 6.2: Support planning and strategy development</td>
<td>5.3: Build fluencies with graduated levels of support for practice and performance</td>
</tr>
<tr>
<td>C5: The environment facilitates management of information and resources to achieve desired learning outcomes.</td>
<td>6.3: Facilitate managing information and resources</td>
<td>6.1: Guide appropriate goal setting 6.2: Support planning and strategy development</td>
</tr>
<tr>
<td>C6: Intentionally provides supports for students’ problem solving and critical thinking abilities.</td>
<td>N/A</td>
<td>3.2: Highlight patterns, critical features, big ideas, and relationships</td>
</tr>
<tr>
<td>C7: Facilitates student self-monitoring of progress.</td>
<td>6.4: Enhance capacity for monitoring progress</td>
<td>6.4: Enhance capacity for monitoring progress</td>
</tr>
<tr>
<td>D1: Promotes learner choice and self-determination</td>
<td>7.1: Optimize individual choice and autonomy</td>
<td>7.1: Optimize individual choice and autonomy</td>
</tr>
<tr>
<td>D2: Provides a variety of activities relevant to all learners.</td>
<td>7.2: Optimize relevance, value, and authenticity</td>
<td>7.2: Optimize relevance, value, and authenticity</td>
</tr>
<tr>
<td>D3: Promotes sustained effort and focus.</td>
<td>7.3: Minimize threats and distractions</td>
<td>7.3: Minimize threats and distractions</td>
</tr>
<tr>
<td>D4: Encourages learners’ use of strategic planning to complete instructional tasks.</td>
<td>6.2: Support planning and strategy development</td>
<td>6.2: Support planning and strategy development</td>
</tr>
<tr>
<td>D5: Encourages collaboration and communication among learners.</td>
<td>8.3: Foster collaboration and community</td>
<td>9.2: Facilitate personal coping skills and strategies</td>
</tr>
<tr>
<td>D6: Supports multiple levels of challenge.</td>
<td>7.1: Optimize individual choice and autonomy 8.2: Vary demands and resources to optimize challenge</td>
<td>8.2: Vary demands and resources to optimize challenge</td>
</tr>
<tr>
<td>Observation code</td>
<td>Ours</td>
<td>Basham et. al</td>
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</tr>
<tr>
<td>D8: Provides formative progress monitoring and content checks.</td>
<td>8.4: Increase mastery-oriented feedback</td>
<td>6.3: Facilitate managing information and resources 6.4: Enhance capacity for monitoring progress 9.3: Develop self-assessment and reflection</td>
</tr>
<tr>
<td>D9: Provides closure that reiterates big ideas and instructional purposes.</td>
<td>3.2: Highlight patterns, critical features, big ideas, and relationships 8.1: Heighten salience of goals and objectives</td>
<td>8.1: Heighten salience of goals and objectives 8.4: Increase mastery-oriented feedback</td>
</tr>
</tbody>
</table>
APPENDIX E: AVERAGED UDL CHECKPOINT SCORES AND MEASURE OF CONSISTENCY
Table 13: Average scores for UDL checkpoints for pre (baseline) and post (implementation) semester(s) for each instructor

<table>
<thead>
<tr>
<th>Checkpoints</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>2.00</td>
<td>1.85</td>
<td>1.20</td>
<td>0.55</td>
<td>1.67</td>
<td>2.80</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1.2</td>
<td>0.67</td>
<td>0.40</td>
<td>0.80</td>
<td>0.95</td>
<td>0.33</td>
<td>1.40</td>
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<td>0.50</td>
<td>0.85</td>
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<tr>
<td>1.3</td>
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APPENDIX F: INSTRUCTOR PRE-INTERVIEW PROTOCOL
Ice Breaker:

So how long have you been teaching in this field?

1. How much autonomy do you have in the way you teach your class?
   a. Did you design the material for the course? If not, do you know who did?
      i. How much freedom do you have in designing/choosing the material?
   b. Have you received any training or professional development regarding teaching? If so was any of this training in designing/planning a course?
      i. Have you received any training or professional development regarding teaching students with disabilities?

2. For your class, how is new course material or content introduced to students (examples could be PowerPoints, worksheets, group work)? Why do you present content in that way?
   a. Have you found any of these to be particularly beneficial for students? How so?
      i. Have any students had significant difficulties with any of these?
         1. If so why do you think this was the case?
   b. In what forms do students have access to this information outside of class (examples could be lecture notes, book, videos)?

3. How do you evaluate students’ knowledge in your classroom (for example do you rely mainly on paper-based tests/quizzes or are there group projects, worksheets, etc.)?
   a. Have you found students to excel at any of these in particular? If so why?
      i. Have any students struggled with any in particular?
         1. If so why do you think this was the case?

4. How do you get students to engage with complicated tasks? (e.g. scaffolding, goal setting, reward structures) Do you do anything else to motivate students to learn the class material, if so what do you do?
   a. Have you found this to be successful in motivating students?
      i. Why do you think this was the case?
   b. Have you found any of these to be more or less successful for particular students?
      i. If so why do you think this was the case?
5. How often are students involved in working with the content material either alone or in a group during class?
   a. What kind of tasks does this include?
   b. What about outside of class?
   c. Do they receive feedback from their work and if so what does this look like?
   d. What difficulties have students encountered in group work?

6. Have you worked with students with disabilities in your classroom? What sorts of disabilities have students disclosed or do you suspect have been represented in your students?
   a. In your experience, have these students performed the same, better, or worse than the students without disabilities?
   b. What are some specific challenges or successes you have experienced in teaching students with disabilities, if any? [1]

Say: Some students struggle with “executive functions” which includes attentional control, reasoning, working memory, problem solving, planning, etc.

Ask: Have you come across students with these types of difficulties in your courses?

7. Have you had any students request accommodations because of their disability? Examples of these include extra time on tests, a quiet room to take a test in alone, etc.
   a. If so, what are some examples?
   b. What are your opinions on the ones you’ve had to make?
   c. What difficulties have you had in delivering accommodations?

8. How would you describe the attitude on your own campus and in your department related to the instruction of students with disabilities? [1]
   a. What resources do you know that are available to students with disabilities?
      i. What barriers exist for students and for faculty/administrators in using these resources? [1]
   b. In your time at the University, have you noticed any change in the number of students with disabilities in your classes? [2]

9. Are you familiar with the term “Universal Design for Learning”? If so, what have you heard about it? If not, explain (“Universal Design for Learning is a framework
for enabling all students to engage naturally in your class, reducing the need for accommodations. The idea carried over from architecture, where Universal Design was a movement to design for access to spaces as part of the design process rather than adding on things like ramps as an afterthought. These changes frequently make the space, and the classroom, more accessible to all, not just those with disabilities. For example, while curb cuts are added to sidewalks for people in wheelchairs, they make navigation easier for those with strollers or bikes and joggers.

What do you think of the idea of a UDL classroom versus accommodations?

10. Is there anything we haven’t covered concerning any experience you’ve had with students with disabilities in your classroom?
APPENDIX G: INSTRUCTOR POST-INTERVIEW PROTOCOL
Ice Breaker:
So overall how has your class gone this semester?

1. For your class, have you implemented any new practices/strategies for how new course material or content is introduced to students (examples could be PowerPoints, worksheets, group work)? If so, what were they?
   a. If so, why did you choose to do this?
      or
      If not, is there any you’d like to implement or are you satisfied with your current means of presentation?
   b. Have you found any of these to be particularly beneficial for students?

2. Have you implemented any new practices/strategies for how you evaluate students’ knowledge in your classroom (for example do you rely mainly on paper-based tests/quizzes or are there group projects, worksheets, etc.)? If so, what were they?
   a. If so, why did you choose to do this?
      or
      If not, is there any you’d like to implement or are you satisfied with your current means of presentation?
   b. Have you found students to excel at any of these in particular? If so why?

3. Have you implemented any new practices/strategies to get students to engage with complicated tasks? (e.g. scaffolding, goal setting, reward structures) Do you do anything else to motivate students to learn the class material, if so what do you do? If so, what were they?
   a. If so, why did you choose to do this?
      or
      If not, is there any you’d like to implement or are you satisfied with your current means of presentation?
   b. Have you found this to be successful in motivating students?
      i. Why do you think this was the case?

4. Which of these practices will you continue implementing in the spring, if any?
   a. If you started a new course, would you carry on any of these practices/strategies? If so which ones?

5. What have been some overall successes you've experienced this semester regarding implementing UDL and/or supporting SWDs in your course?
6. Have you had any significant difficulties this semester regarding implementing UDL and/or supporting SWDs in your course?

7. What could the researchers do to better support you in making learning more accessible in your course?

8. Is there anything we haven't covered concerning any experience you've had this semester?
APPENDIX H: STUDENT FOCUS GROUP INTERVIEW PROTOCOL
Opening Statement:
Thank you so much for coming here and giving us your time. So the purpose of this focus group is to hear from you all about your experiences in the current class you’re in. I greatly appreciate your participation as you truly are the only ones who can share the experiences you’ve had, and so I look forward to hearing what aspects of the course you found particularly beneficial or detrimental.

Concerning the structure, I’m just going to be going through a few questions to understand the class and what you did or didn’t like about it. We just want to hear your honest experiences, and so there are no wrong or right answers. Also you do not need to answer a question if you do not want for any reason.

Before we begin, does anyone have any questions?

Notes:
Icebreaker

• What is everyone’s major?

1. In what ways does the teacher present the information or give you access to the information? (examples could be powerpoints, worksheets, group work, online lectures etc.)
   a. In what ways did you find how material was presented to be particularly beneficial for you?
   b. Conversely, what caused the presentation of material to be challenging or ineffective for you?

(Note Space)

2. How is your understanding of the material evaluated? (For example, does the instructor rely only on tests or were there other methods of assessment such as group projects, presentations, worksheets, etc.?)
   a. (if many ways) Do you enjoy this diversity or would you have preferred just one means of evaluation?
   b. (if just one way) Do you enjoy the just one means of evaluation or would you have preferred more diversity?
   c. What kind of things did the instructor or class do to support you accurately expressing your understanding of the material?

(Note Space)
3. Do you feel motivated to learn the information in this class, and if so why?
   a. What kind of things does the instructor do to help or increase your motivation?
   b. What kind of things does the instructor do to hinder or decrease your motivation?

(Note Space)

Now I would like to discuss some specific practices your instructor does that haven’t been discussed thus far.

4. We know your instructor did [insert UDL inspire practice]. Did you know this was occurring?
   a. Did you find it to be beneficial or detrimental and how come?

(Repeat this question, covering any new implemented practices not naturally discussed in first 3 questions.)

(Note Space)
5. Is there anything else you would like to share about your experiences in this class and how it was taught by your instructor?
APPENDIX I: INSTRUCTOR UNIQUE PRACTICES
Table 14: UDL checkpoints and corresponding unique practices coded from instructor interviews. (I) denotes that the practice occurred in class, (O) denotes that the practiced occurred out of class, and (B) denotes that the practice occurred in and outside of class.

<table>
<thead>
<tr>
<th>Checkpoint</th>
<th>Unique practices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Uploading course content online (O)</td>
</tr>
<tr>
<td></td>
<td>• Broadcasting screen to computers in front of students (I)</td>
</tr>
<tr>
<td></td>
<td>• Digital version of book (O)</td>
</tr>
<tr>
<td>1.1</td>
<td>• Using online simulations (B)</td>
</tr>
<tr>
<td></td>
<td>• Option to use online resources for assignments (B)</td>
</tr>
<tr>
<td></td>
<td>• Encouraging online resources (I)</td>
</tr>
<tr>
<td></td>
<td>• Website/external online resources for course content (O)</td>
</tr>
<tr>
<td>1.2</td>
<td>• Encouraging online resources (I)</td>
</tr>
<tr>
<td>1.3</td>
<td>• Demo of lab before students start lab (O)</td>
</tr>
<tr>
<td>1.4</td>
<td>• Using online simulations (B)</td>
</tr>
<tr>
<td>2.1</td>
<td>• Providing a formula sheet (B)</td>
</tr>
<tr>
<td>2.2</td>
<td>• N/A</td>
</tr>
<tr>
<td>2.3</td>
<td>• N/A</td>
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<td>2.4</td>
<td>• N/A</td>
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<td>2.5</td>
<td>• Online guide for new skills (O)</td>
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<td></td>
<td>• Website/external online resources for course content (O)</td>
</tr>
<tr>
<td></td>
<td>• Assessment to check student prior knowledge (B)</td>
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<tr>
<td>3.1</td>
<td>• Activity/resources before lab/class to pre-teach concepts (O)</td>
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<tr>
<td></td>
<td>• Reviewing prerequisite concepts in class (I)</td>
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<td>• Identifying content which will be on test (I)</td>
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<td>• Test reviews by instructor/TA (O)</td>
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<td></td>
<td>• Identifying important concepts at beginning and end of class (I)</td>
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<tr>
<td>3.2</td>
<td>• Website/LMS with overview of important concepts (O)</td>
</tr>
<tr>
<td></td>
<td>• Bolding important instructions on quizzes/exams (I)</td>
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<td>• Repeating important information in class (I)</td>
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<td>• Having students identify main points during class (I)</td>
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<td></td>
<td>• Worksheets guiding students through content (I)</td>
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<td></td>
<td>• Guiding student thinking by asking questions or giving tips (I)</td>
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<td></td>
<td>• Class discussion focusing on challenges students encountered (I)</td>
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<td></td>
<td>• Guides for how to structure lab notebook (O)</td>
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<tr>
<td>3.3</td>
<td>• Providing guidance for how to approach problems step-by-step (I)</td>
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<tr>
<td></td>
<td>• Using online simulations (B)</td>
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<td>• Providing example of assessment to practice with (O)</td>
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<td></td>
<td>• Providing recommendations for how to succeed in course (I)</td>
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<tr>
<td>3.4</td>
<td>• Providing real world examples (I)</td>
</tr>
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</table>
### Checkpoint Unique practices

- Problem solving in class (I)
- Online guide for new skills (O)
- Course content in context relevant to students (I)
- Having students explain new concepts to peers (I)
- Students presenting and discussing results (I)
- Assignments outside of class for practice (O)
- Providing increased time on assessments (I)
- Allowing students to earn points lost on assessments (O)

#### 4.1
- Providing alternative times for test reviews
- Allow students to complete missed assignments
- Giving students option to submit assignments online (O)
- Encouraging students to change seats to better receive content from instructor (I)

#### 4.2
- Demo of lab before students start lab (O)
- Providing links to online resources (B)
- Online guide for new skills (O)
- Group chat/facebook group for course moderated by instructor/TA (O)
- Website/external online resources for course content (O)

#### 5.1
- N/A
- Providing multiple solutions for problems in and out of class (B)
- Gradually increasing challenge level of practice (B)
- Varying level of resources available for use on assessments (I)
- Providing example of assessment to practice with (O)

#### 5.2
- N/A
- Encouraging students to preview and review material (I)
- Providing set schedule for assignments/assessments (O)
- Encouraging students to engage with peers/instructors (I)
- Worksheets guiding students through content (I)
- Asking questions or giving hints to guide student thinking (I)

#### 5.3
- Providing an example of what completed deliverable would look like (ex. notecard, lab report) (O)
- Providing guidance for how to approach problems step-by-step (I)
- Identifying contexts when concept is used
- Providing example of assessment to practice with (O)
- Providing an example of what completed deliverable would look like (ex. notecard, lab report) (O)

#### 6.1
- N/A
- Worksheets guiding students through content (I)
- Guiding student thinking by asking questions or giving tips (I)
- Engaging reserved students in discussion (I)

#### 6.2
- Problem solving in class (I)
Checkpoint  Unique practices

- Assignments outside of class for practice (O)
- Providing example of assessment to practice with (O)
- Providing feedback on completed work (B)
- Providing feedback as students engage with activity (I)
- Worksheets guiding students through content (I)
- Guiding student thinking by asking questions or giving tips (I)
- Having students explain new concepts to peers (I)
- Having students identify main points during class (I)
- Providing an example of what completed deliverable would look like (ex. notecard, lab report) (O)
- Notifying students of time to complete task (I)
- Worksheets guiding students through content (I)
- Rubric for assessments/deliverables (O)
- Students design lab procedure (I)

7.1
- Students allowed to choose group members (I)
- Providing real world examples (I)
- Course content in context relevant to students (I)

7.2
- Encouraging students to generate their own problems (I)
- Discussions on how content is relevant to student interests/real world (I)
- Reminders for students to stay attentive to task (I)
- Providing breaks during class (I)
- Engaging reserved students in discussion (I)
- Engaging in casual discussion with students (I)

7.3
- Engaging reserved students in discussion (I)
- Using humor (I)
- Restricting the use of cell phones in class (I)
- Broadcasting screen to computers in front of students (I)
- Grading on content, not grammar (O)
- Identifying important concepts at beginning and end of class (I)

8.1
- Test reviews by instructor/TA (O)
- Website/LMS with overview of important concepts (O)
- Providing recommendations for how to succeed in course (I)
- Allowing a variety of resources for tasks (i.e. book, internet, ppts) (B)
- Grading on effort versus performance (O)
- Students design lab procedure (I)

8.2
- Having students make notecard for use on assessment (O)
- Allowing students to earn points lost on assessments (O)
- Providing example of assessment to practice with (O)
- Students allowed to complete unfinished work outside of class (O)
Checkpoint

Unique practices

- Providing increased time on assessments (I)
- Encouraging students to work with peers in and out of class (B)
- Encouraging students to engage with instructor/TA in and out of class (I)
- Having class tasks/assessments be done in groups (I)
- Group chat/facebook group for course moderated by instructor/TA (O)
- Engaging in casual discussion with students (I)
- Engaging reserved students in discussion (I)
- Engaging in whole class discussions (I)
- Engaging reserved students in discussion (I)
- Having students explain new concepts to peers (I)
- Intentionally choosing how groups are formed and if they change (I)
- Group chat/facebook group for course moderated by instructor/TA (O)
- Having students explain new concepts to peers (I)
- Checking in with students who performed poorly on assessments (O)
- Using anonymous student examples for good and bad practices (I)
- Identifying areas of challenge and providing focused feedback (B)
- Group chat/facebook group for course moderated by instructor/TA (O)
- Providing feedback on completed work (B)
- Providing feedback as students engage with activity (I)
- Encouraging students to engage with instructor/TA in and out of class (I)
- Allowing students to practice assessment before official assessment (O)
- Guiding student thinking by asking questions or giving tips (I)
- Peer review of assessments (I)
- Providing example of assessment to practice with (O)
- Using anonymous student examples for good and bad practices (I)
- Group chat/facebook group for course moderated by instructor/TA (O)
- Speeches encouraging students that they can succeed (I)
- Supporting students in setting goals for course (I)
- Encouraging students to persist in course work (I)
- Encouraging the use of mental health campus resources (I)
<table>
<thead>
<tr>
<th>Checkpoint</th>
<th>Unique practices</th>
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</table>
| 9.3       | • Providing breaks during class (I)  
           | • N/A                           |
APPENDIX J: COMPARISON OF UDL ENACTMENT IN OBSERVATIONS AND WRITTEN CURRICULUM
In the table on the next page I provide the checkpoints and the evaluation of their enactment based on our in-class observations and the findings found in the physics [95] and chemistry [94] curriculum papers. A reminder that I defined “high” enactment from observations as two out of three instructors in a discipline having scores of 2 or greater. “Low” enactment from observations was defined as two out of three instructors in a discipline having scores of 1 or lower. For high and low enactment in the written curriculum papers, we consider classifications of “high” or “some” as high enactment and classifications of “low” or “none” as low enactment. “N/A” denotes that the checkpoint was not in the observation item or was evaluated to not be appropriate for analysis in the curriculum papers. A “-” denotes that the checkpoint had neither a high or low enactment.
Table 15: Comparison of UDL enactment from in-class and written curriculum findings

<table>
<thead>
<tr>
<th>UDL Checkpoint</th>
<th>Physics in-class</th>
<th>Physics curriculum</th>
<th>Chemistry in-class</th>
<th>Chemistry curriculum</th>
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APPENDIX K: IRB APPROVAL
To: Westley Janes  
From: UCF Institutional Review Board (IRB)  
Date: May 11, 2020  
Re: IRB Coverage

The IRB reviewed the information related to your dissertation *INVESTIGATING THE INCLUSIVENESS OF STEM COURSES AND REDUCING BARRIERS BY APPLYING THE UNIVERSAL DESIGN FOR LEARNING FRAMEWORK*

Your project data is covered under the following protocol previously approved by the IRB. You are listed as a Co-Investigator on the study and your use of the data is consistent with the protocol.

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<td>ACCESSS: Adapting Collaborative Classrooms to Equally Support Science Students</td>
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If you have any questions, please contact the UCF IRB irb@ucf.edu.

Sincerely,

[Signature]

Renea Carver  
IRB Manager
LIST OF REFERENCES


[53] V. Johnston, University students diagnosed with attention deficit hyperactivity disorder: A hermeneutical phenomenological study of challenges and successes, Liberty University, 2013.


