

**MULTIMODAL SEMIOTICS IN HIGHER EDUCATION:
MEANING-MAKING IN THE STUDY OF BIOLOGY**

Dissertation presented before the
Department of Graduate Studies
College of Education
University of Puerto Rico
Río Piedras Campus
as a partial requirement
for the degree of Doctor of Education

By

Anyeliz M. Pagán Muñoz

© Copyright, 2022

Dissertation presented as a partial requirement
for the degree of Doctor of Education

**MULTIMODAL SEMIOTICS IN HIGHER EDUCATION:
MEANING-MAKING IN THE STUDY OF BIOLOGY**

ANYELIZ M. PAGÁN MUÑOZ

Master of Arts in Translation, University of Puerto Rico, 2014
Bachelor of Arts in Communication, University of Puerto Rico, 2011

Approved on April 22, 2022, by the Dissertation Committee:

Kevin S. Carroll, Ph.D.
Committee Chair

Eduardo J. Suárez Silverio, Ph.D.
Committee Member

Alicia Pousada, Ph.D.
Committee Member

DEDICATION

To Abuelo Turín, who would have been beside himself with joy telling everyone and anyone that his granddaughter got all her smarts from him and would have probably followed that up with, “*Si sale a mí, se la come un caballo.*” I still don’t know what that means, but I sure loved hearing it.

Te amo, abuelo. I miss you.

ACKNOWLEDGMENTS

Throughout my doctoral studies, I have received plenty of support and assistance, and I would like to take a moment and acknowledge those who have helped me in this endeavor.

First, I would like to thank my advisor, Dr. Kevin Carroll, for his mentorship throughout the last few years. His advice has been invaluable both for this project as well as the latter stages of my graduate studies.

I am also incredibly grateful for the comments and suggestions made by my readers, Dr. Alicia Pousada and Dr. Eduardo Suárez, whose input helped strengthen my research.

I would like to thank the other members of the research team: Gabriela Irizarry, Alissia de Vries, and María Dávila, whose contributions to the larger project were essential for conducting this study.

This dissertation would not have been possible without the participation of the professors who welcomed the research team into their classrooms and the students who attended the focus groups. I appreciate their time and disposition to participate in the larger study.

I value my time spent at the College of Education and everything I learned from my professors, especially Dr. Elsie Candelaria, Dr. Gladys Capella, and Dr. Claudia Álvarez. I am also thankful for the research opportunities and academic experiences I was provided by my PEAf mentors, Dr. Don Walicek, Dr. Alicia Montañez, and Dr. Kevin Carroll.

The experience I have acquired these past five years teaching at the Inter-American University of Puerto Rico, Bayamón Campus, was crucial for my development as an educator and a researcher. I appreciate the support of Dr. Anthony Rivera, former Dean of Academic Affairs; Dr. Rafael Salgado, Associate Dean of Academic Affairs; and Dr. Gisela Carreras, Director of the Humanistic Studies Department, for granting me a partial non-teaching load this semester to work on the remaining chapters of my dissertation. The last few months I have also visited the library at Inter Bayamón more times than I can count. I am grateful for all the assistance provided by the entire library staff, especially by Norma Vázquez. Librarians make the world go round!

I feel blessed to have such supportive colleagues and students at Inter Bayamón. I appreciate the tips, feedback, and support that I have received the past few months from Dr. Isabel Garayta, Dr. Juan J. Rodríguez, Dr. Sandra Palmer, Prof. Mary Blanco, Dr. Yessica Albino, and Dr. Yadira Nieves. However, I am especially grateful for the support of my officemates, Prof. Víctor Quiñones and Dr. Vilma Pizarro. Thank you for believing in me and making our shared space a warm and happy place. Furthermore, I cherish all my students, who have held me accountable for my own homework.

Writing a dissertation can involve hours of fighting with Microsoft Word. Dr. Luis García Nevares, thank you for all the tips and tricks you have shared with me throughout the years.

While I have not practiced taekwondo in years, I would like to thank Master Luis Gato Gato. I barely remember any patterns, but the tenets (courtesy, integrity, perseverance, self-control, and indomitable spirit), which we developed every day in the dojang, were crucial for completing my degree.

When I started this journey, I never thought that my life would be interrupted by several major hurricanes, earthquakes, a pandemic, and a house fire. Tío Pollo and Titi Myrna, I am so incredibly thankful for all the help you provided us to make our home livable again after the fire. I am also thankful for the support that I have received from my extended family, from my grandmother Tata's gift of prayer cards to the WhatsApp chat with my cousins, which always makes my day. I kept my end of the deal; now it is your turn. Please do not forget the cake.

I am grateful for the people who have helped keep me sane throughout my doctoral studies. I especially appreciate the support of Cynthia Yordán, Terilí Santos, Leimar García, Juan Carlos Pérez, Nathanael Beltrán, Trevor Osborn, and Linnette Rodríguez, as well as that of the members of Orquesta Jíbara Dr. Francisco López Cruz and its director, Myrna Pérez. I would also like to thank Rafael Zayas, Fiorelys Mendoza, Bianca Rodríguez, and Yadira Comulada for their support and encouragement.

I am lucky to have two great siblings. Thanks to my sister, Angélica, for going on formatting deep dives with me and ensuring that I go home to watch TV with her, and to my brother, José, our resident scientist, for being available for science consultations and memes.

None of my achievements would have been possible without the sacrifices made by my parents, Annie and Josean. I am profoundly grateful to them for instilling in me the value of education and investing in my academic and personal development.

Finally, I am incredibly thankful to my husband, Ramón, who has taken the brunt of the housework and consistently made sure that I did not let frustration take over and took care of myself.

ABSTRACT

MULTIMODAL SEMIOTICS IN HIGHER EDUCATION: MEANING-MAKING IN THE STUDY OF BIOLOGY

Anyeliz M. Pagán Muñoz

Dissertation advisor: Kevin S. Carroll, Ph.D.

This qualitative study examines the semiotic meanings communicated through multiple representations in the teaching of an advanced undergraduate course in biology. Scientific discourse is intrinsically multimodal in nature; in other words, science is discussed and researched using multiple modes that convey meaning (Lemke, 1998). Therefore, to understand and communicate scientific concepts, students must navigate different modes of communication such as speech, writing, images, and discipline-specific symbols, which in the sociolinguistic context of Puerto Rico tend to co-occur with Spanish and English. This research used a case study design influenced by multimodal ethnographic research methods to identify and analyze the modes used by a professor in an undergraduate course in biology in Puerto Rico. Data were collected through video-recorded field observations, course-related documents (such as the syllabus and the PowerPoint presentations used in class), interviews with the professor, and a focus group with the students. The data were coded inductively and deductively using Jaipal's (2009) extension of Lemke's (1998) semiotic function framework (i.e., presentational, organizational, orientational, and epistemological functions). This framework served to clarify the dynamic of the course lessons and the role of different modes in the course. This research revealed that multiple modes were used in the teaching of the course. However, it also revealed that while the course could be described

as multimodal, there was no direct instruction of the modes used to guide students' interpretation of the representations and that a banking model of education was prevalent throughout the classes observed. A conclusion drawn from these findings is that the use and presence of multiple modes of representation alone is not enough to develop students' understanding and interpretation of these representations. Pedagogical implications of a multimodal approach to learning are discussed as well as suggestions for further research.

TABLE OF CONTENTS

DEDICATION	ii
ACKNOWLEDGMENTS	iii
ABSTRACT	vi
TABLE OF CONTENTS.....	viii
LIST OF TABLES	xii
LIST OF FIGURES	xiii
CHAPTER I: INTRODUCTION.....	1
Overview.....	1
Statement of the Problem.....	2
Purpose of Research.....	4
Justification of Research.....	4
Research Questions.....	8
Main Research Question	9
Secondary Research Questions	9
Overview of Research Methodology	9
Definition of Terms	10
CHAPTER II: LITERATURE REVIEW	16
Traditional Semiotics	17
Saussurean Semiology	18

Peircean Semiotics	18
Social Semiotics and Multimodality.....	19
A Multimodal Approach to Teaching and Learning.....	23
Routes to Learning.....	23
Transformation and Transduction.....	25
Scientific Discourse	27
Lemke’s (1998) Semiotic Function Framework	28
Research on Multimodality in STEM Education.....	31
Multimodal Research in K-12 STEM Education.....	31
Research in STEM Higher Education.....	37
Summary	43
CHAPTER III: METHODOLOGY	46
Nature of the Study.....	46
Research Questions.....	48
Research Design	48
Research Context	52
Participant Selection	53
Data Collection	55
Instruments.....	55
Research Procedure.....	57

Ethical Considerations	57
Data Analysis	58
Data Transcription	60
Data Coding	62
Data Triangulation	64
Role of the Researcher	65
Summary	66
CHAPTER IV: FINDINGS	67
The Course	68
The Professor	74
Role as Professor and View of Science	75
Teaching Strategies	80
Functions of Semiotic Modalities	85
Presentational Function	88
Organizational Function	93
Orientational Function	98
Epistemological Function	104
Summary	110
CHAPTER V: DISCUSSION	112
Role of Signs in the Observed Course	113

Modes Used Throughout the Course	113
Functions of Modes Used in the Course	114
Science as an Inherently Multimodal Discourse.....	116
A Banking Method for Developing Critical and Scientific Thinking	119
Pedagogical Implications	124
Research Limitations	127
Suggestions for Future Research	130
Concluding Remarks.....	131
REFERENCES	134
APPENDIX A: CIPSHI APPROVAL LETTER	147
APPENDIX B: CIPSHI EXTENSION AUTHORIZATION	148
APPENDIX C: OBSERVATION PROTOCOL.....	149
APPENDIX D: INTERVIEW PROTOCOLS	150
APPENDIX E: FOCUS GROUP PROTOCOL.....	152
APPENDIX F: CONSENT FORMS	155
APPENDIX G: CITI TRAINING CERTIFICATE	158
APPENDIX H: PROPOSED TRANSCRIPTION MODEL	159
APPENDIX I: FINAL MODIFIED TRANSCRIPTION MODEL	160
BIOGRAPHY	161

LIST OF TABLES

Table 1: Inductive Code List.....	63
Table 2: Data Unit Organizer in Terms of Concepts	87

LIST OF FIGURES

Figure 1: Slide 6 Presentation for Week 4	84
Figure 2: Packed Code Cloud	86
Figure 3: Slide 10 Presentation for Week 2	89
Figure 4: Slide 39 Presentation for Week 6	90
Figure 5: Professor Using a Gesture to Indicate Closeness	91
Figure 6: Prof. Bernard Using a Laser Pointer to Explain a Diagram	95
Figure 7: Slide 3 Presentation for Week 2	96
Figure 8: Prof. Bernard Points with Hand to Photo in Presentation	98
Figure 9: Prof. Bernard Looking and Pointing at Students.....	99
Figure 10: Prof. Bernard Walking across the Room to Address a Student.....	101
Figure 11: Slide 26 Presentation for Week 2	106
Figure 12: Slide 55 Presentation for Week 4	107
Figure 13: Slide 7 Presentation for Week 6	108

CHAPTER I:

INTRODUCTION

Overview

In Puerto Rico, there is a pervasive belief that a career in a Science, Technology, Engineering, and Mathematics (STEM) field is a definitive mark of success. Studying majors such as medicine and engineering is highly encouraged since they are regarded as opportunities for socio-economic mobility on the island and abroad. Given the demand for college majors in STEM, most higher education institutions in Puerto Rico offer several programs in these fields. Biology programs, in particular, are quite popular as they pave the way toward medical school due to their curricula; nevertheless, they are also exceedingly competitive.

This competition in STEM fields is seen within different levels or steps in the study of medicine in Puerto Rico. The first hurdle to overcome is to be admitted to one of these undergraduate science programs, especially the Biology major at the University of Puerto Rico, Río Piedras Campus (UPR-RP), which receives over a thousand applications per year and admits roughly three hundred students who will study Biology as their first, second, or third major, according to statistics from the Office of the Dean of Academic Affairs at the University of Puerto Rico, Río Piedras Campus (UPR-RP, 2022a; 2022c; 2022d). Throughout the past twelve years, the Biology program has maintained an average minimum admissions index (IMI, in Spanish) of 337, the second highest in the entire campus after the School of Architecture (2022b). The IMI is a combination of a prospective student's high school GPA and college admission exam score. The demand for the Biology program is high since many of its graduates are also later admitted to the

School of Medicine of the University of Puerto Rico, which is a lower cost alternative for studying an expensive degree while still being a highly prestigious institution (UPR Medical Sciences Campus, School of Medicine [UPR-MSC SM], 2018). The second and third hurdles would be to continue in the program and to be admitted to medical school, respectively. To graduate from the Biology major, students must pass 126 credits of coursework with a grade of C or better, sixty-five of which are in the natural, or so-called “hard,” sciences (Facultad de Ciencias Naturales, UPR-RP, 2010a; Facultad de Ciencias Naturales, UPR-RP, 2010b).

Among the courses required for admission to the School of Medicine are specific science courses, such as General Biology and Organic Chemistry; general education courses, such as English and Spanish; and bonus science courses, such as Evolution and Microbiology (UPR-MSC SM, 2021). Most of these courses require students to tap into their semiotic resources to understand the subject matter and develop the necessary skills to finish their degrees and succeed in graduate studies in science. As will be discussed, science is intrinsically multimodal in nature; in other words, science is talked about, written about, and conducted in different modes (Lemke, 1998; Kress et al., 2001). This means that in order to understand and communicate scientific concepts, students must navigate through and employ different communicative modes, such as speech, written language, symbols, diagrams, and images (Airey & Linder, 2009; Danielsson, 2016).

Statement of the Problem

Meaning-making in science classrooms has repeatedly been described as a multimodal endeavor (Lemke, 1998; Kress et al., 2001; Jaipal, 2009; Tang, 2013;

Danielsson, 2016; Zhang, 2016). As a discipline, the teaching and learning of science requires the involved parties to navigate the content taught and learn using different modes, which vary in their affordances, in other words, their meaning potentials and limitations, according to Kress (2010). These modes are varied and may include verbal language, written language, graphs, numbers, mathematical equations, content-specific symbols, layout, gestures, and images.

Therefore, learning science entails learning to “juggle” multiple modes and representations. As Danielsson (2016) points out, “to be able to ‘juggle’ with representations, or to make meaning from the teacher’s juggling, is a demanding task for the novice, who is about to learn something new” (p. 88). Making meaning of the teacher’s juggling of modes is also essential for becoming fluent in “a critical constellation of the different semiotic resources—or modes of disciplinary discourse” (Airey & Linder, 2009, p. 28) and become full participants in their community of practice (Lave & Wenger, 1991). In the case of undergraduate students pursuing Biology majors to apply to medical school, their science major courses also serve to help them learn how to communicate multimodally so that they will be prepared for medical school. However, this entails that the professors of these science courses need to teach multimodally, which means that students must become well-versed in the type of multimodal communication used in their discipline.

Lack of understanding and mastery of the “critical constellation of modes” (Airey & Linder, 2009, p. 28) can affect a student’s chance of success in a scientific discipline. In the case of Puerto Rico, the need to master a variety of modes is coupled with the need

to develop a mastery of sub-modes such as academic bilingual competency in Spanish and English. When it comes to required pre-medicine courses, some might be taught exclusively in English without the student's knowledge prior to the start of the semester (Carroll, 2016). Since a career in medicine entails the presence of English at several key stages (such as some content courses, the MCAT, the three United States Medical Licensing Examination [USMLE] exams, and specific-core-rotation exams), proficiency in English may serve as a *de facto* gate keeper for success in the field (Carroll et al., 2021). While translanguaging practices can serve to bridge communicative gaps in required pre-med courses as documented in Carroll et al. (2021), a focus on the multimodal aspect of these courses would shed light on how trans-semiotizing practices may contribute to students' overall learning.

Purpose of Research

The purpose of this qualitative research is to analyze the semiotic meanings communicated by multiple modalities during the teaching of biology concepts in an undergraduate science course at a Puerto Rican university. This study also has the purpose of analyzing how semiotic modalities are used in the course and pointing out features of semiotic modalities that should be used during instruction in higher-education scientific concepts to enhance meaning-making.

Justification of Research

Although there has been an increase in studies related to multimodality in education, particularly in scientific education (Lemke, 1998; Kress et al., 2001; Jaipal, 2009; Jaipal-Jamani, 2011; Liu & Dwi-Nugrohd, 2012; Tang, 2013; Zhang, 2016), there

are still relatively few studies that have focused on multimodality in higher education contexts. In addition, aside from Soto Vega's (2010) study on multimodal media literacy in an ESL college classroom, there have been no previous studies of this nature conducted in the cultural context selected for this research, Puerto Rico, and none in the discipline selected, namely the role of multimodality in higher-education STEM courses in Puerto Rico. Since understanding and communicating through different modes (i.e., multiple representations or modalities) is an essential part of scientific education, it will naturally affect the student's academic performance. This, in turn, will affect retention and graduation rates of the institution and admission rates for future graduate studies, such as careers in medicine.

As Kress et al. (2001) state, while there have been studies on the role of linguistic modes in educational STEM contexts, these have mostly focused on language and not on multiple modalities such as writing, gesture, and image. This is true of the research context selected in which there have been some studies on translanguaging practices in higher-education STEM courses, such as Mazak and Herbas-Donoso (2015), Mazak et al. (2017), and Carroll et al. (2021). While studies on the role of language in educational contexts are certainly important, they do not provide a complete account of communicative interactions in the classroom. Language, both oral and written, is just one of many modes that people use to communicate meaning. In order to study how best to teach various types of content matter to students, it is necessary to understand the nature of communication and those aspects that may hinder the teaching-learning process from a communicative perspective. Regarding the teaching of science in particular,

“understanding the dynamic nature of the interplay of modalities can help science educators make decisions on how to select and sequence modalities in ways that support students’ learning” (Jaipal, 2009, p. 49). This better understanding of multiple representations and modes may, in turn, help teachers make more informed choices regarding which modalities are best suited for conveying different scientific concepts and improve student learning and performance (Jaipal, 2009; Jaipal-Jamani, 2011).

Within the context of Puerto Rico, studying the teaching practices of undergraduate professors is essential to making pedagogical suggestions for improvement. The students enrolled in these courses are typically those who pursue careers in medical professions. Taking into consideration the exodus of medical professionals in Puerto Rico, it becomes increasingly important to ensure the development of future medical professionals for the well-being of the island’s health infrastructure. Throughout the past decade, local and national news media have repeatedly reported on the drain of medical professionals on the island (Coto, 2013; Parés Arroyo, 2016; Pérez, 2017; EFEUSA, 2018). Between 2006 and 2016, around 5,000 physicians moved their medical practice to mainland United States primarily because of economic reasons (Parés Arroyo, 2016). This number has increased throughout the years and was particularly worsened by the aftermath of Hurricanes Irma and Maria in 2017.

According to statistics from the Puerto Rico Health Department (Departamento de Salud de Puerto Rico, 2021), for the 2016-2018 period, there were 11,772 physicians in Puerto Rico, 9,442 of whom were actively practicing medicine. Most of these professionals are based in the San Juan metropolitan area. A news article published by

EFE News Service reported that there are five physicians per every two thousand people on the island (*Legisladora propone trabajar para frenar éxodo de médicos puertorriqueños*, 2018). Even though the medical talent drain decreased since the onset of the COVID-19 pandemic, it is expected to increase once the infection rates stabilize (Díaz Rolón, 2021). Given the effect of the COVID-19 pandemic on the health infrastructure of multiple states, the Biden administration announced in 2021 a federally funded initiative aimed at addressing physician shortages (Rivera Sánchez, 2021). This initiative, which includes Puerto Rico, would allocate \$25 million annually for four years and provide scholarships and student loan repayments in exchange for years of service in a given location. Since the program announced by the Biden administration is slated to last only four years, it would only be a temporary solution.

Although this initiative can help Puerto Rico's health crisis, according to the president of the College of Medical Surgeons, Víctor Ramos, cited in Rivera Sánchez (2021), a permanent tax exemption decree would be more beneficial for stopping the flight of physicians on the island. In 2020, under the recommendation of the Financial Oversight and Management Board for Puerto Rico, federal judge Laura Taylor Swain paralyzed Law 47, which would have extended a fixed income tax rate of 4% to general practitioners and other medical specialties (Rivera Sánchez, 2021). The problem of the exodus of physicians in Puerto Rico is part of the broader systemic issue of a weakening health infrastructure; thus, it is necessary to address other aspects of this issue, which would include the academic formation of future medical professionals.

Given Puerto Rico's aging population (Perreira et al., 2017), ensuring students' success in their academic route toward medical school is paramount. As one of the most popular majors on the island, UPR-RP's Biology program supplies many of the candidates for the School of Medicine of the University of Puerto Rico (UPR School of Medicine). According to admissions data of the UPR School of Medicine (2018), forty-five percent of the 2018 entering class were graduates of UPR-RP. Therefore, studying this context would provide valuable insight regarding the teaching practices that are helping students to be admitted to medical school. Understanding the nature of undergraduate science courses required for medical studies can inform curricular decisions that better prepare students for graduate studies and increase their chances for success. A multimodal approach has the potential of shedding light on identifying effective teaching practices and pedagogical suggestions to improve undergraduate students' understanding of the content matter. Studying the semiotic modalities and multiple representations used in the classroom setting may contribute to documenting how scientific knowledge is produced and disseminated and provide a way to increase access to scientific disciplines (Airey & Simpson, 2019).

Research Questions

The goal of the research was to identify and analyze the variety of multiple modes used by a professor in his teaching of an advanced, undergraduate course in biology. Given the purpose of the study, it was necessary to draft broader research questions in tune with a qualitative approach to research. Since the main research question is more general, the

secondary questions were considered subsets of the main research question. Thus, the study was guided by the following research questions:

Main Research Question

1. What role do multiple modalities play in the study of an advanced undergraduate biology course at the University of Puerto Rico?

Secondary Research Questions

1. What types of semiotic modalities are used by the professor to make content comprehensible?
2. What are the semiotic functions of these modalities?

Overview of Research Methodology

The current study used data from a larger qualitative research study titled “The Role of Language in Studying Medicine in Puerto Rico,” which employed ethnographic methods for data collection and analysis. The main research study focused on how professors used translanguaging pedagogies to make scientific content more comprehensible to their students. The larger study collected video data from two undergraduate science courses of the College of Natural Sciences at the University of Puerto Rico, Río Piedras Campus. It also collected data from interviews with the professors who taught these courses and focus groups with the students who took the courses.

The present study employed an instrumental case study design, as defined by Stake (2003), influenced by multimodal ethnography to understand the role that multiple modes played in the advanced biology course that was observed in the larger study. The

undergraduate course (required for Biology and pre-med students) was co-taught by two non-Puerto Rican professors in a dark amphitheater room with approximately 80 students. The larger study had found that the professors were essential to help students overcome linguistic obstacles to understanding the content matter, since much of the content presented was in English (Carroll et al., 2021).

The dissertation study reported here used the video data collected in the larger study during four hour-and-a-half-long classes as well as data from two interviews with the professor who taught the first half of the course and a focus group with students who took the course. The video data were transcribed by the author of this dissertation using a modified version of Kress et al.'s (2001) transcription model. The transcripts of the video observations, interviews, and focus group interactions were coded for specific and emergent themes and analyzed using Dedoose software.

Definition of Terms

The terms below are defined to help the reader understand the context of this study. They are listed in alphabetical order to facilitate their reference when reading later chapters.

Affordance. The limits of representation of a given mode; in other words, how and for what a mode can be used for (Jewitt et al., 2016).

Banking education. It refers to a view of education, here education “becomes an act of depositing, in which the students are the depositories and the teacher is the depositor” (Freire, 1970/2017, p. 45).

Communication. In social semiotics, it is something that “happens as a result to a prompt; communication has happened when there has been an interpretation; communication is always multimodal” (Kress, 2010, p. 36).

Design. In social semiotics, it is a term that refers to “the situated process in which a sign maker chooses and arranges semiotic resources to realize a particular social function or purpose” (Jewitt et al., 2016, p. 156).

Discourse. “Discourses are resources for representation, knowledges about some aspect of reality which can be drawn upon when that aspect of reality has to be represented. [...] Any given discourse might be realized by different genres [...] and different combinations of semiotic resources” (Van Leeuwen, 2005, p. 275).

Epistemological function. It refers to “what counts as knowledge [...] as communicated during teacher and student discourse and the nature of knowledge [...] communicated by modalities and the interplay of modalities as presented by the teacher” (Jaipal, 2009, p. 53).

Foregrounding. It refers to the status awarded to certain modes in a communicative act. Some may be considered more significant than others depending on the social and cultural environment (Bezemer & Kress, 2016).

Framing. It refers to the shaping and understanding of a message as influenced by the cultural environment. (Kress, 2010).

Genre. “A type of text defined in terms of its structure as a communicative event. Genres are ways of achieving communicative goals.” (Van Leeuwen, 2005, p. 277).

Interest. It refers “to a momentary condensation of all the social experiences that have shaped an individual’s subjectivity – a condensation prompted by the social environment (of which the available *modes* are a significant element) that a sign is made within” (Jewitt et al., 2016, pp. 156-157).

Interested engagement. It shows “that interpreters select what they wish to engage with” (Bezemer & Kress, 2016, p. 39).

Interpretation. In social semiotics, it is “the response to a prior prompt. [...] An *interpretation* is the result of a series of *transformations* in which aspects of the *prompt* and aspects of the resources brought by the *interpreter* are shaped, jointly, into a new semiotic entity” (Kress, 2010, p. 36).

Interpreter. In social semiotics, it refers to the reader of a message-prompt (Kress, 2010).

Learning. In social semiotics, it is a process that “rests on interpretation as the outcome of principled, transformative engagement, no matter by whom or how that engagement has been or is shaped” (Bezemer & Kress, 2016, p. 38).

Mode. A set of semiotic resources that have undergone social organizations (Jewitt et al., 2016). Examples of modes include speech, writing, image, and gestures.

Motivated sign. The “motivated relation of a form and a meaning” that is made in social interaction particularly from the interest of the people involved in the communicative process (Kress, 2010, p. 54).

Multimodal ensemble. Also known as a *semiotic bundle* or *modal ensemble*, this refers to a group of modes that are deployed simultaneously (Bezemer & Kress, 2016). Modes always appear accompanied by other modes.

Multimodality. Model that views of communication as a dynamic process that involves the transmission of multiple and simultaneous messages from different modes (Kress, 2010).

Organizational function. In a meaning-making act, it refers to “relations defining wholes and parts of those wholes, both in the semiotic space of the text and the (ecosocial) interactional space of the meaning-making act itself” (Lemke, 1998, p. 94). Examples of semiotic resources that serve this function would be conjunctions and transition words in the mode of writing that connect words, phrases, and clauses in a text.

Orientalional function. In a meaning-making act, it refers to a stance toward something “to indicate how true or certain the producer wishes the interpreter to take it as being, or to indicate an evaluation of it [...] in the perspective the producer is creating for the interpreter” and includes “the construction of a social relationship between producer and interpreters (present or imagined), and more generally a relative positioning of the producer and ‘text’ [...] in the whole social space of possible discourses and viewpoints on the state-of-affairs” (Lemke, 1998, p. 93).

Presentational function. In a meaning-making act, it refers to a “*presentational* ‘state-of-affairs’ that construes relations among semiotic participants and processes as if they were being observed, objectively and synoptically, from some outside vantage

point.” It “defines the sense in which we speak ‘about’ something, construct a theme or topic, make predications and arguments” (Lemke, 1998, p. 93).

Resemiotization. It “is the re-construal of semiotic choices within and across multimodal processes and texts. [Resemiotization] provides means for understanding how semiotic systems are called into play as social processes unfold” (Jewitt et al., 2016, p. 159).

Rhetor. In social semiotics, it refers to the “maker of a message” (Kress, 2010, p. 26).

Semiosis. The process of generating signs, particularly the “active making of signs in social (inter)actions” (Kress, 2010, p. 54).

Semiotic function. It “may refer to the role of a semiotic ‘part’ in a semiotic ‘whole’” (Van Leeuwen, 2005, p. 284).

Semiotic principle. It refers to “principles for and features of meaning making that apply across modes” (Jewitt et al., 2016, p. 159).

Semiotic resources. They are material resources and immaterial conceptual resources through which a community makes meaning and creates signs (Kress, 2010; Jewitt et al., 2016).

Semiotics. Broadly defined, the study of signs (Chandler, 2017).

Sign. “An instance of the use of a semiotic resource [...] for purposes of communication” (Van Leeuwen, 2005, p. 285).

Signified. It refers to the “meaning we express with a signifier” (Van Leeuwen, 2005, p. 284).

Signifier. It refers to the “observable form we use to communicate something” (Van Leeuwen, 2005, p. 284).

Sign-maker. In a social-semiotic theory of communication, everyone involved in a communicative act (Kress, 2010).

Social semiotics. It is “an approach concerned with how the processes of meaning making (signification and interpretation or ‘semiosis’) shape and are shaped by individuals and societies to realize power and ideologies” (Jewitt et al., 2016, p. 160).

Systemic Functional Linguistics (SFL). It is the “theory of language developed by Michael Halliday and extended by colleagues[, where] [1]language is viewed as a social semiotic system: that is a resource for making meaning” (Jewitt et al., 2016, p. 160).

Text. It is “a complex of signs which is designed to be internally cohesive and coherent, and which is coherent with relevant other semiotic entities in the context of use; and which its maker treats as complete, in terms of its social use” (Bezemer & Kress, 2017, p. 513).

Transduction. In social semiotics, “change [that] occurs across modes, in a shift of semiotic material from one mode to another” (Bezemer & Kress, 2016, p. 52).

Transformation. In social semiotics, “change [that] occurs within the same mode” (Bezemer & Kress, 2016, p. 52).

Transformative engagement. In social semiotics, it involves “how someone has responded to a particular task or *prompt*, and has *transformed* tasks or prompts-as-signs addressed to her or him” (Bezemer & Kress, 2016, p. 37).

CHAPTER II: LITERATURE REVIEW

Communication is traditionally seen as a process that takes place primarily by means of a language. Similarly, when people think of language, they traditionally define it as a form of communication or an entity whose main purpose is to communicate. Language is thus considered the primary vehicle for communication among human beings and is also used to describe other forms of communication. For example, it is common to hear terms such as *body language* and *visual language*, prioritizing the role of language in the communicative process (Kress, 2010). However, communication occurs through multiple modes, and focusing on language alone would present an incomplete picture of communicative dynamics among people.

Early models of communication, such as the linear model, depicted a unidirectional process similar to the radio transmission process where a sender encodes a message and then sends it to a receiver, who, in turn, decodes it (West & Turner, 2004). This manner of visualizing communication implies that communication occurs in a single direction and without any interruption. Over the years, other communication models have refined the process by adding elements, such as context, worldview, and noise. Multimodal semiotics, or multimodality, is one such model of communication that views the process of communication as dynamic and involving multiple messages transmitted simultaneously through different modes (Kress, 2010).

The literature review will begin with a discussion of multimodal semiotics and how it differs from traditional semiotic theory, as well as research done on this area of interest. Since the purpose of the present research was to apply multimodal semiotic

theory to the teaching of scientific concepts, this section will be followed by a description of the nuances of scientific discourse as defined by Lemke (1998). Finally, the chapter will close with a discussion of how multimodality applies to education, focusing on STEM courses and previous studies on multimodality in STEM at different educational levels.

Traditional Semiotics

Broadly defined, semiotics is the study of signs. What constitutes a sign, how it is formed, and how it is interpreted, varies per model and theoretician. However, in general, as Chandler (2017) states, “[a]ll meaningful phenomena (including words and images) are signs. [...] Semioticians study how meanings are made and how reality is represented (and indeed constructed) through signs and sign systems” (p. 2). Although Ferdinand de Saussure and Charles S. Peirce are traditionally considered the pioneers of the study of semiotics, several theories of signs have emerged throughout history (Chandler, 2017). For instance, Chandler (2017) notes that Greek philosophers like Hippocrates, Plato, and Aristotle all discussed semiotic notions, like medical symptoms as signs and the concept of *interpretation*.

Regardless of when signs began to be studied, contemporary semiotics evolved from two main traditions: Saussure’s and Peirce’s. For both theorists, the *sign* is the central concept of semiotics. While Saussure (1972/1998) emphasizes the relationship between the “outer” and “inner” worlds in terms of the meaning and form of an arbitrary sign that is established by social convention, Peirce (1999) focuses on the nature of signs in *use*, developing a classification of signs and the notion of an *interpretant*, that is, “the

meaning of that sign for the recipient” (Kress, 2010, p. 62). Thus, Saussure’s take on what constitutes a sign presents a more “stable” notion of what a sign is or how it comes to be, so individuals themselves cannot change signs (Kress, 2010).

Saussurean Semiology

Considered one of the founders of semiotics, Swiss linguist Ferdinand de Saussure is known for his theory of the linguistic sign and his proposal of a new, more general discipline, which he termed *semiology*, to study “the role of signs as part of social life” (Saussure, 1972/1998, p. 15). According to Saussure (1972/1998), a linguistic sign is a two-sided entity that represents a bond between a concept (i.e., *signified*) and a sound pattern (i.e., *signifier*). The relationship between the signified and the signifier is arbitrary, linear, invariable, and established through social convention. However, Saussure’s perspective does not take into consideration the individual’s interpretation of the sign, and even though he concedes that language is only one type of semiological system, Saussure (1972/1998) believed that it was superior to other sign systems.

Peircean Semiotics

Around the same time Saussure presented his theory of signs, American philosopher Charles S. Peirce introduced his thoughts on a theory of signs under the name of semiotics. According to Peirce (1999), a “sign, or *representamen*, is something which stands to somebody for something in some respect or capacity” (p. 72). In contrast with Saussure, Peirce views the sign as a triadic entity, including a *representamen*, an *object*, and an *interpretant*. The first two components correspond to Saussure’s signifier and signified, but he incorporates another layer to the meaning-making process that

emphasizes the role of an individual's interpretation of the *representamen*. Peirce (1999) also developed a typology of signs, indicating that a sign could be an icon (i.e., a sign that resembles the object in some way), an index (i.e., a sign that directs attention to something), or a symbol (i.e., a sign that has a rule that will determine its interpretant). In this way, Peirce (1999) alludes to signs serving different functions and purposes.

Social Semiotics and Multimodality

A social-semiotic theory of multimodality still focuses on the sign as the core semiotic unit, but, rather than viewing signs as arbitrary, it sees them as *motivated* (i.e., the *motivated sign*). In this theory, instead of people using already established signs as part of their meaning-making and communication process, as Saussure posited, each person is the creator (i.e., the *rhetor* or *designer*) of the signs they use (Kress, 2010). Furthermore, the meaning derived from these individually created signs arises as part of the individual's social environment and interaction. As Kress (2010) indicates, in a social-semiotic theory of multimodality, “‘the social’ is generative of meaning, of semiotic processes and forms, hence the theory is a *social-semiotic* one” (p. 54).

Like Peirce, social semiotics also focuses on the importance of semiosis; however, while Peirce describes *semiosis* as the process of signs in use, social semiotics views semiosis as the process of sign making. According to Gunther Kress (2010), one of the main proponents of social semiotics, “[t]he genesis of signs lies in social actions. In *semiosis*—the active making of signs in social (inter)actions—signs are *made* rather than *used*” (p. 54). This emphasis on sign-making instead of sign-use is a key element that distinguishes social semiotics from other semiotic theories and ideas.

Social semiotics originates from the writings of Michael Halliday's (1978) systemic functional linguistics and adopts his semiotic perspective, specifically the idea that every linguistic act entails making a choice. As Kress (2010) explains, social semiotic theory is based on a series of assumptions:

[S]igns are always newly made in social interaction; signs are *motivated*, not *arbitrary* relations of meaning and form; the motivated relation of a *form* and a *meaning* is based on and arises out of the *interest* of makers of signs; the forms/signifiers which are used in the making of signs are *made* in social interaction and become part of the semiotic resources of a culture. (pp. 54-55)

This description implies that all communication is semiotic work. Furthermore, whereas in traditional communication models there were a sender and a receiver, the attention is now directed toward a *sign-maker*. Following a social-semiotic theory of communication, everyone involved in a communicative act is a sign-maker; thus, as Kress (2010) indicates, this label refers to both the producer and the interpreter of a sign since signs are constantly being *re-made*. According to Jewitt et al. (2016), “[i]nterpreting a sign is viewed as a *remaking* of a sign. Both the producer and the interpreter of a sign are shaped by their social, cultural, political and technological environments” (pp. 67-68).

The creation of signs, according to social semiotics, hinges on the sign-maker's *interest*, that is, “the momentary condensation of all the (relevant) social experiences that have shaped the sign maker's subjectivity” (Jewitt et al., 2016, p. 68). This interest also

leads the sign-maker to select the best resources to convey their message according to the social context of the sign production. Signs are created through semiotic resources and modes; these *semiotic resources* are defined within social semiotics as the way a community makes meaning and include both material resources and immaterial conceptual resources (Kress, 2010; Jewitt et al., 2016). In other words, “[s]emiotic resources are the product of the social meaning-making practices (the semiotic work) of members of a community over time, always as meeting the requirements of that community” (Jewitt et al., 2016, p. 71).

Material resources are also known as *modes* within social semiotics and consist of sets of semiotic resources that have undergone social organization (Jewitt et al., 2016). For example, speech, regardless of the language spoken, is one such set of socially organized semiotic resources. Since the resources are contextually created, modes may vary per culture. However, other regular examples of modes include writing, image, gesture, and layout (Kress, 2010). Immaterial conceptual resources, on the other hand, refer to meaning-making “sub-resources” that are communicated through modes, such as intensity, coherence, and proximity (Jewitt et al., 2016). An example of this would be the use of bold fonts, italics, and underlining in written texts to convey emphasis.

It is important to note that modes do not appear in isolation but rather in a variety of modal configurations or *modal ensembles* (Bezemer & Kress, 2016). For instance, a professor might co-deploy several modes simultaneously by using speech and gestures that refer to other nearby modes like writing and images in a PowerPoint presentation.

Focusing on the role of modal ensembles in learning environments, Bezemer and Kress (2016) state,

In the signs made in a multimodal ensemble, different modes draw attention to different features of the world signified, and in doing so they shape and structure engagement and potentials for learning. Speaking to someone, writing, drawing a map or acting out all provide on the one hand particular accounts of the world, and on the other distinct potentials for learning, making those who engage with these signs as prompts see, feel or reflect on and experience the world differently.
(p. 52)

While different modes might convey similar meanings in different ways, each mode in the ensemble contributes by adding new layers of meanings to the communicative act. Using the term *semiotic bundle*, Arzarello et al. (2009) expand the notion of a multimodal ensemble to describe “a dynamic structure (the signs and their relationships) which can change in time because of the semiotic activities of the subjects” (p. 100). This bundle may include signs produced synchronously or asynchronously. In their research on an eleventh-grade science and mathematics course, Arzarello et al. (2009) found that gestures specifically can serve orientational and organizational functions by supporting thinking processes of the parties involved in the communicative act and providing alternative methods of embodying and organizing information.

A final key element of social semiotics is the notion of modal affordance. As Kress (2010) states, “[l]anguage’ isn’t a big enough receptacle for all the semiotic stuff we felt sure we could pour into” (p. 15). In other words, as a mode, language has certain

limits to what it can convey. These limits, or potentials, upon what a resource or mode can or cannot represent are known as *affordances*. The affordance of a mode affects how and for what purpose a mode can be used (Jewitt et al., 2016). As will be discussed in the next section, the notion of modal affordance is key to understanding why and how scientific discourse is multimodal.

A Multimodal Approach to Teaching and Learning

In a multimodal, social semiotic approach to communication, learning is seen as “the inevitable outcome of any and every engagement with the (socially made) world” (Bezemer & Kress, 2016, p. 37). While a multimodal approach to learning distinguishes between official and unofficial learners, this approach implies that people are constantly learning even when learning is not the goal of the interaction. According to Bezemer and Kress (2016), “Learning [...] rests on interpretation as outcome of principled, transformative engagement, no matter by whom or how that engagement has been or is shaped” (p. 38). Like Freire (1970/2017), a multimodal approach to learning also rejects a banking model of education and argues for transformative engagement.

Routes to Learning

According to Bezemer and Kress (2017), there are two routes to learning: (1) through actions initiated by the interpreter and (2) through actions initiated and shaped by another. While they posit that the first route is the most common because, according to multimodal social semiotic theory, learning occurs in every interaction, they believe that the second route is necessary for community building. Regarding the semiotic work conducted by other members of a community, Bezemer and Kress (2017) state:

Whatever [the learners] encounter has been shaped in often very long social histories, whether practices, objects, processes, material or conceptual. While it may well be the interpreter's initiating action which provides the energy to learn, it is, nevertheless, the world engaged with, which is a world that bears, in everything touched and felt, seen or heard, the traces of past social action, of past semiotic work, evident in the forms, the materials, the practices of *culture*. The world encountered with is a world saturated with the traces of past social semiotic work. (p. 521)

Given that in higher education students are training to become full participants in their field of choice, they need to become proficient in the means of conducting semiotic work set forth by previous members of their professional community. Therefore, even though it is the learner's interest that drives their semiotic production, teaching faculty must become agents who shape their engagement (Bezemer & Kress, 2016).

What a person has learned will be evident in the signs of learning they produce. According to Bezemer and Kress (2017), "[Each sign] makes evident what the sign-maker (as *learner*, or otherwise) had attended to, had noticed, and what the effects of such 'noticings' are on the sign-maker's/learner's resources" (p. 521). In other words, all signs produced by students demonstrate what they were paying attention to at the time that they were produced. However, signs of learning never provide a complete picture of what a person has learned because like all other signs, they are always partial and limited based on the constraints imposed by the context (Bezemer & Kress, 2017). For example, in the context of a classroom, students would be restricted to the modes afforded to them

by the professor. In settings where instructors use more collaborative learning techniques and strategies that involve sign production, a student might have a wider range of modes to choose from, such as speech, gesture, writing, images, etc. In a more traditional lecture setting, where students mostly listen to the professor, their signs of learning are limited to a few select modes like gesture and speech.

Since professors and trainers prefer certain texts and modes over others, they hold more power and agency in the communicative act because they are the agents who select and order the texts and modes that will produce some type of engagement. This means that “modes have a large effect in shaping what the sign-maker can do and does; modes set limits to the sign-maker’s agency” (Bezemer & Kress, 2017, p. 520). Consequently, this perpetuates the idea that certain methods of meaning-making are preferable over others and ultimately certain signs of learning will not be recognized, limiting access to some learners. Embracing a multimodal approach to learning entails the recognition of sign-makers’ semiotic work as stated by Bezemer and Kress (2017), “[s]ocially, these are questions of politics and power; semiotically and pedagogically, they are translated into valuations of different ways of seeing the world” (p. 528).

Transformation and Transduction

In multimodality, the processes of transformation and transduction are essential for understanding meaning-making given that signs always appear in conjunction with other signs in multimodal ensembles and that all semiotic resources have different affordances. Because all modes have different affordances, they all offer various possibilities for learning or shaping engagement (Bezemer & Kress, 2017). In other

words, modes vary in their pedagogical and disciplinary affordances, as defined by Airey (2015).

Transformation and transduction are common processes in the teaching-learning process as they both involve the remaking of signs. The term *transformation* refers to changes made within the same mode (i.e., intramodal changes); these are changes to the arrangement (Bezemer & Kress, 2017). For example, paraphrasing or summarizing a written text into another written text would constitute a type of transformation. Translating a text from Spanish into English would also constitute a type of transformation according to social semiotic theory. *Transduction*, on the other hand, refers to changes between modes (i.e., intermodal changes) (Bezemer & Kress, 2017). An example of transduction would be explaining using speech what was expressed in written language. As Bezemer and Kress (2017) state,

[...] modal choices in transformation and transduction have epistemological and social effects. They shape what the new text looks like, and therefore what is made available to those who choose to engage with the text and how [...]. At the same time, they change the resources of the sign-makers who retextualize: by re-making signs in the same or in other modes new understandings are achieved.
(p. 526)

In other words, transformation and transduction represent what a sign-maker considers valuable knowledge and have the potential of showcasing a person's learning as well as developing new knowledge.

When it comes to disciplinary knowledge, communities of practice like scientists establish the meaning of specific signs or how certain semiotic resources should be interpreted (Volkwyn et al., 2019). Since earning a college degree entails learning disciplinary knowledge, the task of the learner thus becomes learning to transduce correctly the semiotic meanings agreed upon by the community. According to Volkwyn et al. (2019), focusing on students' transduction processes is important because they can reveal their learning and makes it possible for instructors to verify their learning. The use of traditional semiotic resources used in the field and the incorporation of new semiotic resources are signs of learning that make continuity and change possible within a discipline (Bezemer & Kress, 2017). This implies that when choosing learning tasks and planning lessons, professors should take into account the semiotic resources required to “construct the desired disciplinary meanings” (Volkwyn et al., 2019, p. 25).

Scientific Discourse

As a field of study, science has been known for its ability to describe, explain, and understand how the world works. Part of this endeavor has required scientists to employ different modes, as defined in the previous section, to present and discuss scientific phenomena. Thus, the descriptive and explanatory nature of science has led it to not rely exclusively on verbal language in order to talk about specific topics, such as continuous change and covariation (Lemke, 1998). As Lemke (1998) states,

Science is not done, is not communicated, through verbal language alone.

It *cannot* be. The ‘concepts’ of science are not solely verbal concepts, though they have verbal components. They are semiotic *hybrids*,

simultaneously and essentially verbal, mathematical, visual-graphical, and actional-operational. The actional, conversational, and written textual genres of science are historically and presently, fundamentally and irreducibly, *multimedia genres*. To do science, to talk science, to read and write science it is necessary to juggle and combine in various canonical ways verbal discourse, mathematical expression, graphical visual representation, and motor operations in the world. (p. 87)

For example, in order to talk “science,” scientists employ a variety of modes to express complex relations between concepts. A visual representation, according to Lemke (1998), will be better suited than language for expressing shape or relative positions.

Seeking to prove his theory of science as multimodal, Lemke (1998) conducted a preliminary study in which he surveyed several professional scientific print publications to verify the frequency in which other non-verbal-textual semiotic expressions were used. Among these expressions, he found that, in addition to verbal written expressions, scientists commonly use, combine, and integrate graphs, diagrams, tables, drawings, maps, photographs, and mathematical expressions. More importantly, however, Lemke (1998) believes that all resources used in science are organized into three generalized semiotic functions: presentational, orientational, and organizational meanings.

Lemke’s (1998) Semiotic Function Framework

The three semiotic functions that Lemke (1998) describes are related to Halliday’s (1978) linguistic metafunctions: ideational, interpersonal, and textual. However, according to Lemke (1998), Halliday’s (1978) typology should be used when discussing

the resources of language, while his should be applied to other semiotic resource systems. Nevertheless, researchers, such as Jaipal (2009), who have used Lemke's typology in their studies have extended the presentational, orientational, and organizational meaning functions to language as well.

As Lemke (1998) explains, these three semiotic functions work together, sometimes overlapping in ways that "can modulate meanings of each kind in each other semiotic modality" and "*multiplying* the set of possible meanings that can be made" (p. 92). Given the potential of semiotic resources to cross-multiply, it is possible to convey more meanings than are possible through a single resource alone. In this way, a single resource may have a "tri-functional" purpose and convey presentational, orientational, and organizational meanings.

The first of the three meaning functions, the presentational aspect, refers to "the sense in which we speak 'about' something, construct a theme or topic, make predictions and arguments" (Lemke, 1998, p. 93). In other words, the presentational function is descriptive, given that it constructs what is taking place in a given context. Extrapolating this definition to the context of a science classroom, Jaipal (2009) indicates that the presentational function in the teaching-learning process is reflected by "conceptual aspects such as explaining meanings, making predictions and arguments, and understanding of context" (p. 52).

While the purpose of the presentational aspect is to "tell us what we are being shown, what is being supposed to be 'there,' to be happening, or what relations are being constructed among the elements presented" (Lemke, 1998, p. 93), the orientational aspect

serves more as an evaluative stance toward what has been presented. For example, through an orientational stance, a science teacher may project their feelings toward the usefulness or accuracy of a theory, an idea, or a textbook. In Lemke's (1998) words, a meaning-making act "can indicate how true or certain the producer wishes the interpreter to take it as being, or to indicate an evaluation of it as good or bad, ordinary or surprising, necessary or obligatory" (p. 93).

Finally, the organizational aspect includes acts that define parts and unite them (Lemke, 1998). Put differently, the organizational aspect comprises semiotic resources that function similarly to transition words and phrases in writing. This organizational function of semiotic resources can be seen across modes, regardless of their form, such as the use of headings in layout and depiction in visual signs. According to Lemke (1998), "As material objects, depictions participate in interactions that define parts and unite them into wholes in the ecosystem networks where objects are viewed and used" (p. 94).

These three semiotic functions have been used by different researchers to describe the operation of the Science classroom. However, some years later, as part of her multimodal semiotics discourse analysis on meaning-making in a Biology classroom, Jaipal (2009) extended Lemke's (1998) tripartite framework to include a fourth aspect: the epistemological function. This fourth function focuses on the nature of knowledge, which, according to Jaipal (2009), is concerned with "what counts as knowledge [...] as communicated during teacher and student discourse and the nature of knowledge [...] communicated by modalities and the interplay of modalities as presented by the teacher" (p. 53).

The researcher's use of this framework allowed her to relate semiotic functions to science learning outcomes and present it as an alternative to maximize the use of semiotic resources in the classroom to reinforce student learning via scaffolding. Capitalizing on different semiotic resources and multiple resources would, therefore, tap into students' learning styles and multiple intelligences as defined by Gardner (2006). The next chapter will discuss how this framework was used to analyze the data collected for the purposes of the present study.

Research on Multimodality in STEM Education

While Lemke (1998) analyzed multimodality in scientific texts and developed a framework for understanding the different functions of semiotic resources in science, others have examined how multimodality works in scientific classroom contexts. These studies have looked into multimodality at different educational levels and in different science subjects (e.g., Biology and Chemistry) as well as how a particular mode, such as visual communication or gestures, is used in STEM classrooms. Additional research has been done regarding the role and function of different modes in particular science classrooms. The following pages were organized in two main sections: research in STEM education in K-12 school settings and research in STEM higher education.

Multimodal Research in K-12 STEM Education

Most of the research conducted into multimodality in STEM education has been conducted in elementary and secondary school settings. These studies have focused on a range of topics as well as content matter, including lessons related to biology, chemistry, physics, and mathematics. While there is a host of other foci and research purposes, in

general, the literature reviewed examined multimodality in three main education-related areas: teacher practices, text analysis, and collaborative learning and student peer interaction. Some relevant studies are detailed below.

Teaching Practices. Some studies on multimodality in K-12 STEM education have focused on the teacher's use of modes as part of their lessons. For example, Jaipal (2009) used an extension of Lemke's (1998) semiotic function framework to analyze the classroom discourse use to teach the concept of chemosynthesis by an eleventh-grade honors biology teacher in Canada. Utilizing ethnographic field methods that included several interviews with the teacher where he reflected about his strategies, the author found that the framework developed was useful for presenting how semiotic modalities are selected, sequenced, and modified.

According to Jaipal (2009), the framework can assist researchers in analyzing the modalities used in an educational context and permit teachers to reflect on their multimodal practices and design strategies to help students make multimodal connections. Jaipal's (2009) analysis also revealed how different modes can function as a scaffolding method to enhance meaning-making in the classroom. Jaipal-Jamani (2011) later applied this framework to the pedagogical practices of two high school physics teachers. Jaipal-Jamani (2011) explained that science discourse in an educational context diverges from the science discourse used by professional scientists in that new theories are not being created and theories are instead used to explain scientific phenomena. The modalities used to explain these concepts and theories are "selected by educators based on previous experience implementing them with students in classrooms" (Jaipal-Jamani,

2011, p. 201). The use of the framework allowed the researcher to compare the modalities used by the two teachers and notice that speech was preferred as an expository modality to discuss theories, while the experiential and evidence-based aspects of science were communicated through more visual and action modalities.

In a similar vein, Danielsson (2016) used a social semiotic perspective on multimodality to analyze the different semiotic resources teachers utilize to introduce the concept of the atom as either dynamic or static employing the ideational metafunction of Halliday's systemic functional grammar. The study collected video and photo data from four different high-school classes with Finnish and Swedish professors and students; it studied the professors' presentation of the concept of the atom through speech, gestures, images, and writing, which also included chemical or mathematical symbols.

The study concluded that gestures conveyed the atom as a dynamic concept while images conveyed it as static. More importantly, however, Danielsson (2016) concluded that various modes conveyed similar information in different ways resulting in a redundancy of information that favors content learning. Nevertheless, since there were no discussions with students on the affordance of each mode, students were left to make sense and combine the information by themselves, implying that direct conversations and instruction on the affordance of modes could help students learn content better. However, the analytic framework, Halliday's (1994) systemic functional grammar, employed in Danielsson's (2016) study might not have been the best suited to analyze semiotic work as it was designed for analyzing linguistic modes like speech and writing.

Text Analysis. Education-related multimodal research has focused on different aspects of textual production. While some researchers have examined the texts created by learners themselves, others have studied the textbooks used in science classes. Regarding students' textual production in learning settings, Jewitt et al. (2001) examine the interaction between visual, actional, and linguistic communication in science learning. Employing a multimodal perspective, the authors emphasized the importance of action in the study of science by analyzing how four Year 7 students from the United Kingdom transform a teacher's communication through a variety of modes in the production of texts related to the concept of a biological cell. The researchers observed how students produced their texts, interviewed the students about their work, and analyzed the texts themselves. The analysis demonstrated that the process of constructing a cell was multimodal in nature, involving different modes such as images, actions, speech, and writing as well as "collating, selecting, and adapting information from a range of modes" (p. 16). The study also concluded that the variation in the texts produced by the students demonstrated not only their cognitive learning process but also that the differences between them represent how individual students viewed the lessons, transformed information, and reflect their interests.

Like other researchers on multimodality in education, Manghi (2013b) employed a qualitative study to analyze and compare the semiotic artifacts used in the pedagogical discourse of middle-grade history and biology teachers in Chile. The study found that while history and biology professors used similar modes in their teachings, such as speech; writing on a chalkboard; and images, they were used in different combinations

and at different times. Manghi's (2013b) study also suggests that images, in particular, vary in their semiotic potential and affordance depending on the course and subject matter. More importantly, however, the author indicates that the study showed that the lessons focused more on comprehension of the material rather than text production; thus, students did not have many opportunities for making signs and communicating multimodally, which was also true regarding the evaluation practices observed in the study.

Manghi (2013a) reinforces these findings, indicating that while the genres used in the participants' teaching practices served to build students' semiotic literacy, it is necessary to incorporate learning activities and evaluation strategies that allow learners to transform and transduce information and showcase their learning multimodally. This concept of semiotic literacy is aligned with that of multimodal literacy, as explained by Lemke (1993) and Klein and Kirkpatrick (2010). Manghi's (2013a; 2013b) suggestions also imply that students should have a more active role in their learning in order to benefit from multimodal instruction and acquire multimodal literacy. Special attention should thus be provided to classroom discourse practices as well as the materials and evaluation strategies used to promote students' positioning as communicators and critical thinkers (Moje, 1997).

While Jewitt et al. (2001) analyzed texts produced by learners and Manghi (2013a; 2013b) studied those used by teachers, Das Neves et al. (2016) analyzed the didactic value of images related to cells in middle-grade and high-school biology textbooks used in Brazil. Basing their analysis on cognitivist theory for multimedia

learning, the authors analyzed the images included in seven textbooks and classified them as decorative, representational, organizational, and explanatory, which are categories akin to Lemke's (1998) presentational, organizational, and orientational semiotic functions. Despite not analyzing the textbooks within their context of use, the authors suggested that images might facilitate comprehension of abstract concepts. Das Neves et al. (2016) also highlighted that textbook developers should minimize the use of decorative and representational images and increase the number of organizational and explanatory images, since the latter have more didactic value than the former. According to the authors, developers should also carefully consider the placement of images so that students do not have to flip pages to find the images related to the writing and thus minimize confusion among students.

Collaborative Learning and Student Peer Interaction. Studies like Frejd (2018) and Volkwyn et al. (2019) have focused more on the social aspects of student interaction and collaborative learning at different levels. Frejd (2018) employed a qualitative approach to assess how six-year-old students engaged with each other and used multiple representations to make meaning related to evolutionary biology questions. In focus groups, the children were provided maps, photographs, and figurines and asked questions about four big cats (e.g., lion, snow leopard, jaguar, and tiger). The study found that children used the resources provided as communicative, resource-providing, and argumentative tools. As communicative tools, the children used the figurines for demonstrative purposes when discussing one of the species. They also used images to gain information about the species and different aspects of the resources provided to

create arguments and explain their reasoning to their peers. Frejd's (2018) findings illustrate that, even at a young age, humans employ a variety of resources to make meaning.

Likewise, Volkwyn et al. (2019) studied the process of transduction in science learning within a physics laboratory. Framed by a lesson on the direction of the Earth's magnetic field that required the use of a hand-held electronic measurement device, the authors used ethnographic data collection methods to observe how a pair of students engaged in meaning-making practices and transduced information learned from interpreting signs emitted by the device. As part of the transcription and analysis, the authors identified three separate instances of transduction of meaning. Volkwin et al.'s (2019) findings suggest that instructors should consider the disciplinary and pedagogical affordance of the resources they will use in their lessons and leverage the use of specific modalities to capitalize on their affordance to foster transduction processes. The authors also explained that keeping an eye out for student transductions of new semiotic resources, such as the use of gestures with speech to explain a concept, was important because they were a sign that learning was taking place.

Research in STEM Higher Education

Unlike studies related to science education at the primary and secondary levels of instruction, studies on the role of multimodality in university science education are relatively few. Within the last few years, there has been increased interest in this research context. Many of these studies have focused on the nature of disciplinary discourse and disciplinary affordance, emphasizing that students must acquire fluency in specific

modes; the role of new digital technologies in higher education teaching and learning; and the analysis of texts used to teach university-level science courses as well as texts produced by learners in higher education. Furthermore, these studies have explored how studying multiple representations in science and science teaching may increase access to the discipline (Airey & Simpson, 2019).

Disciplinary Discourse and Affordance. Some research on multimodality in STEM higher education have focused on the notions of disciplinary discourse, disciplinary affordance, and pedagogical affordance. According to Airey and Linder (2009), science learning at the college level requires mastery of the disciplinary discourse of the field, “the complex of representations, tools and activities of a discipline” (p. 28), which implies acquiring proficiency in a “critical constellation of the different semiotic resources—or *modes* of disciplinary discourse” to be successful academically.

Based on their theoretical analysis of anecdotal illustrations of interviews with Swedish undergraduate students regarding their experience being taught physics in Swedish and English, Airey and Linder (2009) concluded that science disciplinary discourse at the university level is multimodal, repetition is a necessary element of university science learning, and this repetition is how students become proficient in disciplinary discourse. Like Manghi (2013a; 2013b), the authors also highlighted that students need opportunities to practice using multiple representations to acquire proficiency in their disciplinary discourse as well as evaluation and assessment criteria that reflect the multimodal aspects of their field. In addition, Airey and Linder’s (2009) analysis supports that of Jewitt et al. (2001) in that transformation and transduction

practices reflect not only signs of learning but also can serve as tools for students to “notice discrepancies between their way of knowing and that of the discipline” (p. 44). Like Jewitt et al. (2001) and Andersen and Munksby (2018), Airey and Linder (2009) also conclude that teachers must consider the selection and sequencing of modes in their teaching to maximize students’ meaning-making practices and learning.

Studies such as Airey and Eriksson (2019) and Samuelsson et al. (2019) at the college level and Dolo et al. (2018) at the K-12 level have focused on the disciplinary and pedagogical affordance of specific tools in classroom settings. Airey and Eriksson (2019) question the pedagogical accessibility and affordance of a key instrument used in astronomy and astrophysics, the Hertzsprung-Russell (H-R) diagram. The authors argue that while the tool has high disciplinary affordance in that it conveys much information to professionals in the field, its pedagogical affordance is low since the H-R diagram includes many distinct features that teachers should unpack. The study identified four main problems that students might face when learning to use the tool, which relate to the history of the tool, omission of important information, difficulty processing large amounts of information, and student expectations about the presentation of the information. Airey and Eriksson (2019) also suggest that, when presenting a new resource to students, teaching faculty members should consider its basic features and how they can enhance students’ learning.

Similarly, Samuelsson et al. (2019) explored the variation in disciplinary and pedagogical affordance of infrared (IR) cameras to investigate thermal phenomena in an undergraduate chemistry course. Furthermore, they looked at the affordance and semiotic

resources of IR cameras as used by both undergraduate students and the graduate students who taught the course. Their results demonstrate that these devices positively impacted students' disciplinary understanding, but it hindered their engagement in terms of their type of actions and talk that lead to more advanced understanding. When compared to the interactions between the instructors who engaged in exploratory talk that was more critical of each other's contributions and suggestions, undergraduate students employed cumulative talk to discuss their interpretations of their findings using the technology through which they contributed ideas and suggestions that were not challenged by their peers. This is similar to Dolo et al.'s (2018) findings using thermal cameras in a middle-grade South African school context, where students' lack of a thorough conceptual understanding inhibited them from engaging in "true dialogue" regarding the class exercise and interpreting information conveyed by the cameras.

Digital Technologies. As explained by Gourlay (2010), higher-education teaching practices have seen an increase in the use of visual modes and digital technologies, such as PowerPoint presentations, which reflect an increase in the range of day-to-day visual practices. While there are several other digital technologies used in higher education, particularly after the start of the COVID-19 pandemic, PowerPoint presentations are commonplace in college lectures. As semiotic artifacts that may include images, text, video, and audio content, PowerPoint presentations may be multimodal in nature.

He et al. (2017) employed a translanguaging lens in the analysis of a multimodal mathematics presentation in a mathematics seminar in Hong Kong. While mathematics

discourse in itself is inherently multimodal (O'Halloran, 2015), the presence of other modes like images, writing in two languages, and speech along with mathematical equations helped to breach the communicative gap in an international context where many in the audience did not speak Chinese (He et al., 2017). Despite giving a more linguistic focus to their semiotic account due to their emphasis on verbal aspects of communication and meaning (Bezemer & Kress, 2020), He et al.'s (2017) study showcases the power of multimodality and multiple modal complexes or ensembles to convey meaning and increase access to different groups.

According to Hill et al. (2012), the prevalence of PowerPoint presentations in higher education has made students expect its presence in the classroom, but it does not necessarily promote critical thinking, student engagement, or active learning. Within this framework, Bolkan (2019) examined the effect of animations in multimedia presentations on students' attention and learning. Using a sample of 169 students, the author exposed the participants randomly to one of two versions of the same presentation: one in which the information was presented in full and another in which animations were used to insert the information as it was mentioned. Afterwards, the participants were given a multiple-choice test related to the lesson. Bolkan (2019) found that the use of animations in PowerPoint presentations can help students understand information more easily because it reduces cognitive load by segmenting the information and making it easier to process.

Text Analysis. Multimodal studies in STEM higher education mostly focus on the students' production of texts, which is understood as the production of coherent and cohesive complexes of signs (Bezemer & Kress, 2017). Analyzing students' text

production can provide valuable insight into their learning and cognitive processes as well as their interests. In a study conducted at a major Midwestern university in the United States, Hand and Choi (2010) used the Science Writing Heuristic approach to analyze the written arguments produced by 111 undergraduate students from organic chemistry laboratory classes. The findings of their study showed that students who incorporated multimodal representations into their arguments made stronger and more reasoned connections to support their claims. Hand and Choi (2010) also found a strong correlation between students' exam scores and the quality of their arguments, suggesting that a higher multimodal literacy (Lemke, 1998; Klein & Kirpatrick, 2010) as well as fluency in a "critical constellation of modes" as termed by Airey and Linder (2009) is pivotal for success in science.

The importance of developing multimodal literacy is also present in the findings of Simpson and Prince's (2018) analysis of a quantitative literacy event in an applied mechanics module. While the authors focused on the development of quantitative literacy, a type of literacy that involves practical problem-solving in response to quantitative information, the question presented to students was multimodal in nature, incorporating not just numerical information but also complex images and writing. Simpson and Prince (2018) argued that the framework used was useful for describing the quantitative literacy demands in the study of science and engineering but that it did not explain the difference between the texts produced by students. The authors emphasized that analytical frameworks were not a substitute for the lived experiences of teachers and

students, suggesting that multimodal research should complement analysis of interactions with data collection instruments that give a voice to those experiences.

In their study of semiotic relations in multimodal texts in surgical education, Bezemer and Kress (2017) analyzed a variety of texts produced in operating theaters in the United Kingdom. They observed over 80 hours of operating time of general surgical operations that involved surgical medical students and trainers. The first text they scrutinized was a written description or recipe of how to remove a gall bladder; the second was a three-dimensional model of an operating theater involving a manikin representing a liver and gall bladder, and the third focused on a consultant who performed a laparoscopic cholecystectomy on a patient. Through their analysis, the authors identified how surgical students introduced new signs in their textual production, which served as signs of learning as explained in Jewitt et al. (2001). Recognizing the transduction process and emergence of new signs of learning is crucial for student development and learning and ensuring access in academia (Bezemer & Kress, 2017).

Summary

As discussed in this chapter, all communication is inherently multimodal in nature. While language has been traditionally seen as the main vehicle for communication, meaning-making occurs simultaneously through and across different modes. Different modes contribute to human interactions to varying degrees according to their individual affordances and always appear in multimodal complexes or ensembles. The study of the meaning of and interaction between modes falls under the purview of multimodal semiotics, a branch of contemporary semiotics also known as multimodality.

Although multimodality can be found in all academic disciplines, the field of science, in particular, is highly multimodal (Lemke, 1998; Kress et al., 2001). As Lemke (1998) explains, scientists must learn to understand and use a variety of modes, which are described by Airey and Linder (2009) as a “critical constellation of modes” (p. 28). These modes communicate different meanings or reinforce similar meanings given that, according to Lemke (1998), the exact same content cannot be expressed through all modes. However, the use of similar messages throughout different modes lends itself to the establishment of a certain level of redundancy, which enables better communication and understanding (Lemke, 1998; Danielsson, 2016). The presence of multiple modal ensembles also enables the emergence of transformation and transduction processes, which pave the road for signs of learning to take place (Bezemer & Kress, 2016; Bezemer & Kress, 2017, Volkwyn et al., 2019).

In terms of education, different modes are used simultaneously for varying purposes. As Duncum (2004) indicates, “[o]ne does not read the language and then the pictures and then listen to the sounds; rather, one takes them in as a *gestalt*, a whole, all at once. This then is the challenge of multimodality for education” (p. 259). While it is true that modes are taken in as a whole, it is necessary to understand which modes are used to teach scientific content, the functions they serve, and the value placed on them, in order to select those modes that are more conducive to subject matter comprehension. As multiple researchers have discussed, the presence of multiple modes of representations alone is not sufficient to develop multimodal literacy, as termed by Lemke (1993) and Klein and Kirkpatrick (2010). It is vital that teachers consider several aspects of

multimodality when designing lessons, materials, and evaluation strategies to promote learning and fluency in a variety of semiotic resources. Above all, it is crucial to provide meaning-making opportunities for students and to recognize diverse representations as signs of their learning, interest, and progress. A multimodal approach to education has the potential to increase access to education by recognizing diverse meaning-making practices.

CHAPTER III: METHODOLOGY

The purpose of this chapter is to introduce the research methodology for the qualitative, multimodal, ethnographic case study of the role of multiple modalities in an advanced biology course at the undergraduate level in Puerto Rico. Such an approach allowed for a more nuanced understanding of multimodality in a higher education setting and provided a way to apply the functional framework developed by Lemke (1998) and later expanded by Jaipal (2009).

The chapter is organized in ten main sections, beginning with a discussion of the nature of the study and a presentation of the research questions that guided the project. Subsequently, the research design employed in the study is discussed and justified, and the research context and participant selection process are described. This is succeeded by a description of the data collection instruments and research procedure. The ethical considerations for this study are then explained, including the steps taken to protect the participants' confidentiality. The last two sections of this chapter detail the data analysis methods used and the role of the researcher.

Nature of the Study

The research carried out for this dissertation repurposed data collected in a larger study titled "The Role of Language in Studying Medicine in Puerto Rico," which was funded by an institutional grant (FIPI, in Spanish) and was led by Dr. Kevin Carroll as the principal investigator (See Appendix A for CIPSHI approval letter and Appendix B for CIPSHI extension authorization). While Dr. Carroll's research focused on how professors employed a translanguaging pedagogy to tap into their students' linguistic

repertoires and make content more comprehensible (Carroll et al., 2021), this research addressed the role of multiple modes in the study of biology at the undergraduate level in the same research context.

Following a qualitative approach, Dr. Carroll's study employed ethnographic research methods to collect and analyze the data. The main research study used video-recorded class observations of two organic chemistry sections and one advanced biology course, focus groups with the students taking these courses, and semi-structured interviews with the professors teaching these courses. The courses under observation were selected because they are required courses for students who wish to pursue graduate studies in medicine.

The larger study collected approximately 34 hours of video data from two sections of an organic chemistry course, each taught by a different professor, and 13 hours of video data from a team-taught section of an advanced biology course. The research team also collected data from seven interviews with the four professors teaching these courses and four focus groups with students taking the courses that were observed. The collected data were later organized by file type, as suggested by Creswell (2019), and coded both inductively and deductively, as defined by Saldaña (2021), by searching for emergent themes and using Jaipal's (2009) extension of Lemke's (1998) framework using Dedoose software. The research discussed in the subsequent sections used data from the larger study and followed a case study design to analyze the data using the framework proposed by Jaipal (2009).

Research Questions

In order to analyze the semiotic modalities used to teach an advanced biology course at the undergraduate level and how they potentially contributed to students' learning, the three questions below emerged. RQ1a and RQ1b are subsets of the main research question since they provide partial answers to RQ1.

RQ1: What role do multiple semiotic modalities play in the study of an advanced undergraduate biology course at the University of Puerto Rico?

RQ1a: What types of semiotic modalities are used by the professor to make content comprehensible?

RQ1b: What are the semiotic functions of these modalities?

Research Design

Since the larger study that collected the data followed a qualitative approach, this research also employed a qualitative research approach. According to Creswell (2019), qualitative research has several characteristics, including the exploration of a problem to gain a deeper understanding of a phenomenon, general and broad research questions and purposes, and data collected in the form of words and text from a limited number of participants. As the author explains, "Qualitative research is best suited to address a research problem in which you do not know the variables and need to explore" (Creswell, 2019, p. 16). Given the purpose of the present research, a qualitative approach was most appropriate to understand the intricacies related to the role that multiple semiotic modalities play in the science course observed.

While the main study followed a more ethnographic approach to its design, this research used a case study design influenced by multimodal ethnography. As Gall et al. (2007) indicate, case study research involves “(1) the in-depth study of (2) one or more instances of a phenomenon (c) in its real-life context that (d) reflects the perspective of the participants involved in the phenomenon” (p. 447). In other words, case studies are conducted in order to understand a phenomenon of interest. A case study design would be suitable to analyze ethnographic data since “[a]s a form of research, case study is defined by interest in individual cases, not by the methods of inquiry used” (Stake, 2003, p. 134). Therefore, this design would allow researchers to study various cases regardless of the method of data collection used. As Stake (2003) indicates, “[c]ase study is not a methodological choice but a choice of what is to be studied” (p. 134).

Following Stake’s (2003) classification of types of case studies, this research is an instrumental case study, rather than an intrinsic case study. Intrinsic case studies are conducted when a researcher is interested in the case itself, that is to say that the researcher is not interested in the representativeness or explanatory potential of the case but instead on its particularity (Stake, 2003). Instrumental case studies, on the other hand, are the opposite. As Stake (2003) explains, in an instrumental study,

The case is of secondary interest, it plays a supportive role, and it facilitates our understanding of something else. The case still is looked at in depth, its contexts scrutinized, its ordinary activities detailed, but all because this helps the researcher to pursue the external interest. (p. 137)

Given the purpose of this study to identify and analyze the multiple semiotic modalities used during the teaching of undergraduate biological concepts, the focus would not be on the peculiarity of the course or even the professor (i.e., the particular case) but rather on the phenomenon of signs and multiple representations in this course, their functions, and their roles. Therefore, the research has an instrumental purpose. As Stake (2003) explains, “[the cases] are chosen because it is believed that understanding them will lead to better understanding, perhaps better theorizing, about a still larger collection of cases” (p. 138). In this instance, the case sought to lend a more nuanced, yet ungeneralizable, understanding of the role and functions of different semiotic modalities in undergraduate natural science courses.

Case study research is characterized by its flexibility both in terms of case and methods selection. Lucca and Berríos (2009) explain, “the quality of this design hinges on the research questions drafted and relevant bibliography on the topic, thus the literature review plays an important role before, during, and after data collection” [author’s translation] (p. 97). Therefore, in this design, the literature review was conceived as a continuously evolving process and was expanded upon after the data analysis. Although Stake (2003) argues that case study research can be undertaken regardless of the methods of data collection, popular strategies to collect data include field observation, interviews, and document analysis since they are fitting data collection strategies to study the perspective of the participants (Lucca & Berríos, 2009).

Following the principles established in Creswell (2019) and Stake (2003), the present research fit the requirements of such a design, since the main research question

was open enough to require a qualitative research approach. Moreover, given the data collection strategies employed in the larger study, a case study design was appropriate to analyze the data collected in the field observations, interviews, and focus groups.

The case study design was combined with a methodological emphasis on multimodal ethnography. Multimodality, particularly doing multimodality, in research is understood in different ways. Jewitt et al. (2016) indicate that selecting one multimodal theory over another involves certain expectations regarding the data collection and analysis methods to be used. Since the present research employed existing data, the decision to select a theory of multimodality was based on the type of data collected and the types of analyses that could be performed with it.

Multimodal ethnography is one of many ways to approach multimodal research. Stemming from a social semiotic approach, which in turn draws from systemic functional linguistics, multimodal ethnography examines both artefacts and interactional practices in context (Jewitt et al., 2016). In other words, “[m]ultimodal ethnography investigates how meanings are produced and understood in social and cultural contexts” (Jewitt et al., 2016, p. 118). By employing both social semiotics and ethnography, this approach enables the researcher to produce a microanalytical account of the artefacts used and the engagement in the selected context.

For example, in her study on the multimodal aspects of early literacy in the digital age, Flewitt (2011) stated that “[w]hile multimodal analysis captured something of the communicative complexity of the studied field, ethnographic approaches to data collection and interpretation helped to situate that complexity in particular social, cultural

and historical contexts” (p. 302). The combination of these methods allows the researcher to focus on the “situatedness of meaning making” (Jewitt et al., 2016), given that meaning is not created in a vacuum.

Furthermore, multimodal ethnography addresses research questions “concerned with the role of everyday processes, practices, and contexts in meaning making” (Jewitt et al., 2016, p. 119). When using this approach, the researcher attempts to answer the research questions by employing observation, field notes, artefact analysis, and unstructured and semi-structured interviews with the participants, all of which were data collection methods employed in the larger study and were aligned with a case study research design as described above.

Research Context

The study centered on an advanced undergraduate biology course at the College of Natural Sciences of the University of Puerto Rico, Río Piedras Campus (UPR-RP), the oldest institution of higher education in Puerto Rico. This public university is one of the most prestigious on the island as well as one of the institutions with the largest student populations. According to statistics compiled by the Division of Institutional Research and Assessment of the Office of the Dean of Academic Affairs, UPR Río Piedras had a total student population of 13,226 students for the first semester of the 2021-2022 academic year (UPR-RP, 2022c). The student population has decreased every year since the 2016-2017 academic year, most likely due to several factors, including the 2017 hurricanes, the student strikes in 2017 and 2021, the COVID-19 pandemic, and lower birth rates in Puerto Rico. Nevertheless, the campus still received on average a total of

9,609 undergraduate applicants over the same period (UPR-RP, 2022d). It has also conferred a total of 14,165 degrees since 2016, 86% of which were at the undergraduate level (UPR-RP, 2021).

While UPR-RP offers a wide variety of degrees across STEM, business administration, and liberal arts disciplines, the most popular degree at the undergraduate level is Biology in the College of Natural Sciences, receiving over 800 applicants per year since 2015 (UPR-RP, 2022d). These applicants compete for approximately 250 spots (UPR-RP, 2022b), making Biology a highly sought-after and competitive degree on campus. Therefore, the students admitted in Biology tend to have some of the highest grade-point averages and standardized test scores on campus. Since the Biology major includes all the required courses for requesting admission to local medical schools on the island, it is often used as a steppingstone for pursuing a career in medicine.

The course that was studied was a required three-credit, advanced-level undergraduate biology course, took place during a semester between 2016 and 2021. Most students taking this course were in their third or fourth academic years and, therefore, close to graduation. This also meant that the students taking the course were likely more fluent in the terminology and concepts of their chosen field of study as well as more familiar with the overall nature and environment of the College of Natural Sciences. The course selected was required for future admission to medical school.

Participant Selection

The larger study used purposeful sampling, as described by Creswell (2019), to collect data from professors who were teaching organic chemistry and advanced biology

at the University of Puerto Rico, Río Piedras Campus, and from students enrolled in these courses. Thus, participants were selected depending on the information they could provide for the understanding of the research topic. Since the focus of the main research was the role of language in studying medicine in Puerto Rico, the courses that were observed were selected from the list of required courses for admission to the UPR School of Medicine.

Given the focus of the present study, using the entire data set collected for the main study would have been impractical. A multimodal analysis requires close attention to “smaller” communicative acts that would normally be overlooked or unrecognized, such as a long glance in a specific direction. Such detailed analysis is time consuming. Pursuing a multimodal analysis with the entire data set would not have been feasible and would have affected the quality of the analysis of the micro-contexts, as described by Blommaert and Jie (2010), where the communicative acts occurred. Therefore, the present study focused on the semiotic modalities produced by a single participant to facilitate the multimodal analysis.

The research focused on the biology course since the terminology used was more accessible to a researcher without a STEM background. Transcribing the organic chemistry video recordings would have been even more time consuming since the researcher would have had to devote more time to double-checking the terms mentioned by the two professors. While originally the research was going to include both professors who co-taught the biology course, the quality of the video recordings of the second professor was not conducive to quality transcriptions or analysis. Consequently, the

second professor was excluded from the analysis. The students who participated in the biology focus groups were also included in this study to triangulate the findings.

Data Collection

The present study used data collected from video recordings of the field observations, two interviews with the professor who taught the first half of the biology course, and one focus group with students who were taking the course. In addition, the author of this dissertation conducted a document analysis of texts used in the course, such as the syllabus and the PowerPoint presentations created by the professor. These instruments are described below.

Instruments

Observation Protocol. Non-participant observations of the selected courses were conducted during the larger study. These field observations followed the observation protocol in Appendix C and were video recorded. Field notes were drafted during the observations by members of the research team. In the case of the biology course, the observation protocol was used for a total of 12 classes since a member of the research team observed the course once a week throughout the entire semester. The observations rendered approximately 13 hours of video data.

As will be discussed more fully later in this chapter, the present research selected and analyzed four of the twelve classes observed. While eight classes were originally slated for analysis, the video recordings for the second half of the semester were largely unintelligible due to technical malfunctions. Given this situation and the fact that the

video recordings of the first professor rendered 119 pages of transcription, those four classes were eliminated from the present study.

Interview Protocol. For each course observed during the larger study, the researchers conducted two semi-structured interviews with the professors. As Lucca and Berrios (2009) indicate, the purpose of such interviews is to “discover the participant’s experiences, visions, and feelings from their perspective” [author’s translation] (p. 324). The interview protocol (see Appendix D) consisted primarily of open-ended questions and was modified during the interviews depending on the participants’ answers. The interview protocol was also drafted in Spanish, the participants’ dominant language. The interviews were each approximately an hour long and were audio-taped and later transcribed. The present research focused on the two interviews collected in the advanced biology course: those that were conducted with the professor who taught the first half of the course.

Focus Group Protocol. In addition to the interviews with the professors, the main research project conducted focus groups with the students from each course. These focus groups used open-ended questions and were videotaped to facilitate their transcription. Similar to the interviews, the focus groups followed a semi-structured approach in order to allow for the introduction of new questions in response to the participants’ statements (See Appendix E for the focus group protocol). In the case of the biology course, the research team conducted one 50-minute focus group, in which six students participated.

Document Analysis. In addition to the data collected using the previous strategies, the present study used document analysis to examine the role of semiotic modalities and multiple representations in select course materials, such as the syllabus and PowerPoint presentations used in the biology course. These texts were later coded and analyzed using Jaipal's (2009) extension of Lemke's (1998) framework, as were the field observations.

Research Procedure

The research procedure implemented for this dissertation consisted of three main stages: expansion of the literature review, data analysis, and reporting. The first stage entailed further developing the current literature review on the topic in order to gain a better foundation in multimodal semiotics to improve subsequent analysis. The second stage involved selecting, preparing, transcribing, coding and analyzing the collected data using Jaipal's (2009) multimodal semiotics framework and triangulation. Finally, during the last stage, the findings were reported.

Ethical Considerations

The larger research study was approved by the Institutional Review Board of the University of Puerto Rico, Río Piedras Campus, prior to any data collection endeavor. Informed consent forms were signed by all the participants in the observations, interviews, and focus groups (see Appendix G for consent forms and Appendix H for CITI program certificate). Other measures taken to protect the participants' privacy included the use of pseudonyms and date ranges.

Given that the present study focused on a single professor in one semester, it was necessary to take extra measures to protect his privacy. First, pseudonyms were used to replace the names of the main participant and the students who participated in the focus group. In the case of the professor, the pseudonym used in the larger study (Carroll et al., 2021) was also used in this study. “Prof. Bernard” was used as the pseudonym for the professor who taught the first half of the course, and “Prof. Peter” was used to refer to the professor who taught the second half. New pseudonyms for the students were provided since numbers had been used as identifiers in the larger study.

Moreover, a date range for the data collection period (i.e., 2016-2021) was provided for the participants’ protection. Therefore, each class analyzed was assigned a number based on its chronological order, and dates were not included when referring to the interviews, focus group, or observations. Lastly, given the multimodal approach taken for this research, the face of the main participant was blurred using Photoshop in photos in which he is facing the camera.

Data Analysis

The data collected were coded using Dedoose software within the multimodal semiotics framework proposed by Jaipal (2009). Dedoose is a cross-platform application for qualitative and mixed methods data analysis. It can be used to analyze data in the form of text, photos, spreadsheets, audio, and video. Furthermore, Dedoose is a cloud-based program, which enables the researcher to access the data from different computers at any time, facilitating data availability. The program also employs encryption

technologies to protect data stored on the cloud and to comply with ethical research principles regarding the confidentiality of the participants.

Dedoose software was chosen for the present research for several reasons. First, the program was used for data storage, coding, and analysis for the larger research project that provided the data for this secondary research. When comparing data analysis software for the larger study, the research team decided on Dedoose because of its cross-platform features and cloud-based technology, which enabled the members of the research team to access the data from different computers with different operating systems. These features make Dedoose a highly collaborative data analysis program. The cross-platform and cloud-based technological features are also reasons why the program was selected to analyze the data for this dissertation.

The data for the present study were analyzed in three stages. The first stage involved organizing and screening. Since the larger study collected approximately 13 hours of video data and social semiotics research entails detailed transcription and analysis (Jewitt et al., 2016; Kress et al., 2001), it would not have been feasible to transcribe all the data. Thus, during the first stage, it was necessary to view all the video data collected, in order to select four complete classes to include in the analysis. The data were selected taking into consideration the quality of the video and audio to facilitate the transcription process and the concepts discussed in the recorded classes since it was preferable to transcribe and analyze classes that covered a single main topic. All the data were organized in terms of concepts and types of modalities, following Jaipal (2009), in order to select the concepts that would be analyzed more in depth.

Data Transcription

The second stage involved transcribing the data units for analysis. The units were transcribed following a modified version of Kress et al.'s (2001) transcription model in written form, which includes time stamps for speech instances in classroom interaction. The written transcription of speech was used as the anchor for the time stamps since it is the most readily identifiable mode when rewatching the video data. Given that the research focused on multimodality as exhibited, or employed, by one of the professors teaching the course, it was necessary for the transcriptions to include speech, visuals, and actions. As Kress et al. (2001) explain, although the majority of classroom data transcripts focus solely on speech, a multimodal theoretical perspective of teaching and learning requires a more detailed transcription process that accounts for how different semiotic resources work together to make meaning.

According to Kress et al. (2001), multimodal transcriptions of classroom interaction should include the use of actions, such as eye movement, facial expressions, gestures, body posture, and location. Therefore, their transcripts consist of a three-column document with the time on the first column, a verbal description of the action on the second column, and the transcription of speech on the third column (see Appendix H for their transcription model). As the authors state, “[t]hese transcriptions can be seen as a textual representation of [their] theoretical conceptualization of the relations between modes; they are the product of an iterative process between [the researcher] and the video data” (Kress et al, 2001, p. 37).

Kress et al.'s (2001) transcription model was modified to include a fourth column representing the text presented on the screen simultaneously with the actions and speech deployed. The second and third columns were also inverted to include speech as the first mode represented in the transcription in order to facilitate making reference to the video data (see Appendix I for modified transcription model). The transcription process required the researcher to review the video data several times in different ways, i.e., audio only, video only, and the video with the audio.

The video data were transcribed using oTranscribe and Microsoft Word. As presented in the company's website, oTranscribe (n.d.) is an open-source web app that enables researchers to transcribe audio- and video-recorded data without switching between programs. It allows researchers to pause the recording and adjust its speed settings using keyboard shortcuts. In addition, the program includes interactive timestamps and can export the transcript to different programs, such as Google Docs. Most importantly, however, it is private since the recording and the transcript do not leave the researcher's device (oTranscribe, n.d.). This program was used to transcribe the speech acts for each class and establish the timestamps to navigate the transcripts more easily.

However, oTranscribe does not provide the option to import transcription models created in a table. Therefore, the speech was transcribed first using oTranscribe in a clean document and later exported using Google Docs. The text was then copied and pasted into the corresponding columns in the transcription model in Microsoft Word. To transcribe the actions, Microsoft Word and a Windows video player were used by

watching the video in one computer screen and transcribing the actions in Microsoft Word in another screen.

Data Coding

After transcribing the video data, the transcripts were coded using Jaipal's (2009) multimodal semiotic framework. As described in the previous chapter, Jaipal's (2009) framework is an extension of Lemke's (1998) three-level meaning-making typology. Lemke (1998) argues that, in communicative events, three aspects of meanings are constructed: the presentational (the conceptual aspects of meaning), orientational (the social aspects of meaning), and organizational (the pedagogical aspects of meaning) functions. As part of her framework, Jaipal (2009) maintains Lemke's (1998) typology and adds a fourth aspect, the epistemological function, which refers to the nature of knowledge. These four functions were the main codes that were used to analyze the data.

In addition to the selected framework, there are other multimodal analytical frameworks that could have been chosen for this study, such as Lemke's (1998) original typology and Halliday's (1994) functions of language. However, this framework was selected because, unlike Halliday's (1994) framework, it does not have language, as it is commonly understood, as its central focus. As Jaipal (2009) explains, Lemke's (1998) framework "extends the use of the typology to include the visual-graphical mode, a mode that is commonly used to express scientific meanings" (p. 52). Therefore, Lemke's (1998) framework would be more suitable for this particular research than Halliday's (1994) since it encompasses the different modes and nuances expressed in scientific

contexts. Jaipal's (2009) extension of Lemke's (1998) framework was selected, however, because it incorporates the additional epistemological aspect, which

The present study used both deductive and inductive coding when analyzing the data. The four semiotic functions of Jaipal's (2009) framework (i.e., presentational function, organizational function, orientational function, and epistemological function) were a set of *a priori* codes. The use of Jaipal's (2009) framework would constitute deductive coding since it served as a pre-established coding system, which is recommended when "inquiry is theory-driven and targets specific experiences, phenomena, actions, and so on that you are certain will appear in the empirical materials" (Saldaña, 2021, p. 40). Inductive coding was also used by identifying emerging codes and themes as the data were reviewed and analyzed. Two main types of inductive codes emerged during data analysis: the modes used in the class and aspects related to demographics and the teaching and learning process (See Table 1 for reference).

Table 1

Inductive Code List

Inductive Codes for Modes	Other Inductive Codes
1. Diagrams	1. Beliefs Regarding the Nature of Science and Scientific Discourse
a. Bar Graphs	
b. Cladograms	2. Concerns about Student Comprehension of Content
c. Line Graphs	
d. Scatter Plots	3. Context
2. Gestures	4. Demographics
a. Hand and Arm Gestures	5. Language as a Barrier
b. Head and Facial Expressions	6. Language of Instruction
3. Images	7. Perceived Level of Course Difficulty

Inductive Codes for Modes	Other Inductive Codes
a. Illustrations	8. Perceptions about Professors
b. Photographs	9. Study Strategies
c. Shapes	10. Teaching Philosophy
4. Movement	11. Teaching Strategies
a. Displacement	12. Translation
b. Leaning	
5. Numbers and Mathematical Expressions	
a. Mathematical Expressions	
b. Mathematical Symbols	
c. Numbers	
6. Props	
7. Speech	
a. Reference to Spoken English	
b. Reference to Spoken Spanish	
c. Spoken-English	
d. Spoken-Spanish	
8. Writing	
a. Reference to Written English	
b. Reference to Written Spanish	
c. English-Writing	
d. Spanish-Writing	

Data Triangulation

After analyzing the data and interpreting the findings, the data were triangulated to improve the accuracy of the study. As Creswell (2019) explains, “Triangulation is the process of corroborating evidence from different individuals [...], types of data [...], or methods of data collection in descriptions and themes in qualitative research” (p. 261). Saldaña (2011) also agrees that triangulation refers to the inclusion of different data

collection methods and at least three different viewpoints. This research employed a variety of data collection methods (observations, interviews, focus group, and document analysis) that served to triangulate the findings and enhance the accuracy of the research. It also included different viewpoints through interviews with the professor, the focus group with the students, the fieldnotes written by a different member of the research team, and the analysis conducted by the author of this dissertation of the observed classes and the documents used in the course.

Role of the Researcher

As a member of the main study's research team, this author personally collected the data of the organic chemistry sections. The data collection process of the organic chemistry sections was almost identical to that of the biology course. While another member of the research team collected most of the data, this researcher conducted the field observations of the first two classes and was part of the weekly research team meetings to discuss preliminary findings and code the data for Carroll et al. (2021).

The researcher is a trained translator certified by the American Translators Association in English and Spanish with ten years of professional experience and an English-as-a-Second-Language professor at a private university in Puerto Rico with five years of experience. Her academic background includes courses in semiotics, bilingualism, language planning, and constructivist educational philosophy as well as courses in foreign languages. The researcher believes that an understanding of multimodal semiotics is an asset to the teaching and learning process since it enables educators to reflect on their unconscious actions and recognize students' signs of learning

that might be overlooked under different circumstances. The researcher's position on the importance of multimodal semiotics in education and constructivist educational philosophy informed her interpretation of the data and findings.

Summary

This chapter reviewed the methodology used in the present study. It began with a description of the nature of the study and the restatement of the research questions that guided the project. Subsequently, it explained why a case study research design influenced by multimodal ethnography was the most appropriate for conducting the study. A description of the research context was also provided, including information about the student population of UPR-RP and the importance of studying the biology major given the number of students who are enrolled in it at the undergraduate level in order to pursue a career in medicine. The participants and the data collection instruments were later described as well as the research procedure and ethical considerations. The chapter concluded with a discussion of the data analysis process, including data transcription, coding, and triangulation, and the role of the researcher in the study and interpretation of findings.

CHAPTER IV: FINDINGS

This study explored how a science professor employed multiple modalities to teach an advanced undergraduate course in biology, specifically which modalities were present throughout his teaching and what their semiotic functions were. A qualitative case study approach influenced by multimodal ethnography was employed for data collection and analysis. Key to the analysis was the use of Lemke's (1998) framework to analyze meaning-making in science genres, as expanded by Jaipal (2009). A mix of deductive and inductive coding was used to analyze the data, for which Lemke's (1998) framework, as expanded by Jaipal (2009), served as the theoretical basis for deductive coding. Thus, the study was guided by the following research questions:

RQ1: What role do multiple semiotic modalities play in the study of an advanced undergraduate biology course at the University of Puerto Rico?

RQ1a: What types of semiotic modalities are used by the professor to make content comprehensible?

RQ1b: What are the semiotic functions of these modalities?

This chapter presents the findings of the data collected through ethnographic field observations. Sixteen media items (464 pages total) were analyzed using Dedoose software. The media included the course syllabus, the transcript of a focus group with the students of the course, transcripts of two interviews with the professor, four fieldnotes written by the member of the research team who conducted the observations, the four PowerPoint presentations used in the observed classes, and four multimodal transcripts of the selected observations. While the syllabus, focus group interactions, and interview

transcripts were coded more inductively for emerging themes to acquire a better understanding of the professor's teaching practice, the PowerPoint presentations, fieldnotes, and multimodal transcripts of the observations were coded both deductively using Lemke's (1998) framework, as expanded by Jaipal (2009) and inductively by identifying the different modes used throughout the selected classes.

In order to answer the research questions, this chapter is organized in three main sections. The first section provides a description of the research context, in particular what the course was about and how it was conducted. The second section describes the professor's teaching experience, practice, and philosophy. The last section presents the results of the multimodal analysis of the four classes selected. The analysis is divided into four subsections according to the functions that comprise Jaipal's (2009) expansion of Lemke's (1998) framework (i.e., presentational, organizational, orientational, and epistemological functions). Each subsection presents examples of identified modes that serve each function.

The Course

The course observed was a three-credit, advanced-level undergraduate biology course which is part of the required curriculum for students majoring in Biology. The course is also included in the list of bonus courses for admission to medical school in Puerto Rico. As such, it is typically taken by fourth-year students in the College of Natural Sciences, according to the suggested curricular sequence for the Integrative Biology track, published by the College of Natural Sciences (Facultad de Ciencias Naturales, UPR-RP, 2010a, p. 1). The course is also considered a guided elective for

students studying Molecular Cell Biology (Facultad de Ciencias Naturales, UPR-RP, 2010b, p. 2).

The course was observed once a week throughout a semester between the years 2016 and 2021 twice a week for an hour and a half in the afternoon in a dimly lit amphitheater in the College of Natural Sciences, containing 80 students. The room had three sections of rows of seats inclined downwards facing the front of the room which featured a large screen and a podium. As observed in the video recordings, the lights in the room were consistently turned off in order to allow for a better view of the PowerPoints on the screen. The walls were painted a dark color and featured a few pictures of animals at the front of the room. The acoustics were not ideal for a learning setting, making it difficult to hear what the professors were saying, particularly from the top rows of the room.

According to the website of the College of Natural Sciences and a tweet from the university's official account, the room was remodeled in the spring of 2021 and now features better acoustics, lighting, and cooling systems as well as an interactive podium, a larger TV screen, wood-like panels, and new seats and tables with AC wall adapters for students, giving a more modern appearance to the room (Facultad de Ciencias Naturales, UPR-RP, 2021). Nevertheless, the basic amphitheater layout was not changed in the recent renovation, which, as a whole, serves an orientational function of meaning, where traditional power relations between the professor and the students are reinforced.

This course was co-taught by two professors. The first half was taught by a professor from Latin America, Prof. Bernard, who spoke Spanish as his first language

while the second half was taught by a European professor, Prof. Peter, who spoke English as a foreign language. Therefore, both Spanish and English were present throughout the course. The main language of instruction during the first half of the semester was Spanish, while English was the main language of instruction during the second half. However, English was continually present throughout the entire semester given that the syllabus, the textbook of the course, all the PowerPoint presentations, and quizzes were in English. While not stated in the syllabus, according to interviews with the professor, the exams given in the course were also in English.

According to the institutional course catalog, the course description is listed as “the process and the patterns of organic evolution; speciation, phylogeny of selected groups and the history of the biota of several regions” [author’s translation] (UPR-RP, 2015, p. 599). However, the syllabus given to the students expands this description, tapping into the epistemological side of evolution and how it relates to overall biological knowledge:

In the course of the semester we will study the mechanisms of the evolutionary process, and resultant patterns of biological diversity. Throughout the course we will discuss major questions in evolutionary biology and how scientist ask and answer those questions. We will also focus on the impact of evolutionary biology on modern issues of health, agriculture, and conservation. A central aspect of the course is working through details of evolutionary theory and quantitative modeling. Of all the biological sciences, evolution is inherently the most

integrative and comprehensive. It is the unifying theory of biology. (course syllabus)

The changes to the course description as well as the course objectives shed light on the professors' learning goals for their students, which focus on the development of scientific thinking. Two out of five learning objects emphasize this aspect of learning, namely “[l]earn to apply rigorous evolutionary thinking to any question in biology” and “[u]nderstand how to ask and answer questions in evolutionary biology” (course syllabus). The rest of the objectives focus on understanding different mechanisms involved in evolution, appreciating the influence of evolution upon other fields of knowledge, and understanding the origin of species and species diversity.

The course observed was mainly lecture based. The class would meet twice a week for an hour and a half, and as stated in the course syllabus, students were expected to have read the assigned chapters of the textbook before each meeting. As noted in the researchers' field notes and the video recordings of the observations, the class largely consisted of the professor speaking with little student interaction. The lectures also relied heavily on the use of PowerPoint presentations, which were created by the professor in English and read as part of the day's lesson. The PowerPoint presentations were made available to students via the learning platform Moodle after the lectures concluded.

In terms of evaluation methods, the professors employed objective, close-ended quizzes and two exams in English. While the quizzes were administered electronically via Moodle, the two exams were in-person events. The questions included in the quizzes were largely taken from the textbook and the professors' PowerPoint presentations,

according to the students who participated in the focus group. When asked whether they used the PowerPoint presentations or the textbook to study, many of the participants admitted that they had not purchased the book and relied heavily on the PowerPoint presentations to study for the quizzes and the exam. As one student mentioned,

Juan: Yo me tomé el riesgo con [Bernard] de decir, pues, mira, en todas las presentaciones que él daba al final ponía un resumen de todos los puntos y eso fue exactamente lo que vino en el examen. No sé si... todavía no he visto el patrón en las presentaciones de [Peter], pero sí veo como que muchas definiciones bien... muchos párrafos mucho más grandes so que, de igual manera, creo que voy a seguir usando las presentaciones. (I took the risk with [Bernard] of saying, well, look, at the end of all his presentations, he would add a summary with the main points, which was exactly what came in the exam. I don't know if... I still haven't noticed the pattern in [Peter's] presentations, but I do see many definitions... many paragraphs are much longer, so I still think that I will continue using the presentations.) (focus group)

A closer examination of the quizzes showed that they consisted of both conceptual and critical thinking questions, the latter of which are in keeping with the emphasis on developing scientific thinking in the course description and learning objectives. However, the focus group with the students revealed that the answers to many of the questions were easily found by means of a Google search:

Interviewer: Les pregunté lo de los *quizzes* en Moodle y el examen presencial, porque me di cuenta de que [Peter] en la última clase dijo que no pueden *googlear*

como en los *quizzes*, o sea, que hasta él mismo sabe que eso es una práctica y les pregunto a usted, ¿Por qué quizás ustedes se confían de Google y cuando viene el examen dicen, “Eah, tengo que estudiar”? (I asked you about the quizzes on Moodle and the in-person exam because I noticed that [Peter] during the last class said that you couldn't google [the answers] like in the quizzes. In other words, he himself knows that this is a common practice, so I ask you, why might you trust Google and then go, “Oh, I need to study” when the exam comes?)

[...]

Juan: Pa' los de [Bernard], él hacía las preguntas y tú podías encontrar la pregunta bien fácil en el PowerPoint o pues, estaba en Google. Pero, ajá, de cualquier manera, sí te tenías que aprender la pregunta para el examen so si la buscaste en Google y no te la aprendiste para el examen, como quiera te vas a colgar. Yo creo que eso es un problema bien grande aquí en Ciencias Naturales, dentro del tema de la individualidad, los profesores, muchas veces, dan un material y tú te tienes que aprender todo y no son muy específicos con lo que tienes que estudiar y pues, te estás fajando estudiándote un montón de cosas que no van a venir en el examen y pues, terminaste colga'o, porque no te estudiaste ese capítulo que decidiste pichar. (For [Bernard's], he would ask questions, and you could find the question very easily in the PowerPoint, or they were available on Google. But, yeah, anyways, you had to learn the question for the test, so if you had googled it, and you didn't learn it for the test, you're still going to fail. I think this is a big problem here in Natural Sciences, given the topic on

individuality. Many times, professors give the material; you have to learn everything, and they're not very specific with what you have to study, and, well, you are pushing yourself to study a lot of material that is not going to come in the exam, and, well, you flunked it because you didn't study that one chapter you decided to ignore.) (focus group)

The student also mentioned that many of the questions from the quizzes were easily found on online. These quizzes were worth 40 points while the two exams were 30 points each. The interviews, the focus group, and the syllabus all suggest that close-ended exams were used and that students were not asked open-ended questions related to evolutionary thinking. According to the grade report in Moodle, the average grade for students enrolled in this course was an 89%, not counting the final exam, which was not included in the grade center calculation.

The Professor

While the course observed was co-taught by Prof. Bernard and Prof. Peter, this study focused on the multiple modalities employed by Prof. Bernard to make the volume of media to analyze more manageable. There were several differences in Prof. Bernard's and Prof. Peter's approaches to the course, both professors employed translanguaging and trans-semiotizing practices in their teaching to make content more comprehensible to students (Carroll et al., 2021). Their differing use of multiple modalities is not within the scope of this study but could be the subject of future research.

As mentioned previously, Prof. Bernard taught the first half of the course from the beginning of the semester until the midterm exam. In contrast to Prof. Peter,

Prof. Bernard used Spanish, his home language, as the language of instruction for his lectures. Nevertheless, English still played a major role in his teaching given that it was the language used in all his PowerPoint presentations, quizzes, and the textbook. He would also use spoken English occasionally when referring to specific terms or reading from the presentation.

At the time of the data collection for the main study, Prof. Bernard was an associate professor and researcher at the College of Natural Sciences with about five years of teaching experience in this institution. He would usually teach two courses on evolution a year: one at the undergraduate level and another at the graduate level. Despite describing his students' general English proficiency as "outstanding" (Prof. Bernard, first interview), as a Spanish-speaker who did his doctoral studies in the United States, he recognizes that not all his students are fluent in English and strives to make content more comprehensible to students to bridge the language gap.

Role as Professor and View of Science

While Prof. Bernard was not asked direct questions about his teaching philosophy, his responses to other questions and his actions in the classroom provide some insight as to how he views his role as a professor, the nature of science and the student experience in the College of Natural Sciences. As an educator, Prof. Bernard seems to value accountability, student questions, the students' right to choose how to learn, and competition. Moreover, as he briefly mentions in his first interview, his pedagogical decisions are based on his previous experiences as a student himself.

Planning Lessons. Prof. Bernard's lectures relied heavily on the textbook to develop his part of the course. According to him, the textbook features complicated concepts in a synthesized manner. Thus, he strives to prepare each class by selecting the most important information and explaining as much as possible in the classroom.

According to Prof. Bernard,

En el libro que usamos aparece todo muy sintetizado, pero son conceptos complicados, entonces trato de preparar la clase escogiendo las cosas más importantes y explicando en el salón de clases lo más que pueda del material, de forma que los estudiantes comprendan, pero hay algunos capítulos que son muy complejos y se utiliza muchos conceptos muy complicados. (The textbook we use is very synthesized, but there are complicated concepts. Therefore, I try to prepare my class by selecting the essential information and explaining in the classroom as much material as I can, so that students may understand, but some chapters are very complex and use several complex concepts.) (second interview)

From this excerpt, it would appear that Prof. Bernard views his role as a professor as a sort of interpreter of the textbook for his students. He believes that by doing this, students can pass the course by paying attention and taking good notes or just reading on their own from the book.

Nevertheless, he recognizes that students learn in different ways, so he does not place much value on class attendance, leaving it up to students to decide whether they prefer to learn on their own or in the classroom. In Prof. Bernard's words:

La realidad yo no me ocupo muchísimo por la asistencia, porque sé que todo lo que discuto en el curso está en el manual. Los que vienen pueden solamente tomar buenos apuntes y sería suficiente para pasar el curso. Los que no vienen, yo asumo que están ocupándose de leer y comprender el material. Depende de tu preferencia como estudiante, pero definitivamente si vienes al salón de clases, me atrevería a decir que no necesitas el manual, además tienes las diapositivas que yo me ocupo de subirlas al final de la clase religiosamente. [...] Si eres un estudiante que le importa su nota, buscará la forma de pasar la clase. [...] Ya estos estudiantes son adultos, entonces, yo sé que se supone que por la beca esté atento a la asistencia, en un principio era así, tomaba la asistencia en todas las clases, actualmente ya dejé de hacerlo. [...] Antes me preocupaba como profesor, pero en realidad, si ellos no hacen su trabajo, al final es su nota. Hay estudiantes que nunca vienen a clase, no los veo durante todo el semestre y luego llegan el día del examen y sacan buena puntuación. No creo que deba preocuparse entonces. Cada estudiante tiene su forma de aprender y deciden entonces si venir o no a clases. (I don't worry too much about attendance because I know that everything I discuss in the course is in the textbook. Those who come to class can just take good notes, which would be enough to pass the course. I assume that those who are not coming to class are working on reading and understanding the material. It depends on your preference as a student, but, definitely, if you come to the classroom, I would dare to say that you don't need the textbook. In addition, you have the slides that I upload [to the learning platform] religiously at the end of

each class. [...] If you are a student who cares about your grade, you will look for a way to pass the class. [...] These students are adults, so I know that because of the [Pell Grant] I'm supposed to pay attention to their attendance. At first, I was like that; I would take attendance every class, but currently, I stopped doing so. [...] Before, I would worry as a professor, but really, if they don't do their work, in the end, it's their grade. Some students never come to class; I don't see them all semester, and then they get a good score on the day of the exam. I don't think they have anything to worry about. Each student has their way of learning, and they can decide whether to come to the class.) (second interview)

This perspective on attendance might be common in the College of Natural Sciences, given the comments of the students who participated in the focus group. When asked about the low attendance rates for the course compared to the number of students enrolled in it, the students stated that while attendance rates depended on each professor's philosophy, there were many students who went to class if there was an attendance grade at stake. Even though the professor does not necessarily place much importance on attending the course, when asked whether he would make any changes to the way he teaches this course in the future, he stated that he would not do anything differently but mentioned that he would like for students to participate more.

Despite the reliance on the textbook, Prof. Bernard made it a point to refer to his own research on evolution throughout his portion of the course. This was a purposeful decision by the professor in order to bring what was learned in the classroom closer to home and help students visualize themselves in the field. According to the professor,

Para mí es muy importante tener ejemplos de investigaciones en Puerto Rico, porque, como estudiante, para mí era muy abstracto, casi inalcanzable, estas investigaciones. A veces veía las investigaciones que presentaban los profesores como si fuera un extraterrestre o algo; simplemente era algo que yo no iba a poder alcanzar. Entonces, pienso que, si tengo investigaciones en Puerto Rico, es algo más familiar, los estudiantes pueden sentir que ellos van a poder hacer esto. (For me, it is very important to present examples of research in Puerto Rico, because, as a student, these studies were very abstract, almost unreachable to me.

Sometimes I saw the studies that my professors presented as alien or something; it was simply something that I wouldn't be able to achieve. So, I think that if I present studies conducted in Puerto Rico, it is something more familiar so that students can feel that they can achieve this.) (second interview)

This excerpt also demonstrates that the professor's previous learning experiences inform his pedagogical decisions, specifically what he would have liked to see as a student.

Addressing Students' Questions and Concerns. As will be discussed later, throughout the course, Prof. Bernard would employ comprehension checks to assess whether his students had any questions. As observed, he would constantly glance from the screen to check on students and scan the room looking for any signs that students were not understanding. Nevertheless, he thought it was strange that sometimes the students seemed lost in the classroom and would not visit him during his office hours:

A veces me pregunto por qué aparecen así como perdidos en el salón de clases y muchas veces no sé si están captando el material. Trato de estar disponibles para

ellos de modo que ellos se sientan que estoy ahí para aclarar cualquier duda, pero algo que me ha extrañado es que los estudiantes no vienen. Veo en otros cursos, por ejemplo, que los estudiantes hacen filas en la puerta de los profesores esperando para ver si pueden atenderlos, y no sé, no sé, realmente por qué no vienen a las horas de oficina. (Sometimes I wonder why they look lost in the classroom, and I often don't know if they understand the material. I try to be available for them so that they feel that I'm here to answer any questions they might have, but something that I find strange is that students don't come. For example, I see that in other courses students stand in line at their professors' doors, waiting to see whether they can speak to them, but I don't know. I really don't understand why they don't come during office hours.) (Prof. Bernard, second interview)

Teaching Strategies

As part of the classes observed, Prof. Bernard consistently employed the same teaching strategies throughout course. The course was implemented mainly through lectures in Spanish. These lectures were always accompanied by PowerPoint presentations with written text in English that featured several images and diagrams that also had captions written in English. At times, the PowerPoint presentation also included multiple-choice exercises that he would present to students. However, the slides were usually split between definitions and explanations in English and images, charts, and diagrams. In addition, the professor incorporated constant sight translation and

comprehension checks throughout the lecture to ensure students' understanding of the material.

Lecture. Prof. Bernard's course could most aptly be described as a traditional lecture. As observed, the lessons mainly consisted of the professor speaking, usually from a podium, while making reference to a PowerPoint presentation. Although the main language spoken in the classroom was Spanish, the professor sometimes spoke in English to emphasize certain terms or read from the presentation. Spanish was also the primary language used by students to ask questions or answer the professor's questions. The professor's use of spoken Spanish and English was accompanied by a wide variety of gestures, such as facial expressions, pointing, and mimicry. Likewise, the professor would move about the room from time to time, specifically when addressing students' questions, and, after the first meeting, he consistently used a laser pointer in his lessons to draw the students' attention to parts of the presentation.

PowerPoint Presentations with Images and Diagrams. As mentioned, each lecture included a PowerPoint presentation with the content of the lesson projected on the large screen at the bottom of the room. Throughout each class, the professor would either read or make constant reference to the contents of the presentation. The slides included definitions and explanations written in English as well as photographs of key scientists and different species, illustrated images, diagrams, and charts and employed different shapes (such as bullets and arrows) to establish relationships between the content elements on the slide.

Translation. As reported by the professor and observed in his lessons, Prof. Bernard employs translanguaging strategies to make content comprehensible (Carroll et al, 2021), in particular Spanish-language discussions, English texts, and constant translations between them. When asked about the difficulties related to English, he noted most frequently among his students, Prof. Bernard stated:

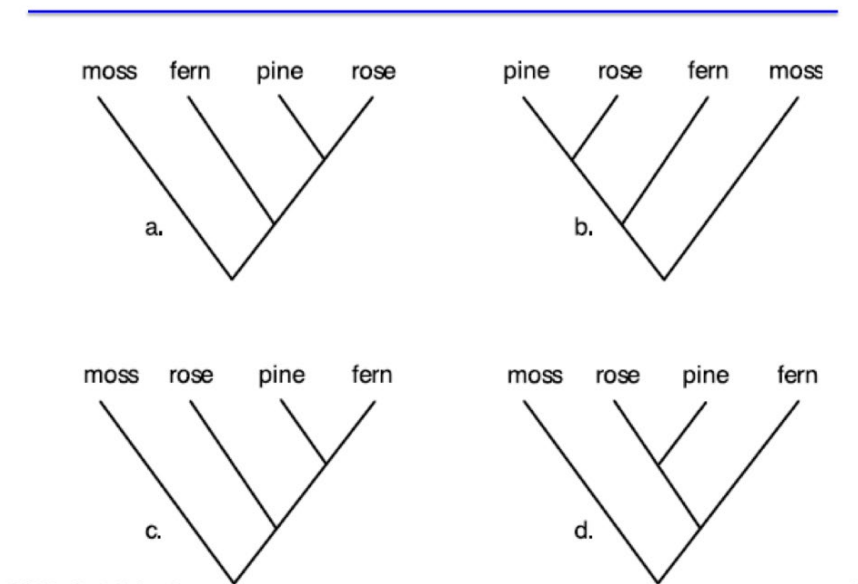
En el examen, yo me imagino que hay varias cosas que ellos no están entendiendo. Algunos de ellos no están entendiendo todo el tiempo cuando las explico acá, pero en el examen es típico que pasa que me llaman cinco y me hacen la misma pregunta, porque no saben la traducción. Hay términos raros, *jargon*, bien particulares que, a menos que tú tengas un vocabulario bien completo, de momento me llamó aquí, me llamó allá, hasta que llega el punto en que me paro al frente y hago la aclaración, porque hay estudiantes que quizás no se atreven a preguntar. (In the exam, I can imagine that they are not understanding several things. Some of them are not understanding when I explain something here, but in the exam, what usually happens is that five of them call me, and they ask me the same question because they don't know the translation. There are unusual terms, jargon, that are very particular, and unless you have an extensive vocabulary... Suddenly, I get called over here, then over there, until it gets to the point that I go to the front of the room and clarify the question because there are students that might not dare to ask their questions.) (first interview)

This excerpt shows that one of Prof. Bernard's main concerns is his students' ability to understand biology-related jargon. He addresses this perceived difficulty by explaining the English terms in Spanish,

Claro lo que hago es explicar en español. No hay más el libro que tenemos es en inglés. [...] A veces si a uno le enseñan un concepto así rápidamente uno no agarra las cosas, pero a veces la redundancia es la que ayuda a que los conceptos se... (Of course, what I do is to explain in Spanish. We have only the textbook, which is in English. [...] Sometimes when you are taught a concept very fast, you don't grasp it well, but at times, redundancy helps concepts...) (Prof. Bernard, first interview).

Based on his response, Prof. Bernard believes that redundancy, or repetition, allows students to internalize the concepts learned. Thus, from his perspective, exposure to a term in spoken Spanish and English as well as written English, which would constitute two different modes or semiotic modalities, is useful for learning science.

Comprehension Checks. In addition to sight translation, the professor would resort to different types of comprehension checks throughout the lesson to ensure that students were grasping the concepts discussed. These comprehension checks came in two forms: short multiple-choice exercises included in the PowerPoint presentations and direct questions asking whether the students had any questions or concerns. At times, the multiple-choice exercises were expressed using English text exclusively, but, at others, they featured diagrams as shown in Figure 1, which was included in the presentation for the fourth week of class on the topic of the tree of life and phylogeny.

Figure 1*Slide 6 Presentation for Week 4***Which one is different?**

These short exercises would be included at seemingly random moments in the presentation and were usually intended to tap into students' critical and analytical thinking. Many were noticed when the professor discussed how to interpret cladograms. Based on the responses given by the students in the focus group, this strategy was well received since it helped them remember the material better and pay more attention in class as seen in this excerpt:

Interviewer: Yo notaba que, en la primera parte del curso, [Bernard] se pasaba poniendo como unas preguntas para chequear a ver si están captando el material,

¿eso es una estrategia que a ustedes les gustaba o los mantenía alerta? (I noticed that during the first part of the course, [Bernard] would repeatedly present questions to check whether you were grasping the material. Was this a strategy that you enjoyed or that kept you alert?)

Manuel: A mí me gustó, porque par de los *quizzes*, se quedaba como inconsciente. Ah, él lo dijo, déjame buscarlo o, pues, es esto. (I liked it because it stayed in your subconscious for several of the quizzes. Oh, he talked about this, let me look for it or, it's this.)

Andrea: A mí también me gusta esa estrategia. Te deja saber si los estudiantes están prestando atención y rápido a uno mismo como que lo despierta y se queda a uno en la mente la pregunta. (I also liked this strategy. It lets you know whether students are paying attention, and you wake up quickly, and the question stays in your mind.)

Juan: Sí, o sea, hoy pasó. Me preguntaron dos veces. La primera no estaba prestando atención y, pues, la segunda vez sí, porque no había estado prestando atención a la primera vez. (Yes, well, it happened today. I was asked two questions. I wasn't paying attention for the first one, and then for the second one, I was because I hadn't been paying attention the first time around.) (focus group)

Functions of Semiotic Modalities

Throughout the four classes analyzed, a wide range of modes and all four semiotic functions (presentational, organizational, orientational, and epistemological) were observed. While there were some differences in the modes used in each class, the four

functions were present to varying degrees in all four classes observed. However, as shown in Figure 2, the presentational aspect was the most frequently found in the data analyzed. Thus, the rest of this chapter is organized in terms of the order in which each aspect of meaning was represented in the data analyzed: presentational function, organizational function, orientational function, and epistemological function. Each section is divided into subsections featuring the modes used that most commonly served each of those individual functions. This organization is based on the code co-occurrence chart generated by Dedoose.

Figure 2

Packed Code Cloud



As noted in Table 2, all four classes discussed multiple concepts with the second class observed on September 11 being the most laden with terminology and concepts.

The average number of modes was consistent throughout the four classes with some variation in the frequency of mode deployment among them. Nevertheless, all concepts across all four classes were taught in roughly the same fashion with comparable types and number of modes used.

Table 2

Data Unit Organizer in Terms of Concepts

Class Analyzed	Concepts	Modes
Class 1 (Week 2)	History of Evolution Natural Selection Modern Synthesis Evolution as Fact and Theory	1. Speech in Spanish 2. Speech in English 3. Text in English 4. Displacement 5. Gestures 6. Images 7. Diagrams 8. Video (only for the last concept)
	Tree Thinking Topology Rooted vs. Unrooted Trees Monophyly Paraphyly Polyphyly Analogy Homology Homoplasy Incomplete Lineage Sorting Hidden Paralogy Horizontal Gene Transfer Global Molecular Clock	1. Speech in Spanish 2. Speech in English 3. Text in English 4. Gestures 5. Props (laser pointer) 6. Images 7. Charts 8. Displacement
Class 3 (Week 6)	Diversification Speciation Extinction Red Queen Effect Mass Extinctions Ecological Opportunity	1. Speech in Spanish 2. Text in English 3. Gestures 4. Props (laser pointer) 5. Images 6. Charts 7. Displacement
Class 4 (Week 6)	Phenotypic Macroevolution Phyletic Gradualism Punctuated Equilibrium Saltation	1. Speech in Spanish 2. Text in English 3. Gestures 4. Props (laser pointer)

Stasis	5. Images
Phylogenetic Conservatism	6. Charts
Living Fossils	7. Displacement
Phylogenetic Niche Conservatism	
Convergent Evolution	
Dollo's Law	
Evolvability	
Predictability and Contingency	

Presentational Function

The presentational function was the code most frequently applied during the data analysis, for a total of 2,031 applications across 15 media items in Dedoose. This is not entirely surprising given that the presentational function deals with conceptual aspects of meaning (Jaipal, 2009), and this is an educational setting where content is being taught to students. As Lemke (1998) states, the presentational function refers to what is “being shown, what is supposed to be ‘there’, to be happening” (p. 93). In this study, this was interpreted as the presentation of definitions, concepts, and explanations to students. While the presentational function code co-occurred with a variety of modes, it was most prevalent in the following three modes: writing, gestures, and speech.

Writing. Given the primary role of the PowerPoint presentations in each class, the code for the presentational function was applied most frequently to the written text in English in the slides (i.e., a total of 628 code applications). These slides contained definitions, descriptions, explanations, and labels in English to present concepts to students. While many images and diagrams were included in the slides for each class, the presentations were grounded in English writing as the main mode of communication.

Figure 3 is an example of a slide where all the English text served the same basic presentational function of meaning.

Figure 3

Slide 10 Presentation for Week 2

What is evolution?

- Groups of organisms (or **populations**) evolve
- Populations may become subdivided and diverge (become different) over time
- Over vast periods of time, these process has resulted in the emergence of millions of different forms of life, all having descended, with modification, from LUCA

While English writing was the most common mode in these presentations, it was frequently co-deployed with images or charts in the same slide, as shown in Figure 4.

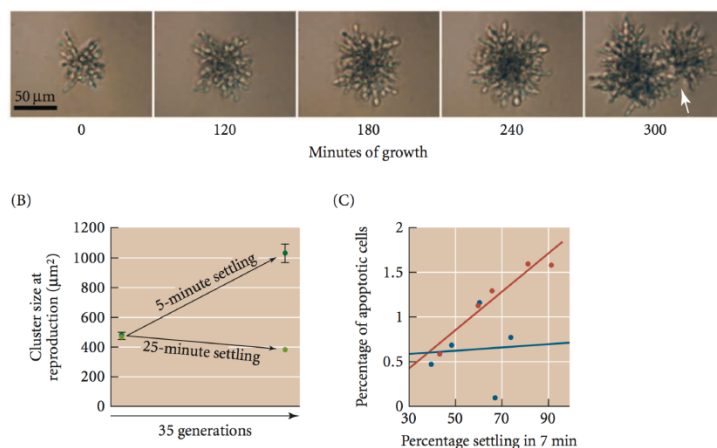
This slide features English text as well as several close-up photographs of the evolution of clusters of yeast cells and two graphs. Even though all three modes are presentational in nature, they all add another layer of meaning to the communicative process, which is also amplified by the professor's oral discussion in Spanish.

Figure 4

Slide 39 Presentation for Week 6

The evolution of novelty and complexity: functional intermediates

Incipient multicellularity evolved in laboratory: clusters of yeast cells settle more rapidly than single cells



Gestures. The presentational function was also commonly found in the gestures used by the professor. These included hand and arm as well as head and face gestures. The presentational function code was applied to hand and arm gestures a total of 539 times and to head and face gestures, 27 times. The gestures usually occurred when the general meaning of another mode was conveyed through gesture as well, creating a redundancy of meaning.

For example, during the first class, when describing what eukaryotes are, the professor stated, “La célula tiene pared nuclear, o sea, el AND no está regado ahí con

todas las células sino está bien compartimentalizado” (The cell has a nuclear wall. In other words, DNA isn’t spread out with the other cells. Instead, it is very compartmentalized) (Prof. Bernard, observation Class 1). The word *regada* (spread out) was co-deployed with a loose up-and-down painting motion to indicate dispersion while the gesture in Figure 5 indicating closeness (hands held close together) was used when he said *compartimentalizado* (compartmentalized). The closeness gesture was co-deployed with the professor’s speech in Spanish as well as a slide labeled “LUCA: last universal common ancestor,” depicting a phylogenetic tree of life with English text identifying different species.

Figure 5

Professor Using a Gesture to Indicate Closeness



Speech. Finally, the presentational function was also found in several instances of speech in both Spanish and English. While the professor spoke mainly in Spanish throughout the course, he also resorted to speaking in English, particularly whenever he

would read from the presentation. The code for the presentational function was applied to spoken Spanish a total of 441 times and to spoken English, 189 times. Since the codes were applied to large blocks of text, these numbers do not accurately reflect the amount of speech that took place in each class.

The presentational function code was applied the greatest number of times during the first class analyzed. This class was the introduction to the course and discussed several definitions and provided a brief history on evolution from before Darwin to today. Therefore, the professor explained several theories (such as Lamarck's theory of evolution) in a single class. The excerpt below is an example provided by the professor explaining how Lamarck thought that species evolved:

Entonces, el ejemplo del fluido, aquí con la jirafa, no. Para Lamarck, entonces, primero nace una jirafa con cuello bien corto, ¿no? A medida que esa jirafa se va extendiendo su cuello para alcanzar las ramas más altas de los árboles, el fluido nervioso, digamos, que empuja la nuca para que se elongue un poco y de esa manera el organismo individual, como individuo, logra elongar su nuca y la descendencia de ese individuo va a tener nuca más largas y entonces el fluido vuelve a actuar y sigue presionando la nuca para que siga elongando y así sucesivamente hasta que tenemos la jirafa con el cuello bien elongado. Entonces, así es como lo veía Lamarck. El individuo por medio del fluido nervioso va elongando ese cuello y va a dejar heredar eso en las generaciones subsiguientes. (So, the fluid example, here with the giraffe, no. For Lamarck, therefore, a giraffe with a very short neck would first be born, right? As the giraffe stretches its neck

more to reach the highest tree branches, the nervous fluid, let's say, pushes the neck to elongate, and thus, the individual organism, as an individual, manages to extend its neck, and its descendants will have longer necks. Thus, the fluid acts again and continues to pressure the neck to continue elongating and so on until we have a giraffe with a very elongated neck. That's how Lamarck viewed it. By means of the nervous fluid, the individual's neck becomes longer, and the subsequent generations will inherit that.) (Prof. Bernard, observation Class 1)

The example shows how the information is presented in a straightforward manner, or, in other words, as Lemke (1998) would say, it presents the "state of affairs" (p. 93). The message is reinforced with the corresponding text in English in the PowerPoint presentation, which contributes to a redundancy of meaning.

Organizational Function

The second most frequently applied code was the organizational function, which was applied a total of 2,012 times in Dedoose and was present in 10 media items. In Lemke's (1998) view, the organizational function refers to "relations defining wholes and parts of those wholes" (p. 94). An example of written language that serves organizational function of meaning would be coordinating conjunctions, which establish relationships between words, phrases, and clauses. In educational terms, Jaipal (2009) interprets the organizational function of meaning as elements that structure and sequence aspects of the course and may include phrases and clauses that indicate what comes next or typographical and compositional tools in written or visual media (Jaipal, 2009). The code for the organizational function of meaning co-occurred most frequently with the

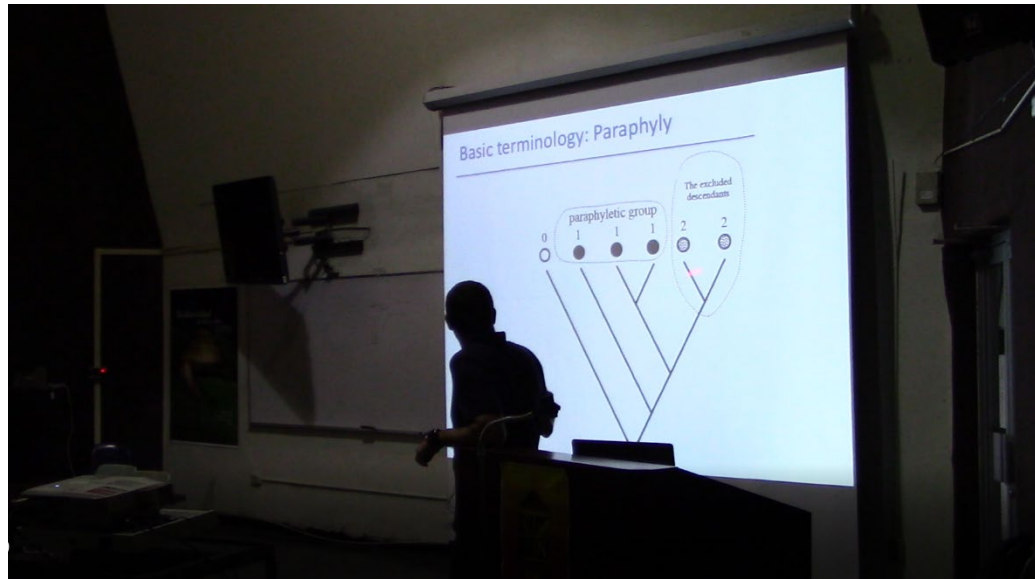
following three modes: props, images (i.e., shapes), and gestures (both hand and arm gestures as well as head and facial gestures).

Props. The term *props* was used in this study was used for a range of actions that did not quite fit in the other main categories of modes given that they included the use of an external device, such as the laser pointer, the computer, or the podium. Even though Prof. Bernard did not use the laser pointer at all during the first class, he used it consistently throughout the other three classes, usually accompanied by hand and arm pointing gestures. Changing the slides of the PowerPoint presentation were also included as signs that served an organizational function. In all, the use of props was deployed and coded as serving an organizational function a total of 754 times.

As shown in Figure 6, the laser pointer was used in different ways to explain biology-related diagrams and charts, such as phylogenetic trees or cladograms. It served to draw the students' attention to specific parts of the presentation. At times, the use of the laser added another layer of meaning depending on the type of movement used (e.g., moving it horizontally as if underlining a text or moving it in circles to highlight an element in the middle). In Figure 6, Prof. Bernard used the laser to point out specific relationships in the cladogram in much the same way as one would point to something with the index finger or use a demonstrative pronoun.

Figure 6

Prof. Bernard Using a Laser Pointer to Explain a Diagram



Images. After props, the mode that most frequently served an organizational function were images, specifically shapes like arrows, lines, or text bubbles. These shapes were included in several slides of the PowerPoint presentations and helped to establish different types of relations among the elements portrayed. The code for the organizational function of meaning was applied 368 times to different shapes across all four PowerPoint presentations in Dedoose.

Figure 7

Slide 3 Presentation for Week 2

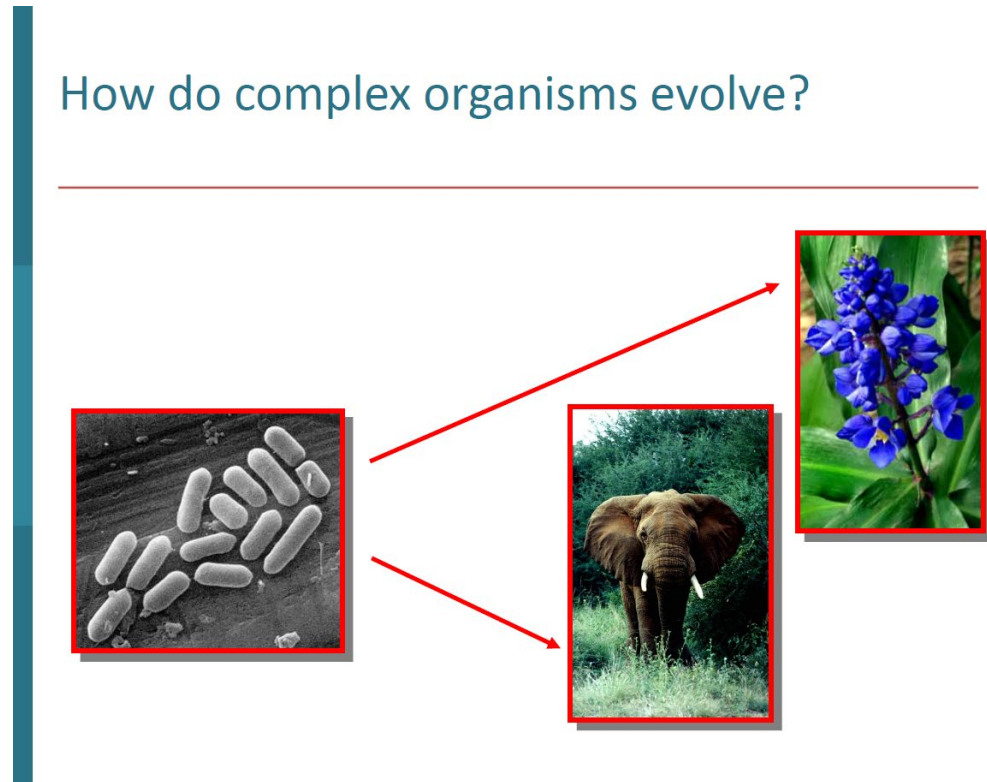


Figure 7 presents a typical example of how shapes were used to convey organizational representations across the PowerPoint presentations. The horizontal red line at the top of the slide, or its equivalent, was consistent across the templates for all four presentations. This line serves an organizational purpose as it separates the title of each slide from the content. Likewise, the two red arrows clearly help to establish a relationship between the bacteria pictured in the left side of the slide and the elephant and the flower to the right. Combined with the question in English at the top of the slide, the

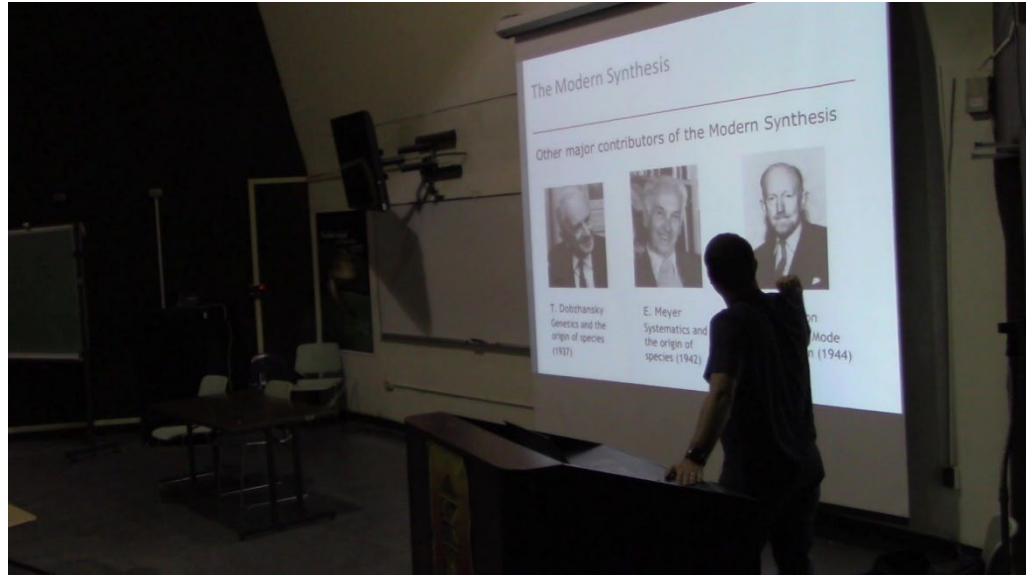
arrows can be taken to mean “this becomes this and this.” Such shapes were also included in complex images and diagrams that, as a whole, would serve a presentational function.

Gestures. Gestures in Prof. Bernard’s course were used in a similar fashion to props, given that, in several instances, props like the laser pointer would replace spontaneous hand and arm gestures like pointing. Head and facial gestures co-occurred with the organizational function a total 214 times, while hand and arm gestures co-occurred a total of 163 times.

Figure 8 depicts the co-deployment of two gestures for an organizational purpose. Prof. Bernard is seen turning his back to his students and looking at the screen. Looking at the screen serves a dual organizational purpose because it directs attention to the screen as well as helps the professor organize his thoughts and remember what comes next in his lecture. In a similar fashion, the open-hand pointing gesture draws a line using the professor’s arm directed at the chart on the screen. These sorts of gestures were fairly common throughout the lectures observed.

Figure 8

Prof. Bernard Points with Hand to Photo in Presentation



Orientalional Function

While the frequency of code application for the presentational and organizational functions was somewhat consistent, there was a substantial drop in how many items were coded for the orientational function. This code was applied 832 times in Dedoose and was present in 12 media items. According to Lemke (1998), the orientational aspect of meaning refers to more social concerns and constructs the relationship between the participants in the communicative event and the value judgments or perspectives that the rhetor is trying to convey (Lemke, 1998). In this way, the orientational function relates to the epistemological function of meaning since it can convey whether something is seen as good or bad. The three main modes that served to convey an orientational meaning in the classes observed were gestures, movement, and speech.

Gestures. In addition to serving presentational and organizational functions, gestures were the most frequently used mode to convey orientational meanings. In particular, head and facial gestures like nodding and gazing helped establish the relationships between the professor and the students. For instance, the professor would stop speaking to glance back at his students and scan the room for a few seconds, checking whether they were understanding the material. Hand and arm gestures like pointing also commonly served an orientational purpose. Head and facial gestures and hand and arm gestures co-occurred with the code for the orientational function a total of 249 and 140 times, respectively.

Figure 9

Prof. Bernard Looking and Pointing at Students

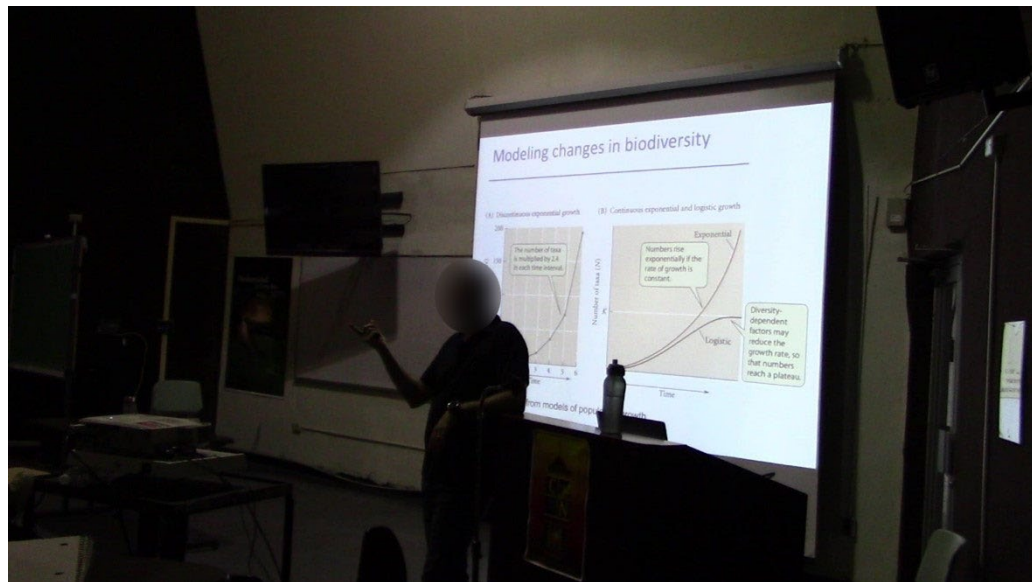


Figure 9 shows a common example of Prof. Bernard's comprehension checks. This teaching strategy was usually co-deployed with gestures and gaze, in that he would

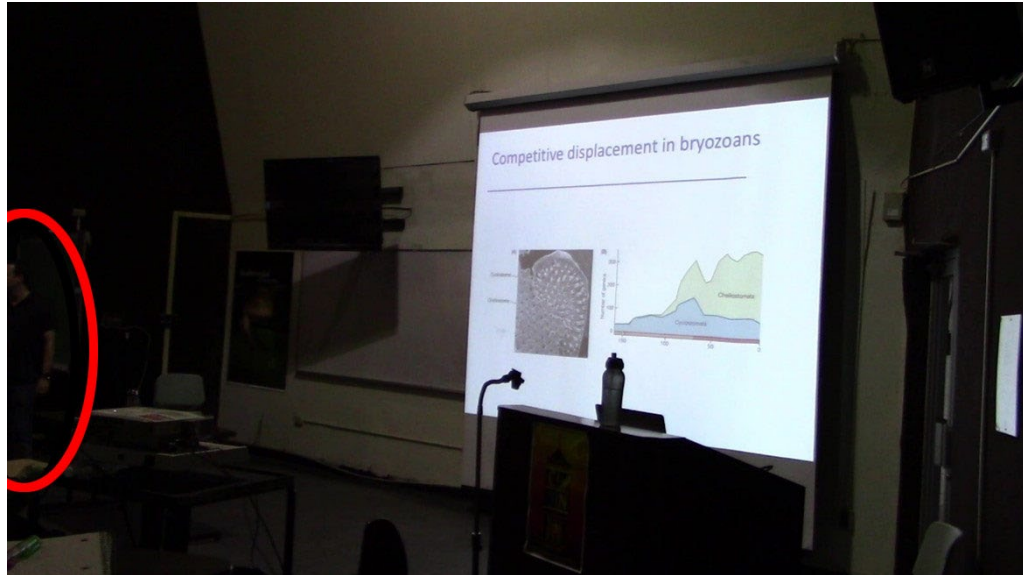
look and point at students denoting that he was expecting a response. Nodding and pointing gestures were also commonly used to give students permission to speak and ask questions in class as well as to call students' attention whenever they were distracted or talking among themselves.

Movement. In addition to gestures, Prof. Bernard frequently used movement or displacement to relate to his students. The codes for movement, displacement, and leaning, co-occurred with the code for the orientational function a total of 144 and 82 times respectively. Actions that were coded as movement included moving to and from the podium, walking closer to students, and leaning on the podium. The layout of the room reinforced a traditional power relationship between the professor and the students, since the professor stood in the center pit near the podium, and the students sat close together looking down at the bottom of the room.

However, the professor would demonstrate concern for his students' understanding by walking closer to students whenever they would ask questions, at times even going up the first few steps to hear them better. Figure 10 shows Prof. Bernard walking to the other side of the room to address a student's question. This mode was co-deployed with a nodding gesture as well as speech in Spanish. Moving closer to the student signals to the student an attempt to understand and clarify their questions and concern and serves to build the relationship between the professor and the student.

Figure 10

Prof. Bernard Walking across the Room to Address a Student



Speech. Orientational meanings were also conveyed by means of spoken Spanish. This was interpreted in the present study as instances of speech in which the professor demonstrated concern for his students' understanding, by asking whether they had any questions or concerns or by posing questions requiring a response, such as his comprehension checks. Spoken Spanish used for an orientational purpose also included instances of speech in which the professor would recount common questions and difficulties that previous students had when taking the course. Speech was also used to highlight important concepts that students needed to remember. The code for the orientational function co-occurred with the code for Spanish-Spoken a total of 127 times, according to the code co-occurrence chart generated by Dedoose.

Spoken Spanish was commonly used to ask students whether they had any questions by means of variations of questions such as: “¿Qué más? ¿Preguntas sobre el examen, sobre los *quizzes*...? ¿Qué más quieren saber? ¿No?” (What else? Questions about the exam, about the quizzes? What more would you like to know? No?) (Prof. Bernard, observation Class 1). However, it was also used to highlight important concepts that students needed to understand completely before moving on to more complex concepts, as in the following excerpt in which Prof. Bernard highlighted the importance of understanding the difference between macroevolution and microevolution and opened a space for students to ask questions:

Así que revisitando este concepto de qué es macroevolución y qué es microevolución. Yo creo que valga la pena que lo tengan bien claro, porque conozco muchos [inaudible] que no entienden la diferencia. No saben cuál es la diferencia entre macro y micro. Entonces, si todavía no la entienden, este es el momento de preguntar antes del examen. (So, revisiting the concepts of macroevolution and microevolution. I think that you should understand this because I know many [inaudible] who do not understand the difference. They do not know what the difference between macro and micro is. So, if you still don't understand it, this is the time to ask before the exam.) (Prof. Bernard, observation Class 4)

As mentioned, spoken Spanish was also used to check sporadically whether students were understanding the material at hand. This mode was co-deployed at times with written English since some oral questions in Spanish were sight translations of the

English text presented on the screen. Nevertheless, some questions seemed to be spur-of-the-moment decisions made by Prof. Bernard to make sure that students were paying attention and understanding as well as to gauge their prior level of knowledge of the subject or related concepts, such as the excerpt below:

¿Por qué sabemos que toda la vida está conectada? ¿Quién me puede explicar eso? ¿Qué características une, digamos, una especie de bacteria y un humano? ¿Qué comparten en común? ¿Cuáles son los *clues* que nos dan a entender que en realidad tenemos un origen común y no son dos ramas que se originaron independientemente? (How do we know that all life is connected? Who can explain that to me? What characteristics join, let's say, a species of bacteria and a human? What do they have in common? What are the clues that let us know that we actually have a common origin and that they are not two branches that originated independently?) (Prof. Bernard, observation Class 1)

Finally, spoken Spanish was used to highlight important concepts that students should know as well as to judge whether something was deemed correct or incorrect by the professor. For instance, in the excerpt below, Prof. Bernard expresses his disagreement with a concept used in the textbook. According to Prof. Bernard:

Este tema del libro... El libro lo llama "macroevolución", pero yo lo encuentro un poco *misleading* ese nombre, porque todo lo que hemos hablado hasta ahora es macroevolución básicamente. Entonces, yo prefiero cambiarle el título a esto a *phenotypic macroevolution* o algo así. O sea, aquí el foco más importante aquí es a los cambios evolutivos a grande escala, pero más que nada en el fenotipo. (This

topic in the book... The book calls it “macroevolution,” but I find that name a bit misleading because everything we have talked about so far is basically macroevolution. Therefore, I prefer to change the title to phenotypic macroevolution or something along those lines. In other words, here, the central focus is on large-scale evolutionary changes but more specifically on phenotypes.) (observation Class 4)

As shown in the excerpt, Prof. Bernard not only expresses his disagreement with the textbook but also explains why he believes it is incorrect, signaling to students what terminology they should use.

Epistemological Function

The code for the epistemological function was applied a total of 237 times across 12 media items in Dedoose. According to Jaipal (2009), the epistemological function refers to communicative events “about the nature of scientific knowledge and the process of constructing scientific knowledge” (p. 53). In other words, the epistemological function refers to modalities that express what counts as valid knowledge and how it is acquired. This was interpreted in the present study as instances in which the professor communicated what counts as evolution, how to think correctly in evolutionary terms, and who is qualified to speak about evolution. Such notions were communicated mainly through writing, specifically writing in English, and speech, both in Spanish and English.

Writing. Writing was the mode that most frequently co-occurred with the epistemological function of meaning (i.e., 118 times). All co-occurrences were instances of English writing in the PowerPoint presentations and the syllabus. While there are

presumably instances of English writing that serve an epistemological function in the textbook, this aspect was not part of the scope of the present study. The instances of written text that serve an epistemological function can be mainly classified in three ways: quotes, in-text citations, and epistemological questions.

Figure 11 shows a slide included in the presentation for the second week of class, in which the professor provided a brief history of evolution to his students. When discussing Charles Darwin's contribution to the field, Prof. Bernard opted to include a direct quote from Darwin's *On the Origin of Species* paired with a photo of Darwin himself. The choice of including a direct quote signals that Darwin is considered an authority on the matter, considering that the professor did not include direct quotes for other theorists discussed in the presentation.

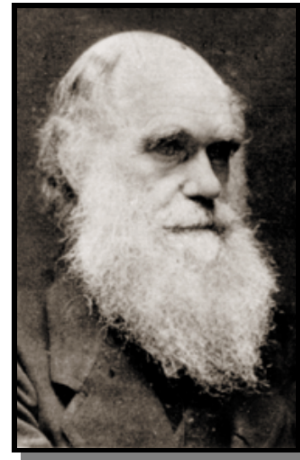
Figure 11

Slide 26 Presentation for Week 2

History of Evolution: Darwin

"As more individuals... are born than can possibly survive, and as, consequently, there is a frequently recurring struggle for existence, it follows that any being, if it vary however slightly in a manner profitable to itself, will have a better chance of surviving, and thus be **naturally selected**"

- *The Origin of Species* 1859



Charles Darwin

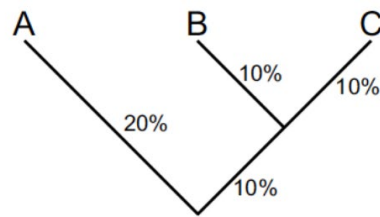
Written English also served an epistemological function whenever the professor would include in-text citations in the PowerPoint presentations. In Figure 12, Prof. Bernard included a parenthetical citation in APA style at the bottom right corner of the slide to denote where the information or the cladogram came from. Like the example of the direct quote, incorporating a parenthetical citation signals to the student what knowledge or whose knowledge is considered valid and acceptable in science. It furthermore models what is expected of scientists or professionals in the field when giving presentations or reporting scientific information.

Figure 12*Slide 55 Presentation for Week 4*

The global molecular clock

Assume that the rate of evolutionary change is constant over time

(branch lengths equal percent sequence divergence)



(Zuckerkandl & Pauling, 1962)

A final way in which written English served an epistemological function was through the presence of rhetorical questions meant to stimulate evolutionary thinking. These questions were usually co-deployed with spoken Spanish since the professor would translate them on sight from the text on the screen. The purpose of the questions is to teach students what they should consider when analyzing aspects of evolutionary biology. Such questions also help stimulate students' critical thinking skills and help them to understand how to analyze cladograms.

Figure 13 features a slide with key questions included in Week 6's lecture on biodiversification. Prior to this slide, Prof. Bernard defined *biological diversity* and

explained the two main approaches for studying it: the ecological approach and the evolutionary approach. To clarify how to use the evolutionary approach to study biodiversity, the professor added the questions in Figure 13. These questions let the students know what aspects they need to take into consideration when studying biodiversification and how to start thinking like an evolutionary biologist.

Figure 13

Slide 7 Presentation for Week 6

Key questions

- Has the number of species on Earth increased steadily since the origin of life?
- Has diversity fluctuated?
- Have some groups declined even as others have increased. Why?
- Why are there so many more kinds of beetles than webspinners—or almost anything else?
- Do groups with more species produce new species at a higher rate? are they more resistant to extinction?
- Is there any limit to the possible number of species, and has that limit been reached?

Speech. As mentioned, the written English that served an epistemological function was commonly co-deployed with spoken Spanish. Given that Prof. Bernard would translate on sight the text in English to Spanish, written English and spoken

Spanish were two modes that were frequently co-deployed. This allows for a redundancy of information and meaning-making modalities that helps students grasp the information through one or more means. According to the Dedoose code co-occurrence chart, spoken Spanish co-occurred with the epistemological function a total 73 times, while spoken English co-occurred a total 55 times.

The excerpt below shows one example of spoken Spanish serving an epistemological function. Prof. Bernard stated the following when discussing how to study biological diversity:

Preguntas que uno se puede hacer al respecto con eso. ¿El número de especies en la Tierra ha incrementado, digamos, gradualmente desde el origen o hemos visto fluctuaciones en la diversidad a través del tiempo? Quizás algunos grupos han declinado su diversidad, mientras que otros han florecido, ¿verdad? Y si es el caso, ¿por qué? ¿Por qué hay tantas de *beetles* y pocos o relativamente pocos *webspinners*? ¿Grupos con más especies producen más especies a una tasa más alta son más resistentes a la extinción? ¿Existe un límite posible al número de especies? Si es así, ¿ya llegamos a ese límite? (Some questions we might ask about this. Has the number of species on Earth increased, let's say, gradually since their origin or have we seen fluctuations in diversity throughout time? Perhaps some groups have declined in diversity while others have flourished, right? In that case, why? Why are there so many beetles and few or relatively few webspinners? Are groups with more species that produce more species at a higher rate more resistant to extinction? Is there any limit to the possible number of

species? If there is, have we reached that limit?) (Prof. Bernard, observation Class 3)

If we compare it to Figure 13, we see that this excerpt is almost a word-for-word translation of the key questions that appeared on the slide. However, it is interesting to note that, in his Spanish rendition, Prof. Bernard favored plural first-person verb constructions like *hemos visto* and *llegamos*. While this could be entirely a coincidence, it could also be interpreted as Prof. Bernard's way to include his students as evolutionary biologists in the making, serving an additional orientational function.

Summary

This chapter presented the findings of the present study, which sought to analyze the role that signs played in a course in evolutionary biology by identifying the modes used most frequently and the semiotic functions they served. The course observed was a required undergraduate course in biology, which was co-taught by two professors. The present study focused on Prof. Bernard, who taught the first half of the semester. As shown in the field observations, Prof. Bernard's class was lecture-based, relied heavily on PowerPoint presentations and had little student participation and attendance. Students were evaluated by means of objective, close-ended examinations like quizzes and multiple-choice exams.

Prof. Bernard employed a variety of modes to teach his portion of the course, namely spoken language, written English, gestures, images, diagrams, and movement. All classes seemed to be grounded in spoken Spanish as the main mode of instruction with written English as a strong secondary mode. All four semiotic functions from Jaipal's

(2009) extension of Lemke's (1998) framework (i.e., the presentational, organizational, orientational, and epistemological functions) were found to varying degrees throughout all four classes analyzed. The presentational function was the most frequently coded and co-occurred the most with writing, gestures, and speech. The second most-coded function was the organizational function, which co-occurred the most with props, images, and gestures. The orientational function was the third most coded and was mostly found in gestures, movement, and speech. Finally, while the epistemological function was present in the data analyzed, it was not as commonly found as the other three functions. It co-occurred most frequently with writing and speech. As evidenced by the findings, some modes served multiple functions, sometimes even simultaneously, while other modes were more specialized.

CHAPTER V: DISCUSSION

This chapter provides a discussion of the major findings of the study reported in Chapter IV in terms of emergent themes and suggestions for pedagogical practice. A multimodal ethnographic case study design was employed to analyze the semiotic meanings communicated through multiple modalities and to point out features of semiotic modalities that could be implemented during the instruction of higher-education scientific concepts to enhance meaning-making.

The chapter is organized in six sections. It begins with responses to the research questions that guided this study:

RQ1: What role do multiple semiotic modalities play in the study of an advanced undergraduate biology course at the University of Puerto Rico?

RQ1a: What types of semiotic modalities are used by the professor to make content comprehensible?

RQ1b: What are the semiotic functions of these modalities?

The next two sections discuss two emergent themes that arose from the data analysis, namely, science as an inherently multimodal discourse and a banking method for developing critical and scientific thinking. The fourth section provides some pedagogical implications of these findings and suggestions for teaching practice and evaluation. The fifth section details the research limitations of this study, and the chapter closes with suggestions for future research.

Role of Signs in the Observed Course

The main research question that guided this study was “What role do multiple semiotic modalities play in the study of an advanced biology course at the undergraduate level in the University of Puerto Rico?”. However, in truth, the answers to the two secondary research questions comprise the response to the main research question, since they ask which modes are used throughout the course and what functions, or roles, they serve. Therefore, the answer to the main research question is divided into two sections, each addressing a specific secondary research question that stemmed from the main one.

Modes Used Throughout the Course

The first of the two secondary research questions that guided the present study (RQ1a) focused on the modes used in the course (i.e., What types of semiotic modalities are used by this professor to make content comprehensible?). Given Lemke’s (1998) assertion that scientific discourse is multimodal in nature, the expectation was that several modes would be observed through the recorded lessons. This is not surprising when communication is viewed from a social-semiotic, multimodal lens (Kress, 2010; Bezemer & Kress, 2016; Jewitt et al., 2016).

The present study found that Prof. Bernard used a variety of modes throughout his lessons and two main genres: lecture and presentation. Prof. Bernard was observed using speech in Spanish and English, writing in English, gestures (including gaze), props, images, diagrams, displacement, and video in his course. These modes often appeared in multimodal ensembles or semiotic bundles, as described by Kress (2010), Bezemer and Kress (2016), and Arzarello et al. (2009), with speech co-occurring frequently with

gestures and written text from the PowerPoint presentations. It could be said that each lesson was mostly foregrounded in speech and writing as the main modes of communication. However, based on the observations, it did not appear that Prof. Bernard sequenced the modes he employed in an intentional manner since the co-occurrence and deployment of modes to teach a variety of concepts was fairly consistent throughout the observed lessons, as shown in Table 1 in the previous chapter.

Since the present study used previously recorded data collected with the lens focused on the professor, there was little information regarding the modes employed by the students to communicate. However, given the observed dynamics of this traditional college lecture, the students mostly communicated with the professor in the classroom using the two modes available to them: gesture and speech. The students' use of speech was evidenced in the video recordings when the professor would stop his lecture to address students' questions or prompt them to answer questions.

Functions of Modes Used in the Course

Following the identification of the modes used by Prof. Bernard in his course, these signs were then coded for the main function that they served based on Lemke's (1998) framework as expanded by Jaipal (2009). Each mode was coded for its presentational, orientational, organizational, or epistemological functions. In several instances, some modes served more than one function and were coded accordingly. While there were some modes that served a particular function more frequently, the four functions were found across different modes.

The presentational function, which refers to conceptual aspects of meaning in which the state of affairs is presented or explained, was the function most commonly found in the data and was most frequently conveyed through writing, gestures, and speech. It is not entirely unexpected that writing and speech were commonly used to convey presentational aspects of meaning since this course exposed students to a myriad of new biological terms and concepts that required definition and explanation. The gestures coded for the presentational function represented or mimicked demonstrations of processes or objects. The presentational function was also served by images (such as photos of the scientists and species mentioned in the course) and diagrams (such as complex charts and graphs like cladograms and splatter, line, and bar graphs).

The second function most commonly coded for was the organizational function. This function refers to how different parts of a semiotic whole are organized and how relationships are established among the parts. The modes that most often served an organizational function of meaning were props, images, and gestures. It should not come as a surprise that the use of a laser pointer and pointing gestures that draw the audience's attention to a specific item would serve an organizational purpose, which was frequently the case as observed throughout Prof. Bernard's lessons. Other elements that served an organizational function were shapes like bullets, arrows, and lines that established a compositional organization in the slides presented to students. However, the organizational function was also observed in the professor's speech patterns through his use of transitional words and phrases like *ahora*, *ahí*, *eso*, and *primero* (*now*, *there*, *that*, and *first*).

The third function, the orientational function, which refers to how certain signs portray a particular viewpoint or stance toward another sign or how they establish a relationship among the participants, was found in the professor's use of gestures, movement, and speech. These modes were commonly deployed to emphasize important or difficult topics and concepts as well as show concern about students' understanding of the course content. Emphatic gestures and phrases like “¡Ojo!” (Take note!) were used to highlight important concepts to which students should pay extra attention. Nodding, walking towards students, and gaze were used to address students and indicate who could speak and when. The professor also used direct questions to prompt students to answer and demonstrate content comprehension. In this way, these modes served to establish or portray the power relations present in the classroom.

Finally, the epistemological function was the least commonly found in the data. The modes that served this function were writing and speech, and it tended to co-appear with the orientational aspect of meaning. Through writing, the professor used the material resource of punctuation to quote renowned scientists whose knowledge and view of science were considered valid. Such quotes were typically translated on sight into spoken Spanish, thus reinforcing multimodally specific views of science.

Science as an Inherently Multimodal Discourse

Prior research has repeatedly described science as a multimodal field, in which multiple representations like writing, speech, graphs, and mathematical symbols are the norm (Lemke, 1998; Kress et al., 2001; Kress, 2003; Klein & Kirkpatrick, 2010). The present study contributes to the larger body of work by depicting how a professor of

advanced biology at the university level also incorporates a wide variety of modes to communicate scientific concepts. To use the terminology of prior research, a “constellation of modes” was seen in Prof. Bernard’s teaching, such as speech, writing, gestures, movement, images, and charts and diagrams.

While the class was foregrounded semiotically in speech and writing as the primary modes, using Spanish and English as their main resources respectively, it was evident that understanding other modes (particularly gestures, images, and diagrams) was crucial for understanding the content of the course. As in He et al.’s (2017) study on translanguaging in a multimodal mathematics presentation, this study found that the professor employed a multimodal approach in his PowerPoint presentations via the use of written English, images, and complex figures like diagrams, charts, and graphs to convey meaning. In this way, it could be said that Prof. Bernard engaged in a basic trans-semiotizing teaching practice.

The multimodal nature of science requires learners of science to become literate in the multimedia genres characteristic of the field. As Lemke (1998) states, to communicate scientifically, “it is necessary to juggle and combine in various canonical ways verbal discourse, mathematical expression, graphical-visual representation, and motor operations in the world” (p. 87). As the discourse of a specialized community, science literacy thus entails becoming proficient in its “cultural practices that encompass specific ways of talking, writing, viewing, drawing, graphing, and acting” (Tang & Moje, 2010, p. 83). Learning to communicate multimodally to represent “scientificness,” as Kress (2003) terms it, is essential for forming part of and signaling belonging to this

specific community and thus serves as an in-group marker and a way of belonging to a “community of practice” (Wenger, 1998)

Building on prior research that states that a major challenge for college students is “handling and understanding highly specialized forms of communication,” Airey and Linder (2009) suggest that before they may experience the full disciplinary knowledge to which multiple representations grant access, students must become fluent in a critical constellation of modes (p. 28). This was observed in the present study since Prof. Bernard’s lectures and presentations were full of specialized terminology and complex diagrams, charts, and graphs that students needed to make sense of. In the case of highly specialized phylogenetic trees, or cladograms, and other complex multimodal charts and graphs, students needed to be able to interpret them to identify, describe, and explain evolutionary processes and phenomena.

The present study also showcases that, as stated by Kress (2010), signs always co-occur with other signs. Therefore, multimodal ensembles were very much present throughout the course. In many cases, the professor would use multiple representations to refer to the same concept in different ways, such as using speech to say the name of a scientist and presenting the written form of the name and a photograph of the person on the screen simultaneously. The joint co-deployment of semiotic modalities, as defined by Lemke (1998), creates a multimodal redundancy that serves to scaffold students’ learning.

A Banking Method for Developing Critical and Scientific Thinking

As detailed in the previous chapter, one of the main objectives of the course observed, according to the syllabus, is to develop students' scientific thinking so that they can apply it to asking and answering questions in biology. While some strategies to assess critical and scientific thinking were observed in the four lessons analyzed, in general, a banking approach, as defined by Freire (1970/2017), was used to teach this course by means of a traditional lecture with little student participation and objective, close-ended evaluations.

According to Freire (1970/2017), in a banking educational model, "the teacher issues communiqués and makes deposits which the students patiently receive, memorize, and repeat. [...] [T]he scope of action allowed to the students extends only as far as receiving, filing, and storing the deposits" (p. 45). This approach is quite similar to the traditional view of communication in which the sender creates and issues a message to the receiver since they both perceive of one of the participants of the communicative act as passive. As shown in the video recordings, including those that were not part of the analysis, each class focused heavily on teacher-talk and showcased sporadic instances of student participation, either through questions they asked or in response to the professor's multiple-choice prompts.

In both interviews with the professor, it was evident that he was concerned about his students' learning and progress. A couple of times, he lamented the lack of class participation as well as scarce attendance to both the course and office hours. Despite yearning for more student participation in lectures, the professor provided few

opportunities for them to do so and little variation in terms of teaching strategies to shape student engagement. The almost “mechanical uniformity of studies and methods” of the day-to-day activities of the class afforded students little freedom to engage multimodally to grow and transform (Dewey, 1997, p. 62). In other words, the design of the course lessons did not capitalize on the meaning-making potentials of the students’ multiple representations.

Even though the present study showed that the professor employed a variety of modes throughout his teaching to make content comprehensible, his use of these modes seemed more intuitive than purposeful. Based on the questions asked in the interviews, only assumptions can be made on the intent and reasoning behind his teaching strategies. However, it can be argued that Prof. Bernard had some tacit knowledge of teaching that was likely shaped through prior learning experiences as a student, which he used as a springboard to mold his lectures whether by replicating strategies he liked and rejecting practices that he did not. This assumption can be made based on his recollection of the challenges he faced during his studies and the students’ revelation that this course was very similar to others in the College of Natural Sciences.

When looking at the dynamics of the course as a whole, in which teacher-talk was predominant, and the evaluations were objective and close-ended, it is difficult to gauge whether the goal of developing the students’ scientific and critical thinking was met. While the research team did not have access to the two exams given in the course, it did have access to the quizzes on the learning platform. These quizzes contained three to five questions on average and evaluated students on material from the course. According to

the students in the focus group, it was possible to answer the quizzes just with the content heard in class and reviewing the PowerPoint presentations uploaded to the learning platform. Some of the students from the focus group admitted that they did not own or use the book and relied exclusively on the class lectures and presentations to answer the quizzes. They also recalled an interaction with Prof. Peter, who taught the second half of the course, where he stated that during the exam, they would not be able to Google the questions like they could during the quizzes. A closer look at the quizzes revealed that the questions focused on lower-order skills, such as remembering and understanding, rather than skills that required more critical thinking and analysis.

In addition, in the focus group, the students disclosed that, despite the challenges posed by the translanguaging nature of the class and its concepts and terminology, they did not believe that the course was as difficult as they expected it to be. According to two students:

Juan: Yo creo que nosotros determinamos eso a medida que nosotros vamos cogiendo la clase y viendo como es el *flow* de cómo está corriendo la clase. Este..., verdad, lo que yo le estaba diciendo a varios compañeros es que esa clase puede ser mucho, mucho más difícil de lo que nos están, o por lo menos, lo que nos han examinado ahora mismo. [fillers] Por eso al principio teníamos ese miedo, si verdaderamente estábamos estudiando lo que, verdad, si una semana te daba o si tenías que estudiar más. Esa era la pregunta y creo que el nivel de dificultad no está tan alto como ellos pudiesen hacerlo si verdaderamente ellos quisieran. (I think that we decide that as we take the course and see what the

dynamic is like. So, I was telling several classmates that this class could be much, much harder than what they have, or at least, what we have been evaluated on so far. [fillers] That's why at the beginning we had that fear, about whether we were really studying what... whether a week would be enough or if you had to study more. That was the question, and I think that the level of difficulty is not as high as it could have been if they had truly wanted to make it more difficult.)

Eric: Yo creo que también el nivel de dificultad no ha sido como se espera, como él dijo, que esta clase puede ser más difícil de lo que es, pero es porque ellos dan dos exámenes. El primero fue como diez capítulos y el otro también, pues tú no puedes ponerlo bien difícil, porque no hay forma de que un estudiante se aprenda todo eso. Pero, si hubiesen dividido el curso en cuatro exámenes, lo más seguro hubiese sido bien retante. (I also think that the level of difficulty has not been what we expected, as he said. This course can be much more difficult than it is, but that's because they give two exams. The first one was ten chapters long, and the other one was also that long, so you can't make it too difficult because there is no way a student can learn all of that. But, if they had divided the course into four exams, it would have likely been much more challenging.) (focus group)

The students' statements shed some light on one of the possible reasons for the poor class attendance and participation in the course as well as the high performance of the students. It also raises the question as to whether the students' scientific and critical thinking was truly assessed throughout the course as intended in the syllabus. Based on the students' responses, the dynamics of the course, and the questions from the quizzes, it can be

assumed that the evaluations required students to memorize content and deposit it for the exam or quiz.

A more student-centered approach incorporating their production of multiple representations could have also been beneficial for their learning and interpretation of discipline-specific, multimodal diagrams, such as cladograms, which are generally used to represent relationships among species. The students who participated in the focus group indicated that they did not feel the need for tutoring sessions for this course, with the exception of the interpretation of these diagrams. As the students mentioned:

Interviewer: Yo vi que [Peter] habló de unas tutorías que hay para el curso, ¿alguno de ustedes ha tomado estas tutorías? (I noticed that [Peter] talked about some tutoring sessions for the course. Have any of you gone to those sessions?)

Manuel: Es que eso fue como para la segunda parte, al principio no había, porque yo pregunté y no, no había. (That was for the second part; at the beginning, there weren't any because I asked, and there weren't.)

Interviewer: En la primera parte quizás, ¿lo hubieras necesitado o te hubiera gustado tenerlo? (Would you have needed them, or would you have liked to have gone to them at the beginning of the course?)

Manuel: Sí, lo necesitaba en la primera parte para poder leer las cladogramas mejor y logré pidiéndole a otro estudiante que me explicara. (Yes, I needed them to read the cladograms better during the first part, and I managed to understand them by asking another student to explain them to me.)

Interviewer: ¿Ustedes se sienten igual que hubieran necesitado las tutorías durante la primera parte del curso? (Do you also feel that you would have needed tutoring during the first part of the course?)

Juan: No personalmente, pero la primera parte había un poco más de, o sea, te podían dar una cladograma, este o un árbol filogenético o lo que sea y tú tenías que interpretarlo y te podían hacer diferentes problemas y tú tenías que, pues, resolver el problema y que, si no entendías bien con la clase del profesor, pudieses necesitar un poco más de ayuda, pero en esta parte de la clase, no creo que, verdad, porque yo creo que son más términos. (Not personally, but in the first part, there was a little more... They would present a cladogram or a phylogenetic tree, and you had to interpret it, and they would pose different problems, and you had to, well, solve the problem, and if you didn't understand the professor's class well, you might have needed a little bit more help. But, in this part of the class, I don't think that... because I think it's more terminology.) (focus group)

The excerpt above showcases that some students may have struggled more with the multimodal ensembles that required interpretation in the course. Therefore, an approach that pays more attention to students' understanding and production of multimodal representations could have been beneficial for students' learning and development of critical thinking.

Pedagogical Implications

Embracing a multimodal, social semiotic frame in education undoubtedly has certain implications for professional pedagogical practice. These implications affect the

design of learning at different levels from individual classroom practice and course design to a larger institutional level as it relates to professors' professional development and curriculum design. Using a multimodal, social semiotic approach also has direct implications for the accessibility of the curriculum at the course and institutional levels, providing space for different perspectives to be represented in education.

Multimodality and social semiotics as they relate to education provide the space for encouraging more student-centered strategies, given the emphasis on recognition of the different types of signs of learning exhibited by the various participants in the communicative act (Bezemer & Kress, 2016). By rendering various modes and signs of learning "visible," a multimodal, social semiotic framework involves taking seriously all signs "regardless of who made the sign, or in what *mode*" (Bezemer & Kress, 2016, p. 5), thus offering more agency and value to perspectives that might be underrepresented or undervalued. As stated by Bezemer and Kress (2016),

In a social semiotic approach, the aim is to document, analyse and evaluate what *is* learned, not what is *not* learned. It is to notice and render visible learning that often goes unnoticed, and that, in being taken for granted, has been and too often still remains invisible (p. 61).

In this way, multimodality is closely linked to constructivist and humanist educational paradigms.

Naturally, such an approach would require more opportunities for student participation. While it is true that people are communicating meaning constantly, a setup like the one observed makes few modes available for students (i.e., speech and gesture).

The obvious implication is that professors should look for new designs for shaping engagement, in which students are able to use multiple representations to showcase their interest and exhibit other signs of learning. Some ways that professors could shape engagement to make it transformative could be by breaking up the traditional lecture dynamics to include collaborative learning and in-class activities involving different modes, such as creating diagrams, reports, and presentations.

Given that meaning is created socially, as viewed not just by social semioticians like Hodge and Kress (1988) but also by psychologists like Vygotsky (1934/1962) and Bruner (1990), collaborative work in the classroom setting is crucial, as is general student interaction and participation. As Kress (2014) maintains, “design is both a means of translating social change into semiotic shape and a means of bringing the interests of every member of a social group in the social-semiotic world, through their own work as rhetors and designers” (p. 145). Thus, shaping engagement through learning designs that allow for students to become rhetors and designers is important to make the curriculum more accessible.

Jaipal’s (2009) extension of Lemke’s (1998) framework can assist professors in shaping multimodal engagement. This framework can help faculty members “reflect on their choices and sequencing of modalities” (Jaipal, 2009, p. 68), enabling them to think critically about the best combinations of modes and teaching strategies for stimulating students’ production of multiple representations and learning as well as the best combinations of modes for creating bonds and relationships among the parties involved in the classroom. For instance, the present study showed that Prof. Bernard used gestures,

speech, and displacement to relate to his students and show concern for their progress. By knowing which modes are used for what specific purposes in the classroom, professors can experiment with different resources within each mode to make meaningful connections with their students. In other words, a multimodal, social semiotic framework can help professors understand their own communicative practices and use them in more purposeful ways.

Lastly, as Airey and Linder (2009) and Lemke (1998) state, mastery of specific modes is critical for success in science. This claim is supported by the results of Hand and Choi's (2010) study of multiple modal representations in organic-chemistry arguments at the college level, since their findings suggest that students who are able to embed multimodal representations in their laboratory arguments can produce better arguments. Their findings also suggest that there is a need to provide opportunities for students to engage with multiple modal representations as part of the course in order to learn how to incorporate these multimodal representations and use them appropriately (Hand & Choi, 2010). Therefore, it is vital that courses include exercises that require students to engage in the production of multiple modal representations in order to gain the mastery necessary for their field. One way to achieve this is by including a variety of evaluation methods that step beyond traditional objective, close-ended examinations (Manghi, 2013a; Manghi, 2013b).

Research Limitations

Although measures were taken to ensure that this study was methodologically sound, there were certain limitations, namely in terms of the possibility of generalization,

restrictions related to the existing data, and the affordance of the modes associated with transcription and dissertation as genres. Since the research consisted of a qualitative case study of a single case, it is difficult to generalize the findings as they are linked to one specific context. However, the findings provide information about how to apply a multimodal semiotic framework in a scientific higher-education context, which, if replicated in similar contexts, may contribute to understanding the role of multimodality in education and, more specifically, university science education.

The other limitations of this study are related to the existing data collected in the larger study between the years 2016 and 2021. The analysis for the present research was constrained to the video data collected for the larger study. Therefore, in the case of corrupted video data (e.g., a technical failure), it was not possible to recreate the same research context or interview again the students who took the course for this study. Moreover, given the different focus of the original study, the interviews did not include questions related to multiple representations or modes, which would have aided the analysis of the professor's actions in the classroom. Asking specific questions about the professor's knowledge of multimodal semiotics as they apply to a classroom setting would have helped clarify the sequencing and layering of modes displayed.

In addition, the video recordings were limited in their focus. The main study centered on the role of language in the study of medicine in Puerto Rico and the teaching strategies the professors used to make scientific content more comprehensible for their students. Due to the emphasis on the teaching strategies, there was little to no variation in camera angles, and the camera focused solely on the professor and the screen. The use of

a single camera and the lack of variation in angles limited the multimodal analyses possible, since it was not feasible to analyze two-way interactions between the professor and the students. However, that did not mean that the footage could not be used to conduct a multimodal analysis of the professor's teaching practices as presented in the recordings.

Most of the existing data from the course were collected by a different member of the research team who received training from the rest of the team members on how to conduct the field observations and notes. However, all members of the research team participated in the development of the informed consent forms and the protocols for the observations, interviews, and focus groups. The members of the research team also met weekly during the data collection phase to discuss the progress of the research, actions to take, improvements to the research instruments, and emerging themes.

Finally, the genre in which dissertation is written could also be considered a limitation of the study. *Dissertation* as an academic genre involves a limited number of modes for the rhetor to choose from when making meaning: writing, images, symbols, and layout. The genre also must conform to the requirements and practices established by an institutional authority that limit the possibilities of representation. For a multimodal study, this means that the examples included might not be the best to explain specific phenomena given the affordance of the modes ascribed to the dissertation genre, which are more static in nature. Therefore, some complex actions that are difficult to describe in writing and which cannot be appreciated in still images were not included in the discussion of findings.

The limitations of modal affordance also apply to the transcriptions used for data analysis. Like *dissertation*, *transcript* as a genre includes a limited set of available modes for making meaning, from which writing emerges as the main resource. In a multimodal study involving video data, putting speech, gestures, and other modes into writing comprises an act of transduction (Bezemer & Mavers, 2011) or resemiotization (Iedema, 2003). There are aspects of the varied modes observed throughout the course that cannot be properly conveyed in the transcripts due to the affordance of the modes associated with the transcript genre. This characteristic of the transcript genre also made it difficult to quantify the deployment of each specific mode in the communicative acts that comprise the course.

Suggestions for Future Research

Given the limitations of the present study, several recommendations can be made for future research, both in terms of methodological aspects as well as focus and purpose. Since the study focused on a single participant in just one semester, replicating the study with a larger number of participants and in other courses would provide a better understanding of the faculty members' existing multimodal and pedagogical practices. Knowing the faculty's practices can help determine which strategies better serve to enhance students' understanding and production of multiple modal representations.

To minimize the number of limitations in future replicated studies, several methodological considerations should be taken into account regarding the design and use of data collection instruments. For instance, future studies could employ multiple video cameras and microphones to capture interactions in other areas of the classroom and

focus on different participants beyond the professor. In addition, future studies should also modify interview and focus group protocols to incorporate questions related to multimodal awareness, design, and production. Such questions would minimize the number of assumptions made by the researcher when interpreting and triangulating the data.

While there have been several studies focusing on different aspects of multimodality in primary and secondary education, there have been few in higher education settings. Most studies of multimodality in STEM education in general have focused on what teachers do in the classroom, but, as Hand and Choi (2010) indicate, the embedding of multiple modal representations in textbooks, the incorporation of multimodal learning opportunities for students, and the role of peer tutoring in developing multimodal competence still need to be researched. Thus, future studies should focus on experimenting with different teaching and learning strategies involving multimodality and on documenting their effect on students' learning.

Concluding Remarks

The study reported in this dissertation employed a case study design influenced by multimodal ethnographic research methods to examine how a professor of an advanced undergraduate biology course used different modes in his teaching practice. Data collected from video recordings, field observations, interviews, and a focus group were used to guide the subsequent analysis, which was conducted using Jaipal's (2009) extension of Lemke's (1998) framework of semiotic functions. The findings support the assertion of different researchers that science discourse is inherently multimodal, given

that multiple modal representations were consistently co-deployed throughout the observed lessons, including speech, writing, gestures, images, and diagrams.

While the results revealed the presence of multiple modal representations as designed and produced by the professor, very few multiple modal representations were observed from the students. Even though the camera focused exclusively on the professor as rhetor and students did not appear on camera, the field notes from the observations recorded by a member of the research team and the recordings themselves shed some light as to the types of modes and modal representations the students were able to produce in class. Since the class followed a traditional lecture design, students had few modes available for making meaning, namely speech and gesture. They also had limited possibilities to become the main rhetors in the communicative act. The dynamics of the class and the responses of the students who participated in the focus group suggest that students need more room to design and produce their own multiple modal representations as part of the course in order to develop mastery of the modes required by their discipline.

As Bezemer and Kress (2016) indicate, adopting a multimodal, social semiotic approach to education requires relinquishing the special status historically afforded to speech and writing as “better” meaning-making modes. A multimodal, social semiotic approach to teaching and learning also has the possibility of increasing access to education, blending well with practices associated with constructivist and humanist teaching philosophies. The semiotic function framework employed can help faculty members reflect on their own use of multiple modal representations and devise new

teaching and learning strategies to help students take full advantage of the benefits of multimodality.

As an instrumental case study of a single participant, it is not possible to generalize from these findings. Therefore, replicating the study with a larger number of participants over a longer period would be advisable to verify the applicability of Jaipal's (2009) extension of Lemke's (1998) framework. Further research should still be conducted in higher education contexts as it is underrepresented in the literature. These studies could focus on students' design and production of multiple modal representations as well as the effectiveness of varied strategies that focus on the use of different modes on students' learning and development in the field. As documented in this research, the study of biology involves interpreting multiple modes of representation. Studying the semiotic work conducted in science classrooms at the higher education level has the potential of providing a more complete account of the communicative aspects of the course as well as revealing learning opportunities for developing and capitalizing on students' semiotic repertoire.

REFERENCES

- Airey, J. (2015). *Social semiotics in higher education: Examples from teaching and learning in undergraduate physics*. DIVA Portal. <https://www.diva-portal.org/smash/get/diva2:867422/FULLTEXT01.pdf>
- Airey, J., & Eriksson, U. (2019). Unpacking the Hertzsprung-Russell diagram: A social semiotic analysis of the disciplinary and pedagogical affordances of a central resource in astronomy. *Designs for Learning, 11*(1), 99-107. <https://doi.org/10.16993/dfl.137>
- Airey, J., & Linder, C. (2009). A disciplinary discourse perspective on university science learning: Achieving fluency in a critical constellation of modes. *Journal of Research in Science Teaching, 46*(1), 27-49. <https://doi.org/10.1002/tea.20265>
- Airey, J., & Simpson, Z. (2019). Increasing access to science and engineering—The role of multimodality. *Designs for Learning, 11*(1), 138-140. <https://doi.org/10.16993/dfl.144>
- Andersen, M. F., & Munksby, N. (2018). Didactical design principles to apply when introducing student-generated digital multimodal representations in the science classroom. *Designs for Learning, 10*(1), 112-122. <https://doi.org/10.16993/dfl.100>
- Arzarello, F., Paola, D., Robutti, O., & Sabena, C. (2009). Gestures as semiotic resources in the mathematics classroom. *Educational Studies in Mathematics, 70*(2), 97–109. <https://doi.org/10.1007/s10649-008-9163-z>
- Bezemer, J., & Kress, G. (2016). *Multimodality, learning and communication: A social semiotic frame* (1st ed.). Routledge.

- Bezemer, J., & Kress, G. (2017). Continuity and change: Semiotic relations across multimodal texts in surgical education. *Text&Talk*, 37(4), 509-530.
- Bezemer, J., & Kress, G. (2020). Semiotic work in the science classroom. *Cultural Studies of Science Education*, 15, 71-74. <https://doi.org/10.1007/s11422-019-09957-4>
- Bezemer, J., & Mavers, D. (2011). Multimodal transcription as academic practice: A social semiotic perspective. *International Journal of Social Research Methodology*, 14(3), 191–206. <https://doi.org/10.1080/13645579.2011.563616>
- Blommaert, J., & Jie, D. (2010). *Ethnographic fieldwork: A beginner's guide*. Multilingual Matters Limited.
- Bolkan, S. (2019). Facilitating student attention with multimedia presentations: Examining the effects of segmented PowerPoint presentations on student learning. *Communication Education*, 68(1), 61-79. <https://doi.org/10.1080/03634523.2018.1517895>
- Bruner, J. (1990). *Acts of meaning: Four lectures on mind and culture* (Revised ed.). Harvard University Press.
- Carroll, K. S. (2016). Language policies in Puerto Rican higher education: Conflicting assumptions of bilingualism. *Current Issues in Language Planning*, 17(3-4), 260-277. <https://doi.org/10.1080/14664208.2016.1201186>
- Carroll, K. S., de Vries, A., & Pagán Muñoz, A. (2021). Future doctors in training: Translanguaging in an evolution course. *Critical Inquiry in Language Studies*, 18(1), 4–25. <https://doi.org/10.1080/15427587.2020.1864635>

- Chandler, D. (2017). *Semiotics: The basics* (3rd ed.). Routledge.
- Coto, D. (2013, April 18). Doctors flee Puerto Rico for US mainland. *St. Louis Post – Dispatch*. <https://uprrp.idm.oclc.org/login?url=https://www-proquest-com.uprrp.idm.oclc.org/newspapers/doctors-flee-puerto-rico-us-mainland/docview/1328322536/se-2?accountid=44825>
- Creswell, J. W. (2019). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (6th ed.). Pearson.
- Danielsson, K. (2016). Modes and meaning in the classroom – The role of different semiotic resources to convey meaning in science classrooms. *Linguistics and Education*, 35, 88–99. <https://doi.org/10.1016/j.linged.2016.07.005>
- Das Neves, R. F., Carneiro-Leão, A. M. D., & Ferreira, H. S. (2016). A imagen da célula em libros de biología: uma abordagem a partir da teoria cognitivista da aprendizagem multimídia. *Investigações em Ensino de Ciências*, 21(1), 94-105.
- Departamento de Salud de Puerto Rico. (2021). *Informe estadístico de médicos (2016-2018) y profesionales de la salud (2016-2019) en Puerto Rico: Decimocuarto registro*. San Juan, Puerto Rico: Secretaría de Planificación y Desarrollo. (Secretaría Auxiliar de Planificación y Desarrollo, División de Evaluación y Monitoreo, Programa de Análisis Estadísticos).
- Dewey, J. (1997). *Experience and education*. Touchstone.
- Díaz Rolón, A. (2021, June 9). Destacan merma en el éxodo de salubristas. *El Vocero de Puerto Rico*. <https://uprrp.idm.oclc.org/login?url=https://www-proquest-com.uprrp.idm.oclc.org/newspapers/desta>

[can-merma-en-el-éxodo-de-salubristas/docview/2589329881/se-2?accountid=44825](https://doi.org/10.16993/df.96)

Dolo, G., Haglund, J., & Schönborn, K. (2018). Thermal cameras as a semiotic resource for inquiry in a South African township school context. *Designs for Learning*, 10(1), 123-134. <https://doi.org/10.16993/df.96>

Duncum, P. (2004). Visual culture isn't just visual: Multiliteracy, multimodality and meaning. *Studies in Art Education*, 45(3), 252–264.

<https://doi.org/10.1080/00393541.2004.11651771>

EFEUSA. (2018, April 18). Representantes P.Rico legislan medidas adicionales para evitar éxodo médicos. *Agencia EFE*. <https://www.efe.com/efe/usa/puerto-rico/representantes-p-rico-legislan-medidas-adicionales-para-evitar-exodo-medicos/50000110-3588295>

Facultad de Ciencias Naturales, Universidad de Puerto Rico, Recinto de Río Piedras.

(2010a). *Currículo del Programa de Bachillerato en Ciencias con Concentración Énfasis en Biología Integrativa* [PDF document].

https://natsci.uprrp.edu/biology/wp-content/uploads/sites/2/2018/06/Opusculo_BI_Feb2010-ilovepdf-compressed.pdf

Facultad de Ciencias Naturales, Universidad de Puerto Rico, Recinto de Río Piedras.

(2010b). *Currículo del Programa de Bachillerato en Ciencias con Concentración Énfasis en Biología Celular Molecular* [PDF document].

https://natsci.uprrp.edu/biology/wp-content/uploads/sites/2/2018/06/Opusculo_CM_Feb2010.pdf

Facultad de Ciencias Naturales, Universidad de Puerto Rico, Recinto de Río Piedras.

(2021, March 30). *Anfiteatro CN-142 es reinagurado*. Retrieved January 9, 2022, from <https://natsci.uprrp.edu/2021/03/30/anfiteatro-cn-142-es-reinagurado/>

Flewitt, R. (2011). Bringing ethnography to a multimodal investigation of early literacy in a digital age. *Qualitative Research*, 11(3), 293–310.

<https://doi.org/10.1177/1468794111399838>

Freire, P. (2017). *Pedagogy of the oppressed* (M. Bergman Ramos, Trans.). Penguin Random House. (Original work published 1970)

Frejd, J. (2018). “If it lived here, it would die.” Children's use of materials as semiotic resources in group discussions about evolution. *Journal of Research in Childhood Education*, 32(3), 251-267. <https://doi.org/10.1080/02568543.2018.1465497>

Gall, M. D., Gall, J. P., & Borg, W. R. (2007). *Educational research: An introduction* (8th ed.). Pearson.

Gardner, H. E. (2006). *Multiple intelligences: New horizons in theory and practice*. Basic Books.

Gourlay, L. (2010). Multimodality, visual methodologies and higher education. In M. Savin-Baden & C. H. Major (Eds.), *New approaches to qualitative research: Wisdom and uncertainty* (pp. 80–88). Routledge.

Halliday, M. A. K. (1978). *Language as social semiotic: The social interpretation of language and meaning*. Edward Arnold.

Halliday, M. A. K. (1994). *An introduction to functional grammar* (2nd ed.). Edward Arnold.

- Hand, B., & Choi, A. (2010). Examining the impact of student use of multiple modal representations in constructing arguments in organic chemistry laboratory classes. *Research in Science Education*, 40(1), 29–44. <https://doi.org/10.1007/s11165-009-9155-8>
- He, P., Lai, H., & Lin, A. (2017). Translanguaging in a multimodal mathematics presentation. In C. M. Mazak & K. S. Carroll (Eds.), *Translanguaging in higher education: Beyond monolingual ideologies* (pp. 91–120). Multilingual Matters.
- Hill, A., Arford, T., Lubitow, A., & Smollin, L. M. (2011). “I’m ambivalent about it”: The dilemmas of PowerPoint. *Teaching Sociology*, 40, 242-256. <https://doi.org/10.1177/0092055X12444071>
- Hodge, R., & Kress, G. (1988). *Social semiotics*. Cornell University Press.
- Iedema, R. (2003). Multimodality, resemiotization: Extending the analysis of discourse as multi-semiotic practice. *Visual Communication*, 2(1), 29–57. <https://doi.org/10.1177/1470357203002001751>
- Jaipal, K. (2009). Meaning making through multiple modalities in a biology classroom: A multimodal semiotics discourse analysis. *Science Education*, 94(1), 48–72. <https://doi.org/10.1002/sce.20359>
- Jaipal-Jamani, K. (2011). A semiotics discourse analysis framework: Understanding meaning making in science education contexts. In S. C. Hamel (Ed.), *Semiotics: Theory and applications* (pp. 191–208). Nova Science Publishers.
- Jewitt, C., Bezemer, J., & O’Halloran, K. (2016). *Introducing multimodality*. Routledge.

- Jewitt, C., Kress, G., Ogborn, J., & Tsatsarelis, C. (2001). Exploring learning through visual, actional and linguistic communication: The multimodal environment of a science classroom. *Educational Review*, 53(1), 5–18.
<https://doi.org/10.1080/00131910123753>
- Klein, P. D., & Kirkpatrick, L. C. (2010). Multimodal literacies in science: Currency, coherence and focus. *Research in Science Education*, 40(1), 87–92.
<https://doi.org/10.1007/s11165-009-9159-4>
- Kress, G. (2003). Genres and the multimodal production of “scientificness.” In C. Jewitt & G. Kress (Eds.), *Multimodal literacy* (pp. 173–186). Peter Lang.
- Kress, G. (2010). *Multimodality: A social semiotic approach to contemporary communication*. Routledge.
- Kress, G. (2014). Design: The rhetorical work of shaping the semiotic world. In A. Archer & D. Newfield (Eds.), *Multimodal approaches to research and pedagogy: Recognition, resources and access* (pp. 131–152). Routledge.
- Kress, G., Jewitt, C., Ogborn, J., & Tsatsarelis, C. (2001). *Multimodal teaching and learning: The rhetorics of the Science classroom*. Continuum.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation (learning in doing: Social, cognitive and computational perspectives)*. Cambridge University Press.
- Legisladora propone trabajar para frenar éxodo de médicos puertorriqueños. (2018, April 23). *EFE News Service*. <https://uprrp.idm.oclc.org/login?url=https://www->

proquest-com.uprrp.idm.oclc.org/wire-feeds/legisladora-propone-trabajar-para-frenar-exodo-de/docview/2029048377/se-2?accountid=44825

Lemke, J. (1993). *Multiplying meaning: Literacy in a multimedia world* (ED365940).

ERIC. <https://files.eric.ed.gov/fulltext/ED365940.pdf>

Lemke, J. (1998). Multiplying meaning: Visual and verbal semiotics in scientific text. In

J. R. Martin & R. Veel (Eds.), *Reading science: Critical and functional perspectives on discourses in science* (pp. 87–113). Routledge.

Liu, Y., & Dwi-Nugroho, A. (2012). The social semiotic construction of chemical periodicity: A multimodal view. *Semiotica*, 190(1–4), 133–151.

<https://doi.org/10.1515/sem-2012-0043>

Lucca, N., & Berríos, R. (2009). *Investigación cualitativa: Fundamentos, diseños y estrategias*. Ediciones SM.

Manghi, D. (2013a). Géneros en la enseñanza escolar: Configuraciones de significado en

clases de historia y biología desde una perspectiva multimodal. *Revista Signos*, 46(82), 7–8. <https://doi.org/10.4067/s0718-09342013000200004>

Manghi, D. (2013b). Representación y comunicación del conocimiento en educación

media: Análisis multimodal del discurso de materiales utilizados para la enseñanza escolar de la historia y la biología. *Onomázein*, 35–52.

Mazak, C. M., & Herbas-Donoso, C. (2015). Translanguaging practices at a bilingual

university: a case study of a science classroom. *International Journal of Bilingual Education and Bilingualism*, 18(6), 698-714.

<https://doi.org/101080/13670050.2014.939138>

- Mazak, C. M., Mendoza, F., & Pérez Mangonéz, L. (2017). Professors translanguaging in practice: Three cases from a bilingual university. In C. M. Mazak & K. S. Carroll (Eds.), *Translanguaging in higher education: Beyond monolingual ideologies* (pp. 70–90). Multilingual Matters.
- Moje, E. B. (1997). Exploring discourse, subjectivity, and knowledge in chemistry class. *Journal of Classroom Interaction*, 32(2), 35–44.
- O'Halloran, K. L. (2015). The language of learning mathematics: A multimodal perspective. *The Journal of Mathematical Behavior*, 40, 63–74.
<https://doi.org/10.1016/j.jmathb.2014.09.002>
- oTranscribe. (n.d.). *oTranscribe*. <https://otranscribe.com/>
- Parés Arroyo, M. (2016, July 28). Peligrosa fuga de miles de médicos. *El Nuevo Día*.
<https://www.elnuevodia.com/noticias/locales/notas/peligrosa-fuga-de-miles-de-medicos/>
- Peirce, C. (1999). Logic as semiotic: The theory of signs. In M. Danesi & D. Santeramo (Eds.), *The sign in theory and practice: An introductory reader in semiotics* (pp. 71-94). Canadian Scholars' Press.
- Pérez, J. J. (2017, November 26). Fuga de médicos que no termina. *El Nuevo Día*.
<https://www.elnuevodia.com/noticias/locales/notas/fuga-de-medicos-que-no-termina/>
- Perreira, K., Peters, R., Lallemand, N., & Zuckerman, S. (2017). *Puerto Rico health care infrastructure assessment: Site visit report*. Urban Institute.

https://www.urban.org/sites/default/files/publication/87011/2001050-puerto-rico-health-care-infratructure-assessment-site-visit-report_1.pdf

Rivera Sánchez, M. (2021, October 19). Un incentivo federal detendría la fuga de médicos en la Isla. *El Vocero de Puerto Rico*.

<https://uprrp.idm.oclc.org/login?url=https://www.proquest.com/newspapers/uninc-intivo-federal-detendría-la-fuga-de-médicos/docview/2583904024/se-2?accountid=44825>

Saldaña, J. (2011). *Fundamentals of qualitative research: Understanding qualitative research*. Oxford University Press.

Saldaña, J. (2021). *The coding manual for qualitative researchers* (4th ed.). SAGE Publications Ltd.

Samuelsson, C. R., Elmgren, M., & Haglund, J. (2019). Hot vision; Affordances of infrared cameras in investigating thermal phenomena. *Designs for Learning*, 11(1), 1-15. <https://doi.org/10.16993/df1.94>

Saussure, F. (1998). *Course in general linguistics* (R. Harris, Trans.). Open Court. (Original work published 1972)

Simpson, Z., & Prince, R. (2018). Teaching, learning, and employing analytical frameworks as performance: Analysis of quantitative literacy event in applied mechanics. *Designs for Learning*, 10(1), 76-87. <https://doi.org/10.16993/df1.95>

Soto Vega, K. M. (2010). *Rocking and Reading: Exploring multimodal media literacy in an ESL college classroom* (Publication No. 1504394) [Master's thesis, University of Puerto Rico, Mayagüez Campus]. ProQuest Dissertations & Theses Global.

- Stake, R. (2003). Case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Strategies of qualitative inquiry* (2nd ed., pp. 134–164). SAGE Publications Ltd.
- Tang, K. S. (2013). Instantiation of multimodal semiotic systems in science classroom discourse. *Language Sciences*, 37, 22–35.
<https://doi.org/10.1016/j.langsci.2012.08.003>
- Tang, K. S., & Moje, E. B. (2010). Relating multimodal representations to the literacies of science. *Research in Science Education*, 40(1), 81–85.
<https://doi.org/10.1007/s11165-009-9158-5>
- Universidad de Puerto Rico, Recinto de Río Piedras. (2015). *Catálogo general: Programas subgraduados*. <https://www.uprrp.edu/wp-content/uploads/2015/07/catalogo-2015-subgraduado.pdf>
- Universidad de Puerto Rico, Recinto de Río Piedras. (2021, October). *Distribución de grados conferidos por facultad o escuela, concentración, nivel de estudios y género años académicos 2016–16 al 2021–21*.
https://academicos.uprrp.edu/diia/wp-content/uploads/sites/5/2021/11/4-GradosConferidos_Fac_Nivel_Conc-Genero_2015-2020_Rev2021-11-17.xlsx
- Universidad de Puerto Rico, Recinto de Río Piedras. (2022a, March). *Admitidos por facultad y concentración años académicos 2013–14 al 2021–22*.
https://academicos.uprrp.edu/diia/wp-content/uploads/sites/5/2022/03/b-NRG_Admitidos2013-2021_Rev2022-03-04.xlsx
- Universidad de Puerto Rico, Recinto de Río Piedras. (2022b, March). *Informe de índice mínimo de ingreso y cupo años académicos 2010 al 2021*.

https://academicos.uprrp.edu/diia/wp-content/uploads/sites/5/2022/03/d-IMIsCupos2010-2021_Rev2022-03-04.xlsx

Universidad de Puerto Rico, Recinto de Río Piedras. (2022c, March). *Matrícula total por facultad, concentración, clasificación, nivel y género años académicos 2015–16 at 2021–22*. https://academicos.uprrp.edu/diia/wp-content/uploads/sites/5/2022/03/1-MatriculaTotal2015-2021_1er-2doSemestre_Rev2022-03-04.xlsx

Universidad de Puerto Rico, Recinto de Río Piedras. (2022d, March). *Solicitantes por facultad y concentración años académicos 2013–14 at 2021–2022*. https://academicos.uprrp.edu/diia/wp-content/uploads/sites/5/2022/03/a-NRG_Solicitantes2013-2021_Rev2022-03-04.xlsx

University of Puerto Rico, Medical Sciences Campus, School of Medicine. (2018). *Annual statistical report on admissions: August 2018 – Entering class* [PDF document]. University of Puerto Rico, Medical Sciences Campus, School of Medicine.

University of Puerto Rico, Medical Sciences Campus, School of Medicine. (2021, September). *Requirements for admission* [PDF document]. <https://md.rcm.upr.edu/wp-content/uploads/2021/10/MD-Requirements-Admission-Revised-Sept-2021.pdf>

Van Leeuwen, T. (2005). *Introducing social semiotics: An introductory textbook*. Routledge.

- Volkwyn, T. S., Airey, J., Gregorcic, B., & Heijkenskjöld, F. (2019). Transduction and science learning: Multimodality in the physics laboratory. *Designs for Learning*, 11(1), 16-29. <https://doi.org/10.16993/dfl.118>
- Vygotsky, L. S. (1962). *Thought and language* (E. Hanfmann & G. Vakar, Trans.). M.I.T. Press. (Original work published 1934)
- Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.
- West, R., & Turner, L. H. (2004). *Introducing communication theory: Analysis and application* (2nd ed.). McGraw-Hill.
- Zhang, Y. (2016). Multimodal teacher input and science learning in a middle school sheltered classroom. *Journal of Research in Science Teaching*, 53(1), 7–30. <https://doi.org/10.1002/tea.21295>

APPENDIX A:
CIPSHI APPROVAL LETTER

Universidad de
Puerto Rico

COMITÉ INSTITUCIONAL PARA LA PROTECCIÓN DE LOS SERES HUMANOS
EN LA INVESTIGACIÓN (CIPSHI)
IRB 00000944

AUTORIZACIÓN DEL PROTOCOLO

Número del protocolo: 1718-044

Título del protocolo: The Role of Language in Studying Medicine in Puerto Rico

Investigador: Kevin S. Carroll

Tipo de revisión: Inicial Renovación Modificación

Revisado por:

- Comité en pleno
 Procedimiento expedito bajo la(s) categoría(s) del *Federal Register*
63 FR 60364-60367: F (6 y 7)

Fecha de la revisión: 17 de diciembre de 2018

Otras acciones:

- Condiciones verificadas y aprobadas por Miembro del CIPSHI Personal de Cumplimiento
el 21 de diciembre de 2018.
 Revisión continua cualifica para la evaluación expedita.

Esta autorización expira el 27 de febrero de 2019.

Si la investigación no concluye para esta fecha, tiene que solicitar la renovación de la autorización de acuerdo al tipo de revisión que le corresponda, por el comité en pleno o expedita. Cualquier modificación posterior a esta autorización requerirá la consideración y reautorización del CIPSHI. Además, debe notificar cualquier incidente adverso o no anticipado que implique a los sujetos o participantes. Al finalizar la investigación, envíe el formulario de Notificación de Terminación de Protocolo.

cipshi_deg@upr.edu - <http://graduados.upr.edu/cipshi>

Decanato de
Estudios Graduados
e Investigación

PO Box 21790
San Juan PR
00931-1790

787-764-0000
Ext. 86700
Fax 787-763-6011

Página electrónica:
<http://graduados.upr.edu>



Víctor E. Bonilla Rodríguez, Ph.D.
Presidenta del CIPSHI o
representante autorizado

Patrón con Igualdad de Oportunidades en el Empleo MMVII

APPENDIX B:

CIPSHI EXTENSION AUTHORIZATION

Universidad de
Puerto Rico

COMITÉ INSTITUCIONAL PARA LA PROTECCIÓN DE LOS SERES HUMANOS
EN LA INVESTIGACIÓN (CIPSHI)
IRB 00000944
cipshi.degi@upr.edu - <http://graduados.uprp.edu/cipshi>

CERTIFICACION DE EXTENSION DE LA AUTORIZACIÓN DEL PROTOCOLO

Número del protocolo: 1718-044
Título del protocolo: The Role of Language in Studying Medicine in Puerto Rico
Investigador: Dr. Kevin S. Carroll



El Comité Institucional para la Protección de los Seres Humanos en la Investigación (CIPSHI), *Institutional Review Board (IRB)* de la Universidad de Puerto Rico, Recinto de Río Piedras (UPRRP), consideró este protocolo como de riesgo mínimo en su evaluación inicial y al aprobarlo mediante el procedimiento expedito. Por lo tanto, esta investigación cualifica para la extensión de la autorización y no requiere de la revisión continua anual o renovación de la autorización del CIPSHI (Circular Núm. 09, Año Académico 2018-19).

Yarimar Rosa Rodríguez, Ph.D.
Presidenta del CIPSHI
18 de enero de 2019

Los investigadores son responsables de:

- Proteger los derechos y procurar el bienestar de los participantes.
- Llevar a cabo la investigación según el protocolo autorizado.
- Proveer a cada participante una copia de la hoja de consentimiento o asentimiento aprobada, a menos que haya sido autorizado a tomar el consentimiento de otra manera.
- Solicitar la revisión y autorización de cualquier cambio en el protocolo, incluyendo en las hojas de consentimiento o asentimiento informado, instrumentos u otros documentos pertinentes, y en el personal clave de la investigación.
- Capacitar al personal clave de la investigación y enviar al CIPSHI los certificados del adiestramiento requerido del personal cuando sea reclutado.
- Notificar cualquier incidente adverso o no anticipado que implique a los sujetos o participantes.
- Enviar los informes de progreso de la investigación.
- Enviar la notificación de terminación de protocolo.
- Conservar y manejar los datos y documentos con información de los participantes según el protocolo autorizado y lo acordado con los participantes.

Decanato de
Estudios Graduados
e Investigación

18 Ave. Universidad STE 1801
San Juan PR 00925-2512

787-764-0000
Ext. 88700
Fax 787-763-6011

Página electrónica:
<http://graduados.uprp.edu>

Patrón con Igualdad de Oportunidades en el Empleo MM(VI)

APPENDIX C:
OBSERVATION PROTOCOL

Protocolo de observación

El investigador llegará al salón cinco minutos antes de que comience la clase. Antes de comenzar la observación, el investigador se ubicará en el espacio indicado por el profesor. Colocará la cámara de video en un trípode apuntando hacia el frente del salón de manera que solo se vea el cuerpo del profesor y cualquier imagen proyectada en el salón.

APPENDIX D:

INTERVIEW PROTOCOLS

Protocolo de entrevista Profesores (Primera entrevista)

1. Luego de obtener el consentimiento informado del participante, el investigador iniciará la grabación de audio y video.
2. El miembro del equipo investigador proveerá una breve introducción del estudio y el trasfondo del investigador.
3. El miembro del equipo investigador comenzará la entrevista utilizando las preguntas guías abajo para propiciar que el participante narre sus experiencias relacionadas con el manejo del contenido en inglés en sus cursos universitarios.

Las preguntas a continuación fueron creadas como preguntas guía y tal vez no se utilicen en la entrevista como tal. Se podría añadir otras preguntas dependiendo de la dinámica con el participante.

Preguntas demográficas:

1. ¿Cuál es su puesto actual?
2. ¿Cuántos años de experiencia tiene en su puesto actual?
3. ¿Ha ocupado algún otro puesto administrativo en otras instituciones? ¿Públicas, privadas o ambas?
4. ¿Cuáles cursos suele enseñar?
5. ¿Dónde realizó sus estudios universitarios?
6. ¿Cuál era la lengua dominante durante sus estudios universitarios?
7. ¿Cómo describiría sus cursos universitarios en términos de las lenguas que se utilizaban en ellos?

Preguntas sobre curso a observar:

8. ¿Cuántas veces ha enseñado este curso?
9. ¿Cómo describiría la habilidad en inglés general de los estudiantes que toman sus cursos?
10. ¿Qué tipo de dificultades relacionadas con el inglés suele notar en sus estudiantes con mayor frecuencia?
11. ¿Qué estrategias suele utilizar para ayudar a los estudiantes comprender el material en inglés del curso?
12. ¿Diría que además de impartir el contenido del curso enseña a sus estudiantes inglés? Por favor, explique.

**Protocolo de entrevista
Profesores (Segunda entrevista)**

1. Luego de obtener el consentimiento informado del participante, el investigador iniciará la grabación de audio y video.
2. El miembro del equipo investigador proveerá una breve introducción del estudio y el trasfondo del investigador.
3. El miembro del equipo investigador comenzará la entrevista utilizando las preguntas guías abajo para propiciar que el participante narre sus experiencias relacionadas con el manejo del contenido en inglés en sus cursos universitarios.

Las preguntas a continuación fueron creadas como preguntas guía y tal vez no se utilicen en la entrevista como tal. Se podría añadir otras preguntas dependiendo de la dinámica con el participante y las observaciones en la sala de clases que se llevarán a cabo durante el proyecto.

Preguntas:

El investigador hará preguntas para corroborar y confirmar observaciones realizadas durante el estudio.

APPENDIX E:

FOCUS GROUP PROTOCOL

Protocolo de entrevista: Grupo focal Estudiantes matriculados en cursos bajo observación:

1. Luego de obtener el consentimiento informado de los participantes, el investigador iniciará la grabación de audio del grupo focal.
2. El miembro del equipo investigador proveerá una breve introducción del estudio y el trasfondo del investigador.
3. El miembro del equipo investigador comenzará las preguntas para el grupo focal utilizando las preguntas guías abajo para propiciar que los participantes narren sus experiencias relacionadas con el manejo del contenido en inglés en sus cursos universitarios.

Las preguntas a continuación fueron creadas como preguntas guía y tal vez no se utilicen en el grupo focal como tal. Se podría añadir otras preguntas dependiendo de la dinámica del grupo y las observaciones en la sala de clases que se llevarán a cabo durante el proyecto.

Preguntas demográficas y educación preuniversitaria:

1. ¿Cuál es su edad actual?
2. ¿En qué año te encuentras en sus estudios?
3. Antes de ingresar a la universidad, ¿estudió en una escuela pública o privada?
4. ¿En qué idioma eran sus clases en escuela superior?
5. ¿En qué idioma eran la mayoría de sus libros de texto escolares?
6. Si aplica, ¿podría describir cómo era la dinámica en aquellos cursos que utilizaban un texto en inglés, pero la clase era en español?
7. ¿Podría hablar sobre su bilingüismo y cómo se identifica con ambos el español y el inglés actualmente?
8. ¿Cómo siente que sus cursos de escuela superior lo han preparado en términos de sus destrezas en español e inglés para continuar estudios universitarios?
9. ¿A qué nivel de inglés entraste en a la UPR? (Básico, Intermedio, Honors o Avanzado AP)
10. ¿Qué piensas hacer después de graduarte de la UIPI?

Preguntas adicionales para estudiantes matriculado en la escuela de medicina

11. ¿Dónde hizo su bachillerato y en qué?

12. ¿En qué idioma eran sus clases de concentración de bachillerato?
13. ¿En qué idioma eran la mayoría de sus textos universitarios?
14. Si aplica, ¿podría describir cómo era la dinámica en aquellos cursos que utilizaban un texto en inglés, pero la clase era en español?

Preguntas sobre su experiencia en el curso bajo observación:

El investigador hará preguntas para corroborar y confirmar detalles observados en el curso.

15. ¿Le parecen apropiadas las técnicas que usa el profesor para manejar el contenido en inglés del curso?
16. ¿Cuán representativo es este curso en términos lingüísticos de otros cursos tomados en su disciplina? ¿En qué aspectos se asemeja o se diferencia en términos a los lenguajes usados para presentar y explicar el contenido?
17. What is more important, the English textbook or the Spanish workbook?
18. How does it feel to take this class with mostly the same students from last semester? Does it make you feel more comfortable or less?
19. What is the role of the tutors in your class? Do you aspire to be a tutor one day?

Preguntas sobre experiencia como pruebas estandarizadas:

20. ¿Ha tomado el MCAT?
21. Si no ha tomado el MCAT, ¿cómo se está preparando para tomar el MCAT?
22. ¿Le preocupa el hecho que el examen sea en inglés?
23. Si le preocupa, ¿qué estrategias o medidas está tomando para prepararse mejor para el examen en términos del idioma?
24. Si ya tomó el MCAT, ¿cuál le parece que fue lo más difícil del examen?
25. ¿Entiende que el hecho que el examen sea en inglés haya afectado sus resultados? Si entiende que le afectó, ¿en qué manera?
26. A partir de la experiencia del MCAT, ¿qué medidas, si alguna, tomará para prepararse para futuros exámenes estandarizados como el USMLE Step 1 al 3?

Preguntas sobre su experiencia en otros cursos de premédica o medicina:

27. ¿Cómo describiría la dinámica en términos de lenguaje en la mayoría de sus cursos?
28. ¿Has tenido un profesor que da el curso exclusivamente en inglés? ¿Cómo te sentiste en esa clase?
29. ¿Puede hablarme sobre algún profesor o profesora que entiendas que utiliza buenas estrategias para explicar en clase contenidos del curso escritos en inglés?

30. ¿Qué estrategias utilizas para trabajar con contenidos presentados en inglés al estudiar para tus cursos?
31. ¿Qué opina de tomar cursos en los que las lecturas son en inglés, pero la discusión es en español?
32. ¿Entiende que sus estudios universitarios se han visto afectados por el uso del inglés en sus cursos? Si entiende que se han afectado, por favor explique.

APPENDIX F: CONSENT FORMS



DEPARTAMENTO DE ESTUDIOS GRADUADOS
UNIVERSIDAD DE PUERTO RICO, RECINTO DE RÍO PIEDRAS, FACULTAD DE EDUCACIÓN

HOJA DE CONSENTIMIENTO INFORMADO

Profesores

The Role of Language in Studying Medicine in Puerto Rico

(Versión 6: 11/20/2018)

Descripción

Ha sido invitado a participar en una investigación sobre el papel que juega el lenguaje al estudiar medicina en Puerto Rico. Esta investigación es realizada por Kevin S. Carroll, Profesor Asociado en el Departamento de Estudios Graduados de la Facultad de Educación de la Universidad de Puerto Rico, Recinto de Río Piedras, y Anyeliz Pagán Muñoz, estudiante del programa de Currículo y Enseñanza del Recinto. El propósito de esta investigación es comprender la función que desempeña el lenguaje en la labor de los universitarios que aspiran a convertirse en médicos.

Usted fue invitado para participar en esta investigación porque enseña algún curso de premédica o medicina en el Recinto de Río Piedras o el Recinto de Ciencias Médicas de la Universidad de Puerto Rico.

Se espera que participen aproximadamente 49 personas en este estudio: 45 estudiantes universitarios y cuatro (4) profesores. Si acepta a participar en esta investigación, consentirá a: la observación de su curso en su totalidad (semanas 1-15 o su equivalente) con grabación de video, la entrega de exámenes y pruebas cortas del curso, luego de su administración en el curso (Si consiente a entregar los exámenes y las pruebas cortas, estas solo se examinarán en términos lingüísticos. No se examinarían los exámenes y las pruebas cortas de los estudiantes como tal.), y dos entrevistas con el equipo de investigación. Las entrevistas serán de aproximadamente treinta a sesenta (30-60) minutos de duración cada una y se grabarán en audio con el propósito de que los investigadores puedan documentar debidamente sus palabras. Durante las entrevistas, se harán preguntas enfocadas en sus experiencias educativas como profesor de premédica o medicina con énfasis en cómo ha manejado situaciones lingüísticas en su salón de clases para fomentar la comprensión de los estudiantes. Es posible que aparezcan extractos de audio de su entrevista en publicaciones o presentaciones del equipo investigador. De publicarse algún extracto de las grabaciones de video, no se incluirá su nombre, aunque su voz e imagen pudieran identificarlo como participante en este estudio. No obstante, antes de utilizar cualquier extracto de video o audio para publicación en algún taller de mejoramiento profesional, el equipo investigador se comunicará con usted para su aprobación final.

Riesgos y beneficios

Los riesgos asociados a este estudio son mínimos. Se limitan a la posibilidad de que se sienta incómodo durante las entrevistas y la observación en clase. Si desea, podrá retirar su participación en cualquier momento. No obstante, los investigadores se asegurarán de proveer un ambiente de confianza y confidencialidad que permita que se sienta cómodo y seguro en todo momento durante la entrevista.

En cuanto a las observaciones en clase, podría existir el riesgo de que la dinámica de la clase se vea afectada al inicio del semestre por la presencia del observador y la videocámara. Sin embargo, se espera que sus estudiantes se vayan acostumbrando paulatinamente a la presencia del observador y la videocámara a medida que avanza el semestre. Además, el observador se ubicaría con la videocámara en el lugar indicado por el profesor de modo que interfiriera lo menos posible con el desarrollo normal de la clase. Dicha videocámara estaría enfocada en el profesor y no en los estudiantes. El observador no participaría de manera alguna en la dinámica del curso; solo observará el curso y tomará anotaciones pertinentes al estudio. El observador apagará la grabación en cualquier momento si así lo desea el profesor.

La participación en este estudio es completamente voluntaria. Este estudio no conlleva costo alguno para el participante. Esta investigación conlleva como beneficio directo para el profesor participante el uso didáctico de las grabaciones tomadas durante las observaciones para colocarlas en la plataforma de Moodle, u otra plataforma en línea, de su curso para que sus estudiantes las usen como repaso. En el caso de que el participante quiera usar su copia de las grabaciones de video, debería conseguir la autorización correspondientes. Además, este estudio tiene como beneficio indirecto esperado la aportación de una

Página 1 de 2

P.O. Box 23304 San Juan, Puerto Rico 00931-3304 Tel. 787-764-0000 ext. 89195, 89203 <http://ege.uprrp.edu>
Patrón con igualdad de oportunidades en el empleo M/M/V/I

Confidencialidad

Su identidad será protegida en todo momento. Todo documento, incluida esta hoja de consentimiento con su firma, será guardado por el investigador principal, Kevin S. Carroll, permanentemente bajo llave o en un archivo protegido por contraseña. Las grabaciones en audio y video también se almacenarán permanentemente, en un archivo protegido por contraseña. Una vez el audio sea transcrito por los investigadores, toda información o datos que puedan identificarlo directa o indirectamente, tal como su nombre, se clasificará bajo un pseudónimo (nombre inventado) para proteger su identidad. Estas transcripciones, que utilizan pseudónimos y que no contienen información que le pudiera identificar, serán archivadas para futuros proyectos e investigaciones en las cuales otros estudiantes graduados o profesores interesados en el tema tendrán acceso solo a dichas transcripciones. El acceso a las hojas de consentimiento y las grabaciones de audio y video se limitará al equipo de investigación, así como Oficiales del Recinto de Río Piedras de la Universidad de Puerto Rico o de agencias federales responsables de velar por la integridad en la investigación podrían requerirle al investigador los datos crudos obtenidos en este estudio, incluido este documento. Por otra parte, el equipo investigador no puede garantizar que la información compartida en el grupo no sea revelada por otros participantes.

Derechos

Si leyó este documento y decidió participar, por favor entienda que su participación es completamente voluntaria y que tiene derecho a abstenerse de participar o a retirarse del estudio en cualquier momento sin ningún tipo de penalidad. También tiene derecho a no contestar alguna pregunta en particular. Además, tiene derecho a recibir una copia de este documento.

Si tiene alguna pregunta o desea más información sobre esta investigación, por favor comuníquese con el equipo de investigación: Kevin S. Carroll vía email a kevin.carroll@upr.edu o por teléfono al 1-520-861-5669. También puede contactar a Anyeliz Pagán Muñoz a anyeliz.pagan@upr.edu o al 1-787-450-8795.

Si tiene preguntas sobre sus derechos como participante o una reclamación o queja relacionada con su participación en este estudio, puede comunicarse con la Oficial de Cumplimiento del Recinto de Río Piedras de la Universidad de Puerto Rico al teléfono 787-764-0000, extensión 86773 o a cipshi.degi@upr.edu.

Permiso de grabación de audio y video

Si está de acuerdo con aparecer en grabaciones de audio y video de esta investigación, por favor haga una marca de cotejo en la línea de abajo.

_____ Estoy de acuerdo con que me graben en audio y video para la investigación.

Su firma en este documento significa que decidió participar en esta investigación después de leer y discutir la información presentada en esta hoja de consentimiento y que recibió copia de este documento

_____	_____	_____
Nombre del participante	Firma	Fecha

Discutí el contenido de esta hoja de consentimiento con el arriba firmante.

_____	_____	_____
Nombre	Firma	Fecha

APPENDIX G:
CITI TRAINING CERTIFICATE



Completion Date 09-Oct-2019
Expiration Date 07-Oct-2024
Record ID 31617460

This is to certify that:

Anyeliz Pagan

Has completed the following Citi Program course:

Investigaciones psicológicas, sociales o educativas (Curriculum Group)
Investigaciones psicológicas, sociales o educativas con seres humanos (Course Learner Group)
1 - Stage 1 (Stage)

Under requirements set by:

Universidad de Puerto Rico, Recinto de Río Piedras Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?wec3b8cbc-ac26-42f8-b78e-9bd625d20a21-31617460

**APPENDIX H:
PROPOSED TRANSCRIPTION MODEL**

Time	Action	Verbal

APPENDIX I:

FINAL MODIFIED TRANSCRIPTION MODEL

Time	Verbal	Action	Text

BIOGRAPHY

Anyeliz M. Pagán Muñoz was born in San Juan, Puerto Rico, and raised in the surrounding metropolitan area near Bayamón. She has a Bachelor of Arts in Communication and a Master of Arts in Translation from the University of Puerto Rico, Río Piedras Campus (UPR-RP). She is a doctoral candidate in Curriculum and Instruction with a specialization in Teaching English as a Second Language at the same university.

As an academic, she has experience teaching English as a Second Language (ESL), research, and public speaking at the undergraduate level. She is a full-time English instructor at the Inter-American University of Puerto Rico, Bayamón Campus, and has taught ESL part-time at UPR-RP's College of General Studies. As a graduate student, she had several assistantships where she had the opportunity to work as an editor and translator in the UPR Translation Center and the UPR Self-Study Office as well as a research assistantship in the College of Education under the mentorship of Dr. Kevin Carroll.

In addition, she is a Spanish↔English translator certified by the American Translators Association. She has experience translating content from various disciplines, including legal, financial, educational, advertising, and communication texts. She recently finished her third translation collaboration with the Yale Child Study Center at Yale University. She has also collaborated translating documents and developing and proofreading content for K-12 Spanish, History, and Mathematics textbooks, workbooks, and teacher's guides with a major publishing house in Puerto Rico.