WEIZMANN INSTITUTE OF SCIENCE

Thesis for the degree
Doctor of Philosophy

Submitted to the Scientific Council of the
Weizmann Institute of Science
Rehovot, Israel

עבודת גמר (תזה) לתואר
דוקטור לפילוסופיה

מוגשת למועצה המדעית של
מכון ויצמן למדע
רחובות, ישראל

By
Moriah Ariely

מאת
מוריה אריאלי

שימוש בטקסטים מדעיים מסוגות שונות: פיתוח אוריינות מדעית-דיסציפלינארית בקרב תלמידי ביולוגיה בתיכון

Using scientific texts as a means to promote disciplinary scientific literacy among high-school biology students

Advisor:
Prof. Anat Yarden

מנחה:
פרופ' ענת ירדן

January 2018

טבת תשע"ח

Acknowledgments

I would like to express my sincere gratitude to my advisor Prof. Anat Yarden. Thank you for all your support and encouragement throughout the years. For your patience, motivation and immense knowledge. I am grateful for your valuable guidance and for allowing me to realize my own ideas. You have provided me with the tools and knowledge to grow as researcher.

I wish to thank the members of my research committee: Prof. Edit Yerushalmi and Prof. Baruch Shwartz for all their insightful advices and for sharing their immense experience and knowledge with me.

I also wish to thank Prof. Zohar Livnat for her cooperation and valuable assistance, and for providing insight and expertise that greatly assisted the research.

I am especially thankful to the teachers from the Rothschild-Weizmann Program for Excellence in Science Education for sharing their thoughts and insights with me, and to the students who took the time to fill the questionnaires. This research would not be possible without their cooperation.

I would like to thank Yetty Veron for her valuable help with the statistical analyses, and the members of the graphic team for their creativeness and good advice.

Finally, I want to thank all my colleagues and friends at the biology group for always listening and willing to help, and for the moral and professional support whenever it was needed. I want to thank my colleagues at the science teaching department for all their assistance.

Most of all I wish to thank my family, and especially my husband, Ziv. You have made all this possible. Thank you for always believing in me, and for encouraging me to pursue my dreams. To my daughters, Yael, Tamar and Noga for your love and support. You fill my life with meaning and joy.

To my father, for all the help.

To my mother, who never questioned my passion for teaching, and encouraged me to follow my heart.

This thesis summarizes my independent research

Table of Contents

1. **Abstract** **10**

2. **Introduction and Rationale** **14**

3. **Theoretical Framework** **18**

3.1 Different perspectives of learning 18

3.2 Reading scientific texts 20

3.2.1 Disciplinary literacy 20
3.2.2 Nature of Science (NOS) - a disciplinary view 22

3.3 The language of scientific texts 24

3.3.1 A functional view of language - Systemic Functional Linguistics 24
3.3.2 Language as a key component of disciplinary literacy 25

3.4 Adapted Primary Literature (APL) 27

3.4.1 APL as an apprenticeship-genre 29

4. **Research goals and questions** **32**

5. **Texts analysis** **34**

5.1 Introduction 34

5.1.1 SFL as a tool for learning about the nature of scientific text genres (registers) 34

5.2 Goals and research questions 40

5.3 Methods 40

5.3.1 Texts selection 40
5.3.2 Systemic Functional Grammar (SFG) 42
5.3.3 Cohesion analysis 51

5.4 Results 54

5.4.1 Systemic Functional Grammar (SFG) analysis of lexicogrammatical items 54
5.4.2 Systemic Functional Grammar (SFG) of process analysis of Edible vaccines articles 63
5.4.3 Cohesion analysis of the Edible vaccines articles 67
5.4.4 Summary and main conclusions from the text analysis 72

6. **Teachers' professional development program** **73**

6.1 Introduction 73

6.2 Goals and research questions 74

6.3 Research context 75

6.4 Course design principles and rationale 75

6.5 Methodology 78

6.5.1 Population 78
6.5.2 Data collection, sampling and data analysis 78

6.6 Results 79

6.6.1 Teachers' development regarding the use of text and NOS 79
6.6.2 Some insights from the professional development program 84
6.6.3 Summary and main conclusions from the teachers' development program 85

7. **Using scientific texts to promote students' epistemological understanding and critical reading skills** **86**

7.1 Introduction 86

7.2 Goals and research questions 87

7.3 Methodology 88
7.3.1 Strategy 88
7.3.2 Population 89
7.3.3 Materials 90
7.3.4 Procedure 91
7.3.5 Data analysis 93
7.4 Results 95
7.4.1 Epistemological understanding of science questionnaire 95
7.4.2 Popular article questionnaire 95
7.4.3 Summary and main conclusions from the two contradictory texts intervention 98
8. Discussion 99
8.1 APL as an apprenticeship-genre 100
8.1.1 The unique linguistic features and semantic relations of the APL article 100
8.1.2 The functionality of the APL language 103
8.2 Towards a disciplinary view of using scientific text 106
8.2.1 Rethinking the use of texts in class 107
8.3 Research implications- taking the language into account 112
8.4 Limitations 114
9. Some practical ideas and future directions 115
9.1 Using texts for learning about the unique features of scientific text genres 115
9.2 Using APL articles for learning about the functionality of language 116
10. References 119
11. Appendices 128

List of Figures

Figure 3.1: The incressing specialization of literacy development (Adapted from Shanahan & Shanahan, 2008)....22

Figure 5.1: The process and the participants in a sample clause, taken from the PSL article (Davoodi-Semiromi et al., 2010) 38

Figure 5.2: "The grammar of experience": a summary of process types in English, adapted from Halliday and Matthiessen (2014). 39

Figure 5.3: Categorization of scientific hedges (Hyland, 1996) 49

Figure 5.4: An example a Material process in clause 5a taken from the PSL article. 50

Figure 5.5: An example of a Mental process in clause 35 taken from the PSL article. 50

Figure 5.6: Examples of Relational processes in clauses 6a and 7a taken from the PSL article....50

Figure 5.7: An example of a Verbal process in clause 34 taken from the PSL article. 50

Figure 5.8: An example of an Existential process in clause 51 taken from the APL article. 50

Figure 5.9: Examples of references to highly technical terms in the PSL and the APL articles....57

Figure 5.10: Comparisson between the lexicogrammatical items; Lexical density, Terms and Nominalizations, in the edible vaccines articles (PSL and APL) and the anthrax article (PSL and APL). 62

Figure 5.11: Comparison between the lexicogrammatical items; passivation and human participation, in the edible vaccines articles (PSL and APL) and the anthrax article (PSL and APL). 63

Figure 5.12: Comparison between the proportion of processes, in the edible vaccines articles (PSL and APL) and the anthrax article (PSL and APL). 66

Figure 5.13: values of unique variables that are considered indexes of cohesion. 68

Figure 6.1: Emerging categories for the teachers' views about their teaching goals when teaching with texts. Categories that emerged at the beginning of the course are marked in white, and categories that were added at the end of the course are marked in grey. 80

Figure 6.2: Emerging categories of teachers' views about teaching the Nature of Science (NOS) .82

Figure 7.1: Changes in students' understanding of the ambiguity, tentativeness, explanatory NOS and argumentative NOS, in the popular articles group (a), and in the APL articles group (b). 95

Figure 7.2: Number of critical questions categorized by the type of criticism, and the total number of critical questions asked by the students in the popular articles group. $*p<.05$ $**p<.001$ 96

Figure 7.3: Number of critical questions categorized by the type of criticism, and the total number of critical questions asked by the students in the APL articles group. $***p<.0001$ 97

Figure 7.4: Comparison between the pre- and post-questionnaire of the popular articles and APL articles groups. *p<.05 97

List of Tables

Table 3.1: A comparison between primary scientific literature (PSL) and adapted primary literature (APL). Shared features are marked in bold. 30

Table 4.1: Summary of research goals and questions 33

Table 5.1: Number of words in sampled paragraphs for each text....42

Table 5.2: Analysis of lexical density in the paragraph taken from the PSL article. Content items are underlined....45

Table 5.3: Analysis of lexical density in the paragraph taken from the popular article. Content items are underlined....45

Table 5.4: Abstraction analysis- nominalizations identified in each of the analyzed paragraphs....46

Table 5.5: Analysis of technicality in the paragraph taken from the PSL article. Technical terms are underlined. 46

Table 5.6: Analysis of technicality in the paragraph taken from the PSL article. Technical terms are underlined. 47

Table 5.7: Analysis of passivation and human participation in clauses taken from the PSL article paragraph. Passivations are underlined....48

Table 5.8: Analysis of passivation and human participation in clauses taken from the popular article paragraph. Passivations are underlined. Human participation is marked in bold. 48

Table 5.9: Statistical analysis of lexicogrammatical features in the three texts (Edible vaccines) ..55

Table 5.10: Examples of the way technical terms appear in each of the three text genres. 56

Table 5.11: Proportion of highly technical, field-specific terms in the three texts 57

Table 5.12: Examples of hedging (bold) in clauses taken from the PSL article. 58

Table 5.13: Examples of hedging (bold) in clauses taken from the APL article....58

Table 5.14: Examples of hedging (bold) in clauses taken from the popular article. 59

Table 5.15: Statistical analysis of lexicogrammatical features in the two texts....60

Table 5.16: Technical term values (variance) in the three text genres....61

Table 5.17: Proportion of highly technical, field-specific terms in the three texts 61

Table 5.18: Examples of hedging (bold) in clauses taken from the Anthrax PSL article. 62

Table 5.19: Examples of hedging (bold) in clauses taken from the Anthrax APL article....62

Table 5.20: The proportion of process types (out of all processes) in the three articles 63

Table 5.21: The proportion of process types in the PSL and APL articles (Edible vaccines)....64

Table 5.22: The proportion of process types (out of all processes) in the two articles 65

Table 5.23: The proportion of process types in the PSL and APL articles (Anthrax)....65

Table 5.24: Coh-Metrix indexes for parallel sections taken from the PSL and the APL articles 67

Table 6.1: Structure of the course “Science literacy”....76

Table 6.2: The professional experience of the six teachers that participated in this study....78

Table 6.3: Distribution of teachers' views about their teaching goals as presented at the beginning of the course 79

Table 7.1: Reliability scores of the epistemological understanding of science questionnaire (post) 90

Table 7.2: Overview of procedures 91

Table 7.3: Examples of the categorization of students' answers to the pre- and post-questionnaires 94

Table 7.4: The distribution of types of criticism in students' answers in the pre- and post-test. 96

Table 8.1: Various attributes characterizing three text genres: PSL, APL and popular articles, following Yarden et al. (2015). New attributes: main purpose and functionality of language[a] 105

Table 8.2: A model for teachers' professional development towards reaching a mastery of teaching disciplinary literacy (following Eylon & Bagno, 2006). 108

Appendices

Appendix 1- APL article: Vaccine – The Next Generation: Development of Genetically Modified Edible Plants Expressing a Combined Vaccine for Cholera and Malaria.

Appendix 2- APL article: Developing an Inhibitor of Anthrax Toxin.

Appendix 3- Full SFG analysis.

Appendix 4- Clause segmentation.

Appendix 5- Coh-Metrix full cohesion analysis.

Appendix 6- Submitted article: Authentic scientific texts in the science classroom: Taking the language into account.

Appendix 7- Elaborated scientific literacy course plan.

Appendix 8- Two contradictory APL articles.

Appendix 9- Two contradictory popular article.

Appendix 10- Epistemological understanding questionnaire.

Appendix 11- Popular article questionnaires.

Appendix 12- Critical questions rubric.

Appendix 13- Book chapter: Using authentic texts to promote disciplinary literacy in biology.

List of abbreviations

APL	Adapted Primary literature
IMRD	Introduction-Methods-Results-Discussion
PD	Professional Development
PSL	Primary Scientific Literature
SFG	Systemic Functional Grammar
SFL	Systemic Functional Linguistics

1. Abstract

The importance of emphasizing the knowledge and abilities possessed by those who create, communicate, and use knowledge within disciplines has been previously recognized. Learning to read scientific texts requires learning about the unique strategies of reading and writing in a specific discipline. Readers need specific skills and knowledge to support their reading in biology in order to read and understand biology texts. Disciplinary literacy refers to the ability to engage in social, semiotic and cognitive practices consistent with those of content expert. Therefore, being literate in science involves more than having knowledge about scientific phenomena, it involves entering into a different way of thinking and explaining the natural world. High school students are expected to read disciplinary texts. Still, there are many challenges involved in meeting the literacy demands in high schools. Many scholars advocate explicit attention to discipline-specific cognitive strategies, language skills, literate practices, and habits of mind, however, many issues remain unclear regarding the learning goals and the suitable reading strategies to implement in the science classroom aimed at promoting disciplinary literacy.

The main goals of this study are: (1) to illuminate the pedagogical affordances of using Adapted Primary Literature (APL) articles as models for learning the scientific language and scientific reasoning and communication, and- (2) to design and examine text-based strategies aimed at promoting teachers and students' disciplinary literacy. Three studies that were carried out using different methodologies, viewing the use of language in various scientific text genres from the perspective of the text, the teachers and the students, compose this study. In the first study a texts analysis focused on lexical, semantic and structural features in the texts is presented. Systemic Functional Grammar (SFG) was used as an analytical tool for the texts' analysis. Lexicogrammatical features and semantic relations of APL articles were compared to those of PSL and popular articles. Findings from the SFG analysis suggest that the adaptation of the APL articles lowers the lexical complexity and increases the readability of the text, making it more readable and probably more suitable for high school students, while at the same time retaining the authenticity of the scientific writing.

In the second study, the design and assessment of a professional development (PD) program for in-service high school biology teachers is presented. The PD main goal was to develop and assess a genre-based grammar approach for promoting disciplinary literacy among high school biology teachers. The cognitive apprenticeship framework and specifically the APL article as an apprenticeship-genre, was applied throughout the course. This PD is a new model for teachers' PD which emphasizes the linguistic, semantic and structural features of different scientific text genres, and focuses on scientific reading and writing skills. Evidence from discourse analysis suggests that teachers expanded their views about the use of texts in their class, and shifted

towards a more disciplinary view for teaching using texts. Specifically, teachers were able to connect the language of science and the epistemology of science to critically assess different scientific text genres, and use the language of science to reflect on their own teaching and on the APL that they adapted during the course.

In the third study, an intervention aimed at promoting students' NOS understanding and critical thinking skills is presented. In this intervention all the students participated in lessons about argument fallacies, and then one group of students read and debated about two popular articles, and a second group of students read and debated about two APL articles. Students were asked to read and criticize a popular article and to answer a NOS questionnaire, prior to the intervention, and following the intervention. It was found that in both the popular group and the APL group the students provided significantly more fallacies in the post-questionnaire compared to the pre-questionnaire. Thus, students' ability to criticize the popular articles significantly improved. In addition, a significant improvement in students' understanding of the argumentative NOS was found in both groups, and a significant improvement in the understanding of tentativeness was found in the APL article group. These results suggest that although engaging with contradictory articles and debating had a significant effect on students' ability to criticize popular articles, the genre of the text may also influence the students' ability to evaluate evidence.

In conclusion, I suggest that APL articles should be used to develop students' disciplinary literacy, as a *tool* for learning its unique features, and the reasoning that is reflected in the way the articles are written.

Based on the results from the three studies I call for a shift to a more disciplinary view of teaching using texts. I argue that to develop students' disciplinary literacy, teachers should teach their students how to read specialized disciplinary texts, and in doing so they must emphasize the specialized linguistic features and their functionality in these texts. I suggest using APL articles as an apprenticeship-genre, for learning scientific reasoning and communication, and to promote teachers' and students' disciplinary literacy.

תקציר

על מנת ליצור, לתקשר ולהשתמש בידע בדיסציפלינה מסוימת חשוב להבין הבנה עמוקה את הידע והמיומנויות של אותה דיסציפלינה. על-מנת לקרוא טקסטים מדעיים, למשל, הקורא צריך להכיר את האסטרטגיות הייחודיות של קריאה וכתיבה בדיסציפלינה המדעית. כלומר, כדי לקרוא ולהבין טקסטים בביולוגיה זקוקים הקוראים למיומנויות ולידע ייחודיים, ידע דיסציפלינארי שיתמוך בתהליך הקריאה של הטקסט. אוריינות דיסציפלינארית מוגדרת כיכולת להשתתף בפרקטיקות חברתיות, לשוניות וקוגניטיביות הייחודיות לאותה דיסציפלינה, ואשר מאפיינות את היכולות שיש למומחים בתחום התוכן הזה. לכן, להיות בעל אוריינות מדעית משמעותו אינה רק להיות בעל ידע על תופעות מדעיות, אלא גם לאמץ דרכי חשיבה ופרשנויות שונות של התופעות המדעיות. תלמידי תיכון מצופים לקרוא טקסטים דיסציפלינאריים שונים, אולם הם נתקלים בקשיים רבים לעמוד בדרישות האורייניות הנדרשות לשם קריאת טקסטים כאלה בתיכון. חוקרים רבים קוראים להוראה מפורשת של אסטרטגיות קוגניטיביות דיסציפלינאריות, מיומנויות שפה ופרקטיקות אורייניות ייחודיות לדיסציפלינה, אולם מטרות הלמידה ואסטרטגיות הקריאה המתאימות לקידום אוריינות דיסציפלינאריות בקרב תלמידי תיכון עדיין אינם ברורים.

מטרות המחקר הן: (1) לשפוך אור על האפשרויות הפדגוגיות הטמונות בשימוש במאמר ראשוני מעובד (Adapted Primary Literature, APL), כמודל לשימוש בשפה המדעית ובדרכי החשיבה והתקשורת המדעית, ו- (2) לפתח ולבחון אסטרטגיות הוראה מבוססות-טקסט שמטרתן לקדם אוריינות דיסציפלינארית בקרב מורי ותלמידי תיכון. במחקר זה מוצגים שלושה מחקרים שבכל אחד מהם נעשה שימוש במתודולוגיות שונות, ובכל אחד מהם קיימת התמקדות בשימוש בשפה המדעית מנקודת המבט של הטקסט עצמו, ומנקודת מבט של המורים והתלמידים העושים שימוש בטקסטים מדעיים מסוגים השונים.

במחקר הראשון נעשה שימוש ב- SFG (Systemic Functional Grammar) ככלי אנליטי. מספר מרכיבים לשוניים וקשרים סמנטיים נותחו במאמרים מעובדים (APL) והושוו למאמרי מחקר מדעיים (Primary Scientific Literature, PSL) ולמאמר מדעי פופולארי, העוסקים באותם נושאים. הממצאים מהניתוח הלשוני של הטקסט מעידים על כך שבתהליך העיבוד של המאמר הראשוני משולבים שינויים המורידים את רמת המורכבות ואת דרגת הקושי של הטקסט, כך שהוא ככל הנראה מותאם ככל האפשר לקריאה על ידי תלמידי תיכון. יחד עם זאת נמצא שנשמרים המרכיבים הלשוניים המאפיינים את השפה המדעית, ובכך נשמרת האותנטיות של הכתיבה המדעית.

במחקר השני מתואר קורס התפתחות מקצועית של מורי ביולוגיה בתיכון. בתיאור מוצג מודל חדש וייחודי להוראת ביולוגיה עם טקסטים, תוך שימת דגש רב על המאפיינים המבניים, הלשוניים והסמנטיים של טקסטים מדעיים בכלל, ושל מאמר מחקר מדעי ראשוני בפרט. עדויות מניתוח השיח במהלך הקורס מצביעות על כך שהמורים הרחיבו את השקפותיהם בנוגע לשימוש בטקסטים מדעיים בכיתה, וכן שעמדותיהם נעו לכיוון של הוראת המרכיבים הדיסציפלינאריים של הטקסט. בתום הקורס יכלו המורים לקשר בין השפה המדעית לאפיסטמולוגיה המדעית, ולהעריך באופן ביקורתי סוגות שונות של טקסטים מדעיים תוך שימוש בשפה המדעית ככלי לרפלקציה על הטקסטים המדעיים, ועל המאמר המעובד שהם עצמם עיבדו במהלך הקורס.

במחקר השלישי מוצגת התערבות שמטרתה לקדם הבנה אפיסטמית של תלמידים וחשיבה ביקורתית של תלמידים בנוגע לטקסטים פופולאריים. במהלך ההתערבות השתתפו תלמידי כיתה י׳ במערך שיעורים שבמהלכו למדו על כשלים של טיעונים מדעיים. לאחר מכן התחלקו התלמידים לשתי קבוצות שאחת מהן קראה שני מאמרים פופולאריים סותרים והשנייה קראה שני מאמרים מעובדים (APL) סותרים. התלמידים התבקשו לענות על שאלון הבוחן הבנה אפיסטמית וכן לתת ביקורת על מאמר פופולארי לפני ואחרי ההתערבות. נמצא שיפור משמעותי של הבנת הטבע הטיעוני של המדע בקרב תלמידי שתי הקבוצות, ובקרב הקבוצה שקראה את המאמרים המעובדים השתפרה גם הבנת הטבע הטנטטיבי של המדע. עוד נמצא כי חל שיפור משמעותי ביכולת התלמידים להעלות ביקורת על הטקסט הפופולארי בשתי הקבוצות. אולם השיפור בקרב תלמידי הקבוצה שקראה את המאמרים המעובדים היה גבוה משמעותית מהשיפור שחל בקרב תלמידי הקבוצה שקראה מאמרים פופולאריים. ממצאים אלה מצביעים על כך שפעילות עם טקסטים סותרים עשויה להשפיע על ההבנה האפיסטמית של תלמידי תיכון וכן על יכולת החשיבה הביקורתית שלהם. יחד עם זאת נראה שגם לסוגת המחקר השפעה על מרכיבים אלה.

בהסתמך על הממצאים משלושת המחקרים הנ״ל, אני טוענת שעל מנת לקדם אוריינות דיסציפלינארית בקרב תלמידי תיכון רצוי ללמד את התלמידים כיצד לקרוא טקסטים דיסציפלינאריים, ולהדגיש במהלך הלמידה את המרכיבים הלשוניים הייחודיים לדיסציפלינה שיש בטקסטים הללו, ואת האופן שבו מאפייני הטקסט משקפים את התפקידים שבעבורם התפתחה שפה זו. אני מציעה להשתמש במאמר המעובד (APL) כסוגה שוליינית על מנת ללמוד אודות דרכי החשיבה והתקשורת המדעית, ולקדם רכישת אוריינות דיסציפלינארית של מורים ותלמידים בתיכון.

2. Introduction and Rationale

Achieving a literate citizenry is a widely accepted goal in science education (National Research Council (NRC), 2012), however the term 'scientific literacy' is used in various ways throughout the literature (DeBoer, 2000; Hurd, 1998; Kyle, 1995a, 1995b; Mayer, 1997; Millar & Osborne, 1998; National Academies of Sciences, Engineering and Medicine [NASEM], 2016; National Research Council (NRC), 2012; Norris & Phillips, 2003; Osborne, 2002). Although there is some debate about what exactly a literate person should know or do, in the last years reading and writing in science has become accepted as one of the practices needed in order to become literate in science (Ford, 2009; National Academies of Sciences, Engineering and Medicine [NASEM], 2016; National Research Council (NRC), 2012; Norris & Phillips, 2003; Phillips & Norris, 2009; Yore, 2000). Norris and Phillips (2003) suggested two distinct meanings to the term 'scientific literacy': the fundamental sense of scientific literacy which includes the ability to read, interpret and write scientific texts, and the derived sense of scientific literacy, which means being knowledgeable in science. The fundamental sense of scientific literacy (Norris & Phillips, 2003) is "the ability of an individual to construct meaning through interaction with the multiple forms of semiotic communication that are used within the discipline of science" (Osborne, 2014, p.188). This type of literacy is central to scientific literacy, since "a person who cannot read and write is severely limited in the depth of scientific knowledge, learning, and education he or she can acquire" (Norris and Phillips, 2003, p. 224). Thus, literacy is not some kind of adjunct to science – it is a "constitutive of science itself" (Norris & Phillips, 2003; Osborne, 2014). Still, reading is often not seen as an important component of science education (Evagorou & Osborne, 2010).

In a recent report by the National Academies of Science, Engineering and Medicine (2016), science literacy is defined as being familiar with the enterprise and practice of science. This includes understandings of scientific processes and practices, familiarity with how science and scientists work, a capacity to weigh and evaluate the products of science, and an ability to engage in civic decisions about the value of science (National Academies of Sciences, Engineering and Medicine [NASEM], 2016). The importance of emphasizing the knowledge and abilities possessed by those who create, communicate, and use knowledge within disciplines has been previously recognized (Braun & Nuckles, 2014; Fang & Schleppegrell, 2008, 2010; Hynd-Shanahan, 2013;

Lemke, 1990; McConachie, 2009; McConachie & Petrosky, 2009; Moje, 2008; Osborne, 2014). This kind of advanced literacy has been termed 'disciplinary literacy' (Shanahan & Shanahan, 2008), and it is concerned with the strategies of reading and writing in a specific discipline. Accordingly, literacy is not a "toolbox" of strategies to improve reading and writing in different content areas, but an essential part of enculturation and socialization into a specific discipline through its specialized discourse (Fang, 2012; Moje, 2008).

Understanding the need to develop students' disciplinary literacy turned the attention in the recent years to the reading that is done in the science class. It was previously shown that reading can provide an authentic context for learning science, and can help students in learning how to analyze, interpret and communicate scientific ideas (Glynn & Muth, 1994). Learning with Primary Scientific Literature (PSL) articles at the university and college level has been shown to have many benefits, including exposing students to the nature of scientific reasoning and communication, and promoting critical reading, analytical skills, and improved attitudes toward the field of science (Janick-Buckner, 1997; Muench, 2000; van Lacum et al., 2012). However, learning through PSL articles is not a simple task for the novice, and it requires adequate adaptation in order to be employed by high school students (Yarden et al., 2001).

Adapted Primary Literature (APL, Falk et al., 2008) refers to an educational genre specifically designed to enable the use of research articles for learning biology in high-school (Yarden, 2009; Yarden et al., 2001). In the adaptation process, the original PSL articles are adapted to match students' knowledge, reading ability and cognitive skills, while retaining the authentic characteristics of the PSL articles and taking into account the practical reasoning involved in producing scientific knowledge when adapting the article (Yarden, 2009; Yarden et al., 2001). The potential of APL as an educational genre was recently recognized in the last K-12 framework for science education (National Research Council (NRC), 2012) which stated that student should "engage in critical reading of primary literature, adapted for classroom use" (National Research Council (NRC), 2012, p.76). It was previously claimed that reading APL articles can help students to improve their understanding of inquiry, active learning and integration of knowledge (Yarden et al., 2009), their understanding of the nature of science and their ability to criticize (Baram-Tsabari & Yarden, 2005), and their level of inquiry thinking and uniqueness (Brill & Yarden, 2003). Yet, research on students' reading skills and text comprehension has found that students find scientific texts difficult to read and comprehend (Baram-Tsabari & Yarden, 2005; Brill et al., 2004; Fang & Coatoam, 2013; Norris & Phillips, 1994; Schleppegrell, 2006; Shanahan, 2004; Wellington & Osborne, 2001). In the last decades numerous tools and approaches were developed to enhance reading comprehension of scientific texts including; strategic behavioral actions (Graesser, 2007), visual representations, summaries and cooperative learning strategies (Shanahan, 2004), using text structure in identifying (Sjostrom & Hare, 1984) and comprehending main ideas (Davey & Miller, 1990), self-questioning strategies, "cognitive coaching strategies" (Paris & Oka, 1989) and more. However, many of these strategies tend to emphasize the teaching of a generalizable set of study skills across content areas for use in subject matter class (i.e., content area reading, Shanahan & Shanahan, 2012). In recent years many scholars call for a shift to disciplinary literacy instruction that would better support the reading of disciplinary texts (Alvermann & Rush, 2004; Biancarosa & Snow, 2004; Fang & Schleppegrell, 2010; Hynd-Shanahan, 2013; Moje, 2008; Osborne, 2014; Pearson et al., 2010). Accordingly, these scholars advocate explicit attention to discipline-specific cognitive strategies, language skills, literate practices, and habits of mind (e.g., ways of reading, writing, viewing, speaking, thinking, reasoning, and critiquing, Fang & Coatoam, 2013; Shanahan & Shanahan, 2008, 2012). Still, many issues remain unclear regarding the learning goals and the suitable reading strategies to implement in the science classroom aimed at promoting disciplinary literacy.

There are two main goals for this study:

(1) to illuminate the pedagogical affordances of using APL articles as models, for learning the scientific language and scientific reasoning and communication.

(2) to design and examine text-based strategies aimed at promoting teachers and students' disciplinary literacy.

The overall research project addressed three broad concerns: (i) can APL articles serve as an apprenticeship-genre? (ii) how can biology teachers be enabled to use APL articles to promote students' disciplinary literacy? and- (iii) what influence do the text genre have on students' disciplinary literacy?

I attempt to address these concerns by reporting on three studies. Accordingly, each of the studies has different research questions that address these concerns as presented on page 32.

First, I present the literature review which is the basis for all the three studies presented in this thesis. Then, more specific theoretical framework, methods and results are presented for each of the three studies in separate sections; The first section addresses the first concern. It is focused on the linguistic features of APL articles and the role of language for construing meaning. The second section addresses the second concern. It is focused on assessing a professional development program for in-service high school biology teachers, with a strong emphasis on the argumentative structure and the language of scientific texts. The third section addresses the third concern, and it is focused on assessing a unique intervention using contradictory articles of different genres, aimed at promoting 10^{th} grade students' disciplinary literacy and critical thinking skills.

Finally, I conclude and discuss the results from each of the three studies, and their shared implications for promoting disciplinary literacy in high school biology education in the discussion section. I also suggest several new teaching strategies for using APL articles to promote students' disciplinary literacy.

3. Theoretical Framework

The theoretical framework of this study is grounded, on the one hand, in studies of scientific text genres and their different communicative aims and social functions (Bazerman, 1988; Myers, 1991; Swales, 2001), and on the other, on the Systemic Functional Linguistic (SFL) framework which views language as a system for construing meaning and grammar as the realization of social context (Halliday, 1978, 2004).

First, I review different perspectives on learning in an attempt to connect the cognitive and socio-cultural perspectives. Then I review literature about reading in general and reading scientific texts in particular, and about the role of language in construing meaning. More specifically, I review the language from a disciplinary point of view, hence, the functionality of language in producing and organizing scientific knowledge. Finally, I present the APL article and some general review of the adaptation process. More specifically I present the APL as an apprentice genre, in light of the literature about scientific text genres and the disciplinary literacy view.

3.1 Different perspectives of learning

There are distinct perspectives in educational theories that derive from different views about knowing and learning. The cognitive perspective on knowledge emphasizes the understanding of concepts, theories, and general cognitive abilities such as reasoning, planning, solving problems, and comprehending language (Greeno, 1996). Accordingly, knowing means having structures of information and processes (i.e., mental representations) that underlie the individual's conceptions and general abilities (Greeno, 1996; Mason, 2007). According to this perspective, learning is a constructive process of conceptual growth, which often involves the reorganization of concepts, and growth of cognitive abilities and metacognitive processes in general (Greeno, 1996).

The socio-cultural perspective views knowledge as distributed among people and their environment, and communities of which they are part (Greeno, 1996). Accordingly, knowing means belonging, participating and communicating, and therefore knowledge is not an entity in the individual's head, but an activity that must be considered in the context in which it takes place (Mason, 2007). Learning according to this view is specific to, and grounded in the situation in which it occurs. It is a process of enculturation into a community which includes participating in the discourse, practice and thinking of that community (Brown et al., 1989; Greeno, 1996; Mason, 2007).

According to the two perspectives described above, concepts and words tend to be considered either in the context of the individual cognitive system of concepts and models, or as words in a context of a social language or discourse. The information-processing view of the cognitive perspective has analyzed reading through the analysis of language abilities, and language is seen as assisting in the construction of thoughts. Research on reading from this perspective has characterized the reading process as a combination of abilities that involves complex interactions between the reader's mind and the text (Holliday et al., 1994; Kintsch & Van Dijk, 1978), and text comprehension as constrained by limitations of the working memory (Kintsch & Van Dijk, 1978). According to the socio-cultural perspective, reading is viewed as a social activity; an action of doing science that is learned by and from the scientific community, and that is communicated through language (Lemke, 1990).

During the last decades the cognitive and the socio-cultural perspectives have both provided important scientific knowledge and understanding about learning. The cognitive perspective provides insights on individual development of concepts and skills, while the socio-cultural perspective provides insights on participating in social practices. However, it is asserted that the cognitive perspective neglects processes of social interaction, and that the socio-cultural perspective accords little importance to individuals (Anderson et al., 2000; Greeno, 1998). A theoretical framework that combines the cognitive and the socio-cultural theories of learning is the social-constructivism theory of learning (Driver et al., 1994).

The social constructivist perspective focuses on the interdependence of social and individual processes in the co-construction of knowledge. Social constructivism includes the idea that there is no objective basis for knowledge claims, because knowledge is always a human construction. The emphasis is on the process of knowledge construction by the social group and the intersubjectivity established through the interactions of the group (Au, 1998). According to this perspective, learning science is both social and personal in nature. In other words, the process of learning science involves being introduced to science as a "way of knowing" by people who are familiar with the ideas, modes of inquiry, standards of argument and ways of communicating that define science, and also the individuals' construction of knowledge, which requires them to make sense of their experiences and to integrate new views with old ones (Sampson et al., 2013). Social constructivists view reading as a social practice.

Accordingly, the social context affects when you read, what you read, where you read, who you read with and, of course, why and how you read (Yang & Wilson, 2006).

3.2 Reading scientific texts

In the first half of the 20th century reading mostly meant pronouncing words correctly. During this period, efforts to promote grade-level reading were based on the theory that instruction that ensures accurate and fluent decoding by the end of 3rd grade will lead to later comprehension and mastery of other reading literacy challenges (for example learning from text, synthesizing information from multiple sources, analyzing text to infer the writer's point of view, critiquing claims and arguments in text) (National Academies of Sciences, Engineering and Medicine [NASEM], 2016). In recent years many scholars have critiqued this approach and argued that it diverts the attention from the robust developments in reading demands that emerge after 3rd grade, and that secondary schooling texts pose new demands and challenges which require students to develop new capacities for coping with these challenges (Fang, 2013; Fang & Coatoam, 2013; Goldman & Snow, 2015; Norris & Phillips, 2003, 2008; Osborne, 2014; Schleppegrell, 2006; Shanahan & Shanahan, 2012). Accordingly, basic literacy skills, such as perceptual and decoding skills, are necessary for all reading tasks, however they cannot be generalized and applied to all texts, especially as one progresses to those of a more specialized disciplinary nature (Shanahan & Shanahan, 2008).

Text comprehension is a complex task that involves many different cognitive skills and processes. To truly comprehend a text, one should go beyond the words and understand the ideas, and the relationships between ideas, conveyed in the text (McNamara, 2007). A deep comprehension of any kind of text requires readers to link ideas coherently, to scrutinize the validity of claims and to understand the motives of the author. A deep comprehension of scientific texts is even more difficult, especially when readers have minimal knowledge of technical terms and other forms of background knowledge to support their reading (Graesser, 2007). Accordingly, reading should not be seen as a linear process but as inquiry and as "an interpretation of the text, which involves the reader's relevant background knowledge" (Norris & Phillips, 2008, p. 249).

3.2.1 Disciplinary literacy

Students engage in more advanced literacy tasks as they move from primary school, to middle school, high school and college. As the tasks evolve, their language is structured in a more condensed and technical way (Schleppegrell, 2004). By middle school, students' decoding skills are expected to be well-developed, allowing for greater differentiation of reading components in the areas of fluency and comprehension (Cirino et al., 2013). According to the recent framework for K-12 science education, by 12th grade students should develop the ability to extract meaning of scientific text, and in high school this practice should be further developed by providing students with more complex text (National Research Council (NRC), 2012). Thus, high school students are expected to read disciplinary texts. Still, there are many challenges involved in meeting the literacy demands in high schools; texts are underused in science classrooms (Wade & Moje, 2001; Wellington & Osborne, 2001), and much focus is given to generalized literacy strategies, resulting in many students that are lacking the disciplinary literacy skills necessary to succeed in secondary schooling (Fang & Schleppegrell, 2010). Research suggests that teachers often resort to showing or telling students about content as an efficient alternative to actively engaging students in making sense of challenging academic texts (Litman et al., 2017)

Biology, as a scientific discipline, is often described as a 'hand-on' activity (Norris et al., 2009a). As a result, many teachers do not pay much attention to text, since they do not perceive the use of text as part of 'doing science'. These teachers lack the knowledge about the vital role that literacy plays in enhancing science learning, and they fail to mentor their students in the necessary literate practices that would help them read in science (Osborne, 2014). For example, many teachers teach content area reading, and wrongly assume that they are teaching disciplinary literacy. Content area reading approach views literacy as "the ability to use reading and writing to learn subject matter in a given discipline" (Shanahan & Shanahan, 2012, p.7). Content area reading teachers view reading tasks as being similar across the disciplines. These teachers emphasize a generalizable set of skills or strategies, which they believe can be used by students when reading any text in any field to help them with comprehension (Shanahan & Shanahan, 2012). As opposed to "content area reading", disciplinary literacy is grounded in the belief that reading (and writing) are integral to disciplinary practices, and that disciplines differ not only in content, but also in the ways this content is produced, communicated and critiqued (Fang, 2012; Shanahan & Shanahan, 2012). In addition, reading is often perceived by students and their teachers as a process of recognizing words and locating information in the text, and difficulties in reading scientific texts are perceived as difficulties to understand the text's vocabulary. It has been claimed that as a result of this "simple view of reading," students have difficulty interpreting and going beyond the literal meaning of what is written (Norris & Phillips, 2003).

The Pyramid presented in Figure 3.1, adapted from Shanahan and Shanahan (2008), illustrates the way literacy progresses from highly generalizable basic skills (basic literacy) to more sophisticated routines and strategies which are not specifically linked to disciplinary specializations (intermediate literacy), and to disciplinary and technical literacy tasks that require students to use more specialized reading routines and language uses, which are less generalizable and more challenging (disciplinary literacy). Thus, to promote disciplinary literacy there is a need to shift instruction into a more discipline-based approach, including the ways in which scientific texts are taught and handled in the science class.

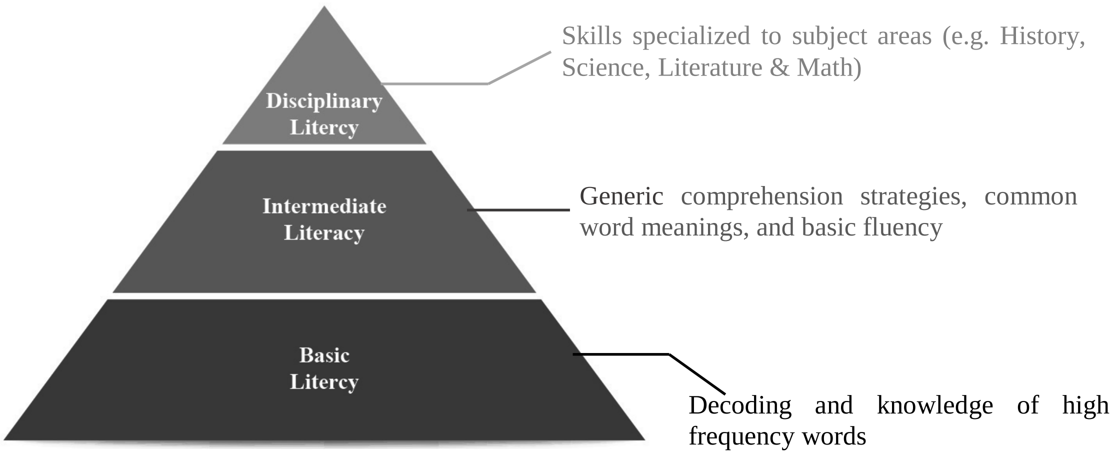

Figure 3.1: The incressing specialization of literacy development (Adapted from Shanahan & Shanahan, 2008)

3.2.2 Nature of Science (NOS) - a disciplinary view

Disciplinary literacy refers to the ability to engage in social, semiotic and cognitive practices consistent with those of content expert. Therefore, being literate in science involves more than having knowledge about scientific phenomena, it involves entering into a different way of thinking and explaining the natural world (Fang, 2012). Namely, being disciplinary literate means becoming socialized into the practices of the scientific community, including its particular purposes, ways of seeing, and ways of supporting its knowledge claims.

The term ‘Nature of Science’ (NOS) refers to values, and underlying assumptions that are intrinsic to scientific knowledge (Schwartz et al., 2004). Although a concise description of NOS is debated among scholars (Schwartz et al., 2004), there is an acceptable level of generality regarding NOS that is accessible for K-12 students (Abd-

El-Khalick et al., 1998). Typically NOS has been referred to as the epistemology of science, science as a way of knowing, or values and beliefs which are inherent to the development of scientific knowledge (Abd-El-Khalick et al., 1998).

Kelly et al. (2012) identified three different conceptualizations of epistemology which influence science learning; (1) the disciplinary view (2) the personal view and (3) the social practices view.

The disciplinary perspective of epistemology considers the role of disciplinary knowledge for science learning. It is concerned with examining issues such as the nature of evidence and the structure of disciplinary knowledge. It is a philosophical view of epistemology focusing on knowledge within practicing scientific communities (Kelly, 2008; Kelly et al., 2012).

The personal perspective of epistemology stems from psychologically-oriented studies of learning, and it is concerned with the ways that individual learners conceptualize knowledge, and how such knowledge influence their learning (Hofer, 2001). This view is focused on personal views of truth, rather than on disciplinary considerations of rationality, truth and justification (Kelly et al., 2012).

The social practices view of epistemology views knowledge as accomplished through social interaction. Thus, according to this view knowledge is neither extant disciplinary entities nor solely personal views. This view examines how, through particular learning events, questions of justification, reasonableness and knowledge claims are negotiated among members of a group. Accordingly it describes the ways that being a member of an epistemic culture locally defines knowledge (Kelly, 2008; Kelly et al., 2012).

Although I acknowledge the importance of personal epistemology for learning, in this study I refer to epistemology from the disciplinary and the social practices views.

The current emphasis on scientific literacy calls for more than the knowledge of concepts and methods in science (Abd-El-Khalick et al., 1998; Schwartz et al., 2004). Despite of that, previous research show that students lack an adequate understanding of NOS (Lederman, 1992; Ryan & Aikenhead, 1992). Even today, current science teaching practices appear to fail in achieving a level of epistemological understanding of science expected of the scientifically literate, with many students holding naïve conceptions about the nature of science (Braun & Nuckles, 2014). It was recently found that PSL articles produced more beneficial epistemological reading outcomes compared to popular articles (Braun & Nuckles, 2014). Thus, the text genre may influence readers' beliefs about science, and their NOS understanding.

3.3 The language of scientific texts

Language is always both natural and cultural, individual and social (Knapp & Watkins, 1994). According to the social-constructivism perspective, language is the most essential system through which humans construct reality, and it is integrally involved with identities and social practices (Gee, 2004). The functional model of language is based on the recognition that language is produced by individuals while the shape and structure of the language is at large socially determined (Knapp & Watkins, 1994). The language functions as a medium of thought, conceptualized from social and communicative points of view (Anderberg et al., 2008; Svensson et al., 2009). The use of language is conceived as a socially-situated activity, and meaning in language is tied to people's experiences in a situated action (Gee, 2001). Language enables experiences to be transformed into meaning, and through this transformation we come to understand the experiential world. The outcome of this transformation is what we call "knowledge" (Fang, 2012). According to Halliday (2004), "understanding and knowing are semiotic processes – processes of the development in the brain of every individual, and the powerhouse of such processes is the grammar" (p.11).

Science is a form of culture, and as such has its own language (Gee, 2001). When asked about the language of science, most people automatically think of technical terms. However, the distinctive quality of scientific language lies in 'the wording' as a whole, and although technical terms are an essential part of the scientific language, they are not the whole story (Halliday, 1993a).

Biology, as a discipline, has its own language, its own ways of thinking and explaining the natural world, and of supporting its knowledge claims. This use of language is mostly apparent in the texts that scientists produce to communicate their findings to other members of their community – the research articles (i.e., PSL articles). As such, scientific texts are not merely tools for storage and transmission of scientific knowledge, they are 'constitutive parts of science', and they are essential vehicles for the expression of scientific thought (Norris & Phillips, 2003).

3.3.1 A functional view of language - Systemic Functional Linguistics

Systemic Functional Linguistics (SFL) is an approach for reasoning grammatically about language. It views language as a system of construing meaning and grammar as the realization of the social context. Language is viewed as a system of options, in which the choice of lexicogrammatical items reflects different social functions

(Halliday, 1993c; Halliday & Matthiessen, 2014). Thus, linguistic choices made by a writer (or speaker) can tell us about his world view, and about the social context. Moreover, the rhetorical and stylistic features of different text-genres and the differences between these features can reflect on their epistemological assumptions and communicative functions (Fang, 2005, 2012; Martin, 1993).

SFL is concerned with texts as the basic unit through which meaning is negotiated. Texts (oral or written), produced in different contexts contain different linguistic features, and realize different social functions (Fang, 2005). Moreover, analysis of discourses using the SFL approach has shown that different text genres, even in the same discipline, include different linguistic features (Fang, 2012; Fang & Schleppegrell, 2010; Myers, 1991; Parkinson, 2001).

The functional model views language from three perspectives (following Knapp & Watkins, 1994); context, text and grammar.

(a) Context: texts are always produced in a context, and although texts are produced by individuals, these individuals are social subjects within a social environment. Thus, texts always relate to the social environment and to other texts.

(b) Text: language is always produced, exchanged or received as text. Thus, language is a system of communication of meaning, organized as cohesive units called texts. Different types of text have distinctive characteristics, depending on what they are aimed to do.

(c) Grammar: grammar is the linguistic resource available to users of a language system for producing texts. A genre-based grammar refers to the manner through which different texts are coded in distinct and recognizable ways. In this sense, knowing the grammar does not mean knowing the correct usage of the language. It means knowing the way the written language functions to communicate experiences and knowledge of the world.

3.3.2 Language as a key component of disciplinary literacy

It is widely recognized that different disciplines have their own jargon. However, it is less recognized that the grammar is also different across disciplines and even across different text-genres in the same discipline (Fang, 2012; Fang & Schleppegrell, 2010; Halliday, 1993a; Myers, 1991; Parkinson, 2001). Disciplines differ in how they generate communicate, evaluate and renovate knowledge (Yore et al., 2004b), and these differences are realized in the way that content experts use language in their social-cognitive practices (Fang & Schleppegrell, 2008). Different scientific text-genres vary in linguistic features and, hence, beliefs about knowledge and knowing they communicate implicitly.

In the PSL articles linguistic features reflect scientists shared beliefs. In contrast to PSL articles, popular articles portray science in ways far removed from these beliefs (Braun & Nuckles, 2014), since PSL articles and popular articles are produced in different social contexts, and have different communicative functions (Goldman & Bisanz, 2002).

Scientific texts (e.g., PSL) have evolved certain grammatical features, figures of speech and rhetorical patterns, which reflect on the scientist' worldview and reasoning (Lemke, 1990; Martin, 1993). The scientific discourse in PSL articles combines theoretical technicality with reasoned argument, each relying on grammar's power of condensing extended meanings in a highly structured and nominalized form (Halliday & Matthiessen, 2014). These features make the reading of PSL articles a challenging task. They contain a high density of information-bearing words, and grammatical processes, such as extended noun phrases, embedded clauses, and nominalizations, that compress complex ideas into a few words (Halliday, 1993b; Osborne, 2014). However, these features are also functional in producing and organizing scientific knowledge, and it embodies a unique world view and reasoning (Martin, 1993). The structure and grammar of PSL articles provide the semiotic means to build arguments throughout the article, reflecting the ways in which scientists do, explain, theorize, organize and challenge science (Fang, 2012; Lemke, 1990; Martin, 1993; Norris & Phillips, 2008; Suppe, 1998; van Lacum et al., 2012).

Popular articles, on the other hand, serve to report new discoveries, which are often not yet accepted by the scientific community. The writers and readers of popular articles are, in most cases, not part of the scientific community, making them "uninvolved observers" (Parkinson & Adendorff, 2004). Accordingly, popular articles share linguistic features that reflect the context and purpose of the genre, focusing on people and what they say or think (Parkinson & Adendorff, 2004).

For students to become scientifically literate, they must, therefore, learn to cope with the specialized language of science (Fang, 2005), and use language in new ways that are specific to the discipline (Osborne, 2002; Schleppegrell, 2004). In this view, learning science is learning the specialized language of science, and understanding the functionality of the linguistic features is crucial to the development of scientific literacy

(Martin, 1993). Thus, a central goal of science education is to help students use the language of science to construct and interpret meaning. Accordingly, one of the science teacher's main objectives is to teach students the 'way of talking' in the scientific discipline, and to explain how to derive the correct meaning from discourse and texts that populate the science classroom (Evagorou & Osborne, 2010; Osborne, 2002).

Several scholars have claimed that one of the major barriers in learning science is learning its language (Lemke, 1990; Martin, 1993; Wellington & Osborne, 2001). Previous studies have shown that specialized academic language in general, and scientific language in particular, pose great challenges for students' comprehension of scientific texts (Fang et al., 2006). In this respect, difficulty in reading scientific texts is often interpreted by readers as a difficulty with the text's vocabulary when, in fact, the difficulty is more likely to lie in the grammar (Halliday, 1993b). Thus, learning to read scientific texts requires learning about the unique strategies of reading and writing in a specific discipline. Readers need specific skills and knowledge to support their reading in biology in order to read and understand biology texts. To shift to more disciplinary reading skills, teachers must understand the role of literacy in the understanding of science concepts and believe in its importance. Teachers should also have a full understanding of the literacy of their own discipline. Biology teachers are content experts, but they often lack the necessary language awareness and literacy strategies to help their students cope with the specific language and literacy demands of the discipline. This is mostly because they were never explicitly taught the ways in which biologists create knowledge, communicate it and critique it. Thus, teachers should have a better understanding of the central role that language plays in their discipline, so they can unpack the implicit understanding of the ways that experts in biology engage in literacy practices (Fang & Coatoam, 2013; Hynd-Shanahan, 2013).

3.4 Adapted Primary Literature (APL)

Reading and analyzing PSL is an authentic scientific cognitive activity, and scientists spend much of their time learning about other scientists' research through reading of research articles (Chinn & Malhotra, 2002). However, reading research articles is not a simple task for the novice. These articles are highly professional and therefore difficult for young students to read and understand. In this respect, popular articles are easier, and were found to raise less negative attitudes toward the reading task compared to students who read a research article (Baram-Tsabari & Yarden, 2005). The language of popular articles does not reflect the language of science as commonly used by scientists. Since students usually do not read PSL articles, they are not usually exposed to the language of science in its normal social function (Wellington & Osborne, 2001). In addition, the texts that students do read in the science class, such as popular articles or textbooks, often do not reflect the core attributes of authentic scientific reasoning, and are antithetical to the epistemology of authentic science (Chinn & Malhotra, 2002).

APL articles refer to an educational genre specifically designed to enable the use of research articles for learning biology in high-school (Yarden, 2009; Yarden et al., 2001). These articles aim to represent science realistically to non-scientists, and to promote important aspects of high school students' scientific literacy that are harder to achieve using textbooks or popular articles.

Research articles are structured in a canonical manner (Yarden, 2009), namely, they follow the Introduction-Methods-Results-Discussion (IMRD) structure. Each sections of the PSL article has a different rhetorical role (Swales, 2001); the Introduction situates the research within already accepted previous work and shows how it is continuous with it, the Methods are shown to match the requirements of quantitative science, the Results try to convince the readers of the validity of the research, and finally, the Discussion tries to convince the readers that the research has an explicatory power. In the process of adaptation of APL articles the canonical structure and the writing style of the article are maintained, while matching the content and the complexity with students' prior knowledge and assumed cognitive abilities (Yarden et al., 2001). The Introduction is modified in order to give the necessary basic background information that was either omitted or quoted in the original paper; Methods are described, however some details are omitted such as amounts, solution compositions, and sometimes methods are omitted as well in order to simplify the research; Results are kept authentic, however if methods were omitted in the Methods section, results derived from these methods are omitted as well. The main figures are kept, with slight modifications; the Discussion about the main ideas are kept and expanded so that students could understand it easily. However, a discussion about findings that were omitted from the results section, or that requires knowledge that the students lack, are omitted; and finally, information and explanations of concepts or technical words that students might not know are added alongside the texts, or in footnotes.

It was previously shown that reading can provide an authentic context for learning science, and can help students in learning how to analyze, interpret and communicate scientific ideas (Glynn & Muth, 1994). Reading APL articles has been found to improve students' understanding of the nature of scientific inquiry, their ability to criticize scientific research, compared to students who read a popular article (Baram-Tsabari & Yarden, 2005; Norris et al., 2012). In addition, following the use of an APL article students' level of inquiry thinking and uniqueness was improved (Brill & Yarden, 2003). APL articles were also found to be useful in promoting students' understanding of scientific and mathematical reasoning and argument, and for introducing modern science into the school (Norris et al., 2009b).

3.4.1 APL as an apprenticeship-genre

3.4.1.1 Cognitive apprenticeship

Theories of situated cognition view learning as enculturation, an act of taking on the behaviors and world view of a culture or knowledge domain that may be achieved through engaging in the authentic activities of the culture (Brown et al., 1989). In other words, learning means to participate in the activities and practices of the community (Lave & Wenger, 1991). The socialization into the community of practice occurs through apprenticeship. A newcomer learns its ways of knowing by participating in the ways of doing that define a community (Brown et al., 1989; Lave & Wenger, 1991).

In cognitive apprenticeship, conceptual and factual knowledge is exemplified and situated in the contexts of its use. Conceptual knowledge thus becomes known in terms of its uses in a variety of contexts. The focus of the learning-through-guided experience is on cognitive and metacognitive, rather than on physical skills and processes. Teaching and learning through cognitive apprenticeship requires making tacit processes visible to learners so they can observe and then practice them. Therefore, apprenticeship methods requires the externalization of processes that are carried out internally (Collins et al., 1988).

According to Lave and Wenger (1991) discourse has an important role in learning. Namely, participating in a community of practice, means learning to talk the way full participants of the community talk. In the apprenticeship model, the purpose is not to learn *from* talk, but to learn *to* talk as part of participation in the community's practices (Lave & Wenger, 1991). Carter et al. (2007) presented the concept "apprenticeship genre" as a genre that can encourage socialization into disciplinary communities.

PSL and APL articles differ in their purpose, target audience and writers, however, they share some characteristics as presented in Table 3.1. PSL articles are written by scientists for other scientists to communicate research findings, while APL articles are written by science educators for students to enable the use of research articles in high school. APL writers modify and adapt an existing PSL text, and these modifications and adaptations which are made in the text should be reflected in the article's language. Nonetheless, since the APL retains the authentic characteristics of PSL such as the IMRD structure and the presentation of science, APL may serve as an apprenticeship genre, and be used for learning the nature of scientific writing, scientific reasoning, use of scientific language, and biological discourse and communication as it is conducted by the scientific community.

Table 3.1: A comparison between primary scientific literature (PSL) and adapted primary literature (APL). Shared features are marked in bold.

	PSL	**APL**
Authors	Scientists (First hand) (Myers, 1989; Yore et al., 2004a)	Science educators and scientists, relying on the original article, and adapting it to student's level (Second hand) (Yarden et al., 2001)
Target audience (readers)	Scientists (The scientific community) (Myers, 1989; Yore et al., 2004a)	Students (A community of science learners) (Yarden et al., 2001)
Structure	**Canonical (IMRD)** (Suppe, 1998; Swales, 2001)	**Canonical (IMRD)** (Baram-Tsabari & Yarden, 2005; Yarden et al., 2001)
Presentation of science	**Uncertain, using evidence to support conclusions** (Suppe, 1998)	**Uncertain, using evidence to support conclusions** (Falk & Yarden, 2009; Yarden et al., 2001)
Authors' purpose	To get claims accepted by the scientific community (Hyland, 1998)	To enable the use of research articles for learning biology in high-school (Yarden et al., 2001)
Author-reader power relations	Readers (i.e. the scientific community) are more powerful than authors. (Myers, 1989).	The writers represent the research community and thus have the authority. Therefor the authors are more powerful than the readers (the students), which are newcomers to the discipline

To conclude, disciplinary literacy refers to the ability to engage in social, semiotic and cognitive practices consistent with those of content expert (Fang, 2012). This view about literacy is grounded in the belief that disciplines differ not only in content, but also in the ways this content is produced and communicated (Fang, 2012; Shanahan & Shanahan, 2012). Knowledge about language lays the foundations of a critical interpretation of scientific texts (Norris & Phillips 1994). Thus, learning the unique linguistic forms and structures that construct and communicate scientific principles, knowledge and beliefs is important for the development of students' disciplinary literacy. Still, in much of science education language is pushed into the background or ignored, while thinking or doing are brought into the foreground as if these tasks had little to do with language (Gee, 2004).

Considering APL as an apprenticeship-genre is somewhat elaborating the definition of Carter et al. (2007) since it enables the instructor to apprentice his/her students into the disciplinary community by learning to talk through analyzing the discourse in the article. Written language learning is facilitated by having those who are more proficient explain their decisions about language use or form to those who are new to the community (Collins et al., 1988). Thus, by using the APL as an apprenticeship genre, the teachers can advance their students and their own awareness of the language of the discipline, and facilitate the enculturation of their students into the scientific discourse community.

4. Research goals and questions

Shifting towards a more disciplinary view for teaching and learning using scientific texts involves, among other things, promoting teachers and students understanding of the structural and linguistic features of the scientific text, and the functionality of these features in producing and organizing scientific knowledge.

Accordingly, there are two main goals for this study:

(1) to illuminate the pedagogical affordances of using APL articles as models, for learning the scientific language and scientific reasoning and communication.

(2) to design and examine text-based strategies aimed at promoting teachers and students' disciplinary literacy.

The first goal of this study is to characterize the linguistic and semantic features of APL articles compared to PSL and popular articles.

The research questions regarding the text analysis are:

- What are the grammatical and semantic features of an APL article compared to a PSL article and a popular article?
- How does the language in the article function in making the text more readable for high school students?

The second goal of this study is to design and examine text-based strategies aimed at promoting teachers' and students' disciplinary literacy. This goal has two parts:

Part I: I developed and taught a science literacy course for in-service biology teachers, aimed at connecting the epistemology of science with research articles.

The research questions regarding the science literacy course are:

- How do the teachers conceive the role of scientific texts in their teaching, and do their conceptions regarding the use of texts develop throughout the course?
- How do teachers conceive their role in developing their students' disciplinary literacy, and do their conceptions develop throughout the professional development program?
- Does the teachers' disciplinary literacy develop throughout the course?

Part II: I developed an intervention using two contradictory texts, aimed at promoting students' epistemological understanding and critical thinking.

The research questions regarding the contradictory texts intervention are:

- Whether and how engaging in an argumentation activity, using two contradictory articles, promotes students' ability to critically asses a popular article?
- Does the genre of the contradictory articles (APL or popular) influence students' ability to critically assess a popular article?
- Whether and how engaging in an argumentation activity, using two contradictory articles promotes epistemology understanding? And does the genre of the contradictory articles (APL or popular) influence such understanding?

A summary of research goals and questions is presented in Table 4.1 below.

Table 4.1: Summary of research goals and questions

Research goals		Research questions
To illuminate the pedagogical affordances of using APL articles as models, for learning the scientific language and scientific reasoning and communication.		a. What are the grammatical and semantic features of an APL article compared to a PSL article and a popular article?
		b. How does the language in the article function in making the text more readable for high school students?
To design and examine text-based strategies aimed at promoting teachers and students' disciplinary literacy.	**Part I:** science literacy course for in-service biology teachers	c. How do the teachers conceive the role of scientific texts in their teaching, and do their conceptions regarding the use of texts develop throughout the course?
		d. How do teachers conceive their role in developing their students' disciplinary literacy, and do their conceptions develop throughout the professional development program?
		e. Does the teachers' disciplinary literacy develop throughout the course?
	Part II: Contradictory-texts intervention for high school students	f. Whether and how engaging in an argumentation activity, using two contradictory articles, promotes students' ability to critically asses a popular article?
		g. Does the genre of the contradictory articles (APL or popular) influence students' ability to critically assess a popular article?
		h. Whether and how engaging in an argumentation activity, using two contradictory articles promotes epistemology understanding? And does the genre of the contradictory articles (APL or popular) influence such understanding?

5. Texts analysis

5.1 Introduction

5.1.1 SFL as a tool for learning about the nature of scientific text genres (registers)

A text is a unit of language in use. It is not a grammatical unit (like the clause), and it is not defined by size. A text is best regarded as a semantic unit; a unit not of form, but of meaning (Halliday & Hasan, 1985). SFL is oriented to the description of language as a resource of meaning, and it is concerned with texts rather than sentences as the basic unit through which meaning is negotiated. Since language is viewed as a meaning-making system, the focus is on the role of grammar in constructing the commonsense interpretation of reality (Martin, 1993).

A register is the constellation of lexical and grammatical features that characterizes particular uses of language. Texts produced for different purposes in different contexts have different features. The register reflects the context of a text's production and at the same time enables the text to realize that context (Schleppegrell, 2002).

Differences between registers are apparent both in the choice of words and in the way that clauses are constructed and linked. The scientific language as a register contains unique lexicon, semantics and structure, which enables the scientists to conduct specialized kinds of cognitive and semiotic work (Fang, 2005; Martin, 1993). Scientific texts can be recognized by the combined effect of several clusters and features and more importantly, by how those clusters and features are related throughout the text. Thus, different text genres in the same discipline are characterized by different linguistic features, and their language varies, as it is used in different contexts for different purposes (Fang et al., 2006; Snow, 2010).

Accordingly, I focused the texts analysis on lexical, semantic and structural features in the texts, as presented in the following sections 5.1.1.1-5.1.1.3. First, I present the linguistic features of scientific texts, and specifically I refer to five key linguistic features of scientific texts (informational density, abstraction, technicality, authoritativeness and hedging). Second, I present six semantic relations that reflect the message of the text (experiential representations, Halliday & Matthiessen, 2014). These relations have a role in building up a world of action, and relationships among entities, and they reflect different experiential representations in the texts, which consist of processes, unfolding though time, and of participants involved in the process in some way. Third, I present the concept of cohesion, and specifically refer to cohesion as a grammatical and semantic feature of texts, which is expressed though grammar and vocabulary, and realized through the lexicogrammatical system.

5.1.1.1 Linguistic features of scientific texts

Analysis of discourse using the SFL approach has shown that the linguistic features of an academic language vary with the discipline. Accordingly, discipline-specific texts are organized linguistically to accomplish particular communicative purposes (Schleppegrell, 2002, 2004). PSL articles (research articles) belong to an authentic genre of communication among scientists, and are mainly used to communicate research findings to the scientific community (Yarden et al., 2001). An examination of more than 1000 data-based PSL articles revealed that articles from different disciplines have a common organizational structure and a variety of speech acts through which authors create an argumentative structure (Suppe, 1998). PSL articles share several key aspects of the grammar of scientific language which make reading them a challenging task; e.g., they have a high density of information, they are highly technical and abstract, and their information is presented in an accurate and objective manner (Fang, 2005; Livnat, 2010b; Schleppegrell, 2002). PSL articles contain many highly specialized words that are specific to the discipline. The high level of technicality in the text is a major obstacle to students' understanding (Fang, 2006). Another challenge is the form of language used to attain conciseness in academic texts, resulting in a high density of information-bearing words, specialized and precise expressions, and grammatical processes that compress complex ideas into a few words (Osborne, 2014).

All of the above features of PSL articles can be summarized into five main linguistic features that characterize scientific texts: (i) informational density, (ii) abstraction, (iii) technicality, (iv) authoritativeness (Fang, 2005) and (v) hedging (Hyland, 1998; Myers, 1989). Mentioning these five features does not imply that they are the only ones that characterize scientific writing. However, these features have been found to pose a great challenge to students' reading abilities and comprehension of scientific texts, where they appear frequently and consistently (Fang, 2005, 2006; Halliday, 1993b; Lemke, 1990; Myers, 1991).

(a) Informational density: PSL articles are characterized by a high density of information, namely the number of lexical words packed in a single clause (Halliday, 1993c). This is partly achieved by the use of longer and more complex noun phrases

(Fang, 2005). Texts that are more lexically dense are considered to be more difficult to read than less lexically dense texts (Halliday, 1993b).

(b) Abstraction: Abstraction is one of the most distinguished features of the PSL article. It is achieved mainly through nominalizations in the text, a grammatical process in which an element having the nature of an action or a process is given a nominal form. In this way, the language reorganizes 'happenings' as if they were 'things', creating a semiotic universe of 'things' that the researcher can observe, measure and experiment with. In scientific discourse grammatical metaphor, a specific type of nominalization is common. In this type of nominalization, one grammatical class (a verb) is substituted by another (noun), while the words remain the same (for example; "the system is responding" vs. "systemic response") (Halliday, 1993b). Nominalizations are challenging for students since much of the semantic information and meaning is hidden in the nominalized words (Fang, 2005), but it is effective in creating a flow of discourse, constantly moving from what has been previously established, to what follows from it next. This is done grammatically by connecting two nominalized groups with a verb saying how the second follows the first . Thus, nominals are functional since they can synthesize or abstract previously presented information into entities, and are therefore effective in developing arguments in the text (Fang, 2005; Schleppegrell, 2004). Moreover, the nominal group is the most powerful resource for creating taxonomies (categories and subcategories), and therefore helps to create technical meaning (Halliday, 2004). Nominalizations are also partly accountable for the informational density of a text, since nominalization allows packing a lot of information in a few words (Schleppegrell, 2004).

(c) Technicality: Technicality is the use of terms or expressions with a specialized field-specific meaning. What makes terms field-specific terms, is the way that they are used by experts in a specific field (Wignell et al., 1993). Namely, when terms are given a field specific meaning, they become technical terms, and they allow establishing a relationship among entities, and constructing classes or categories of entities in the field (Fang, 2005; Wignell et al., 1993). Generally, technical terms are names of objects or phenomena (nouns or adjectives), or verbs describing a unique activity in the discipline. Technical terms can also derive from nominalization and as such, they may function at a somewhat abstract level (Wignell et al., 1993). In disciplinary texts, technical terms have little value in and of themselves. They derive their meaning from being organized into taxonomies (i.e., technical taxonomies), with many layers of organization built into them (Halliday, 1993b). For example, the term “Chloroplast-derived CTB malarial proteins” (Davoodi-Semiromi et al., 2010) has four layers of organization. Taxonomies can become very complicated, and if they are not made explicit, students are left to work them out on themselves (Halliday, 1993b).

(d) Authoritativeness: To convince readers to accept their claims, writers must appear objective, and this is accomplished by making the text as impersonal as possible, by removing the people from it (Hyland, 2002; Parkinson & Adendorff, 2004). Using the passive voice, the actor (the participant performing the action) can be omitted from the clause, allowing the action (and not the actor) to be at the focus of attention. For example, in the following clause, taken from the APL article: “the mice were fed with the genetically modified tobacco plants” there is no actor, and the action (the feeding of mice) is in the focus of attention. For students, this language can seem alienating (Fang, 2005).

(e) Hedging: Hedging is a significant communicative resource and a common feature in PSL articles. It is the rhetorical means of gaining acceptance of claims. It allows writers to anticipate possible opposition to claims by expressing statements with precision and caution (Hyland, 1998). Hedging is an expression of uncertainty concerning the factuality of statements and an indication of the writer’s deference to the readers (Yarden et al., 2015). Hedging can be done by using modal verbs (may, could, etc.) or a modifier (possibly, probably, etc.), or by any other means that suggests alternatives (Myers, 1989).

Popular articles, as opposed to PSL articles, have been found to have fewer nominalizations, less passivation, and to be less informationally dense than PSL articles. They have a non-canonical structure; they present facts with minimum evidence, and are more expository and narrative in nature (Yarden, 2009). The writers of the popular articles distance themselves by treating the propositions in the article as someone else’s claims, and presenting the researchers as “the authority” on which the writers have based their report. Thus, hedging in popular articles is performed mostly to signal the writer’s responsibility for what is being said (Parkinson, 2001). The sources of information in popular articles are the human participants, and objectivity is achieved by reporting the evaluation of authorized experts (Parkinson & Adendorff, 2004).

5.1.1.2 Semantic relations – Experiential representations

Semantic relations reflect the message of the text (experiential representations). Through experiential meaning the writer describes events and things in the external world. From the experiential perspective, the clause as a whole is called a process. Clauses of different process types make distinctive contributions to the construal of experience in the text (See Figure 5.1 for example). The process is represented as being located in, and unfolding through time, and it is realized by a verb (the verbal group in the clause). Nominal groups are referred to as "participants"- they are involved in the process, and prepositional phrase or adverbial groups are referred to as "circumstances" which are associated with the process (Halliday & Matthiessen, 2014).

Clause	we	screened	presence ⁄absence of [antigen-specific] antibodies	in the sera
Group classification	Nominal	Verbal	Nominal	Prepositional phrase
Process analysis	Acting participant	Process	Participant	Circumstances (Place)

Figure 5.1: The process and the participants in a sample clause, taken from the PSL article (Davoodi-Semiromi et al., 2010)

Overall, there are six process types; three major process types, and another three subsidiary process types that are located at each of the boundaries of the major process type (Following Halliday & Matthiessen, 2014, Figure 5.2):

(1) Material processes of happening and doings in the real world.

(2) Mental processes of sensing, thinking and feeling in our conscious and imagination.

(3) Relational processes of classifying and identifying.

(4) Verbal processes of saying (between mental and relational); these are symbolic relationships constructed in human consciousness and enacted in the form of language (like saying and meaning).

(5) Existential processes of existing (between relational and material); phenomena of all kinds are recognized to 'be' – to exist or to happen.

(6) Behavioural processes of acting out of consciousness (between material and mental); represent the outer manifestations of inner workings, the acting out of processes of consciousness such as laughing, and physiological states such as sleeping.

Material, Mental and Relational are the main types of process in the English transitivity system. They are the most frequent types with Material and Relational being significantly more frequent than Mental (Halliday & Matthiessen, 2014).

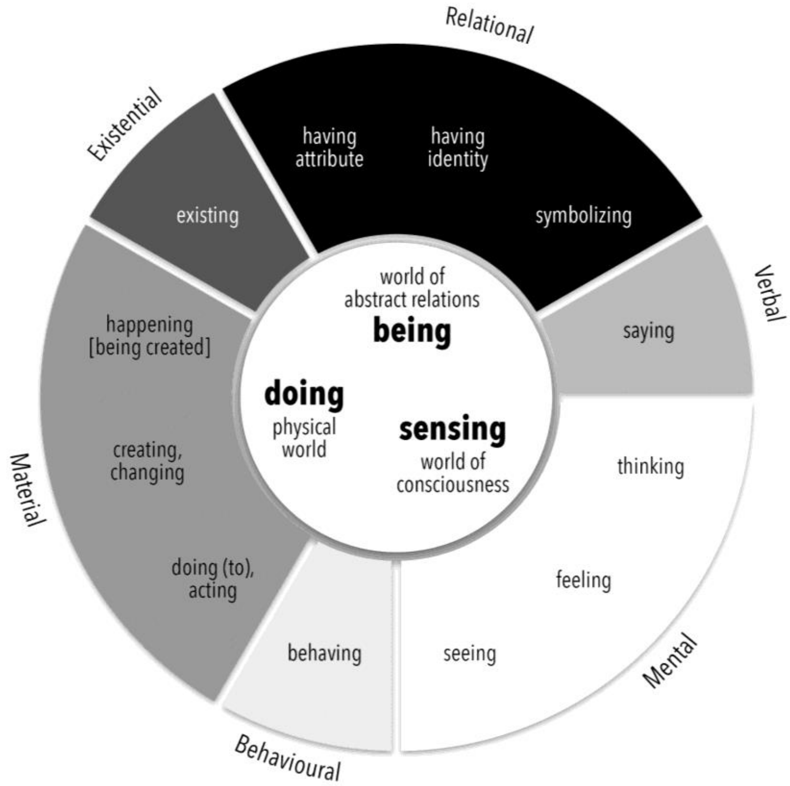

Figure 5.2: "The grammar of experience": a summary of process types in English, adapted from Halliday and Matthiessen (2014).

5.1.1.3 Semantic relations – Cohesion and coherence

Cohesion is the semantic relation between an element in the text, and some other element that is crucial to the interpretation of it. It refers to relations of meaning that exist within the text, and that define it as a text (Halliday & Hasan, 1985). Cohesion occurs where the interpretation of some element in the discourse is dependent on that of another; the one presupposes the other in the sense that it cannot be effectively decoded except by recourse to it (Halliday & Hasan, 1985).

Cohesion is part of the system of a language. Like all component of the semantic system, cohesion is realized through the lexicogrammatical system, and it is expressed partly through the grammar (i.e., grammatical cohesion) and partly through the vocabulary (i.e., lexical cohesion). While conjunction, reference, substitution and ellipsis are cohesive resources within the grammatical zone of lexicogrammar, lexical cohesion operates within the lexical zone and is achieved through the choice of lexical items (Halliday & Hasan, 1985; Halliday & Matthiessen, 2014).

5.2 Goals and research questions

The main goal of this part of my study was to characterize the linguistic and semantic features of APL articles compared to PSL and popular articles.

The selection of language for the APL articles is implicit and was so far performed intuitively by the APL writers. In the adaptation process, the original PSL articles are adapted to match students' knowledge, reading ability and cognitive skills, while retaining the authentic characteristics of the PSL articles and taking into account the practical reasoning involved in producing scientific knowledge when adapting the article (Yarden, 2009; Yarden et al., 2001). Nonetheless, since the APL article is written in a form that can be interpreted by high school students the APL article is somewhat "popularized". The modifications and adaptations made in the text by the APL authors should be reflected in the article's language.

Therefore, my research questions in this part of the study were:

a. What are the grammatical and semantic features of an APL article compared to a PSL article and a popular article?
b. How does the language in the article function in making the text more readable for high school students?

5.3 Methods

5.3.1 Texts selection

5.3.1.1 APL selection

Two APL article were selected for the analysis:

a) Vaccine – The Next Generation: Development of Genetically Modified Edible Plants Expressing a Combined Vaccine for Cholera and Malaria (Zer-Kavod & Yarden, 2013, Appendix 1). This article deals with the production of edible vaccines against cholera and malaria. The article was learned as part of an APL-based curriculum, dealing with cutting edge biological research, and has been incorporated into the biotechnology syllabus for high school biology majors in Israel, as an elective topic (Israeli Ministry of Education, 2011). Since this article was a part of the Israeli syllabus, it was read by scientists, science education researchers and biology teachers, who revised the article and found the paper suitable for students. Therefore, I found the article suitable to be a model for understanding the changes made in the APL article.

b) Developing an Inhibitor of Anthrax Toxin (Baram-Tsabari & Yarden, 2005, Appendix 2). This article deals with a technological achievement, and reports about the design and testing of an Anthrax toxin inhibitor. This article was used in a research study who analyzed students' outcomes of learning after reading the APL article, compared to a popular article (Baram-Tsabari & Yarden, 2005). This article was previously found to contribute to students' ability to raise more scientific criticism of the research work and methodology, and also to suggest more applications of the technology compared to students who read the popular article (Baram-Tsabari & Yarden, 2005).

5.3.1.2 Texts chosen for analysis

The text analysis had two phases, serving two different goals. In the first phase the edible vaccines article was analyzed. Three text genres were chosen for the analysis of the edible vaccines articles: a PSL article (Davoodi-Semiromi et al., 2010), an APL article (Zer-Kavod & Yarden, 2013), and a popular article on the same topic (Guynup, 2000). All three articles dealt with the production of edible vaccines against cholera and malaria. Comparing three versions of the same text, each reporting similar findings to a different target audience for a different purpose, enabled me to fully appreciate the lexicogrammatical differences between the articles.

In the second phase two text genres were chosen for the analysis of the development of inhibitor to Anthrax toxin articles: the PSL article (Mourez et al., 2001) and the APL article (Baram-Tsabari & Yarden, 2005). The goal for the analysis at this phase was to specifically analyze the differences and similarities in the APL articles' language compared to the PSL article. In addition, the analysis was aimed to reveal how two APL articles written years apart (Baram-Tsabari & Yarden, 2005; Zer-Kavod & Yarden, 2013), for different students, by different authors, are different or similar to each other.

The APL articles are written in Hebrew, but the PSL articles and the popular article (about the edible vaccines) were written in English. Since the SFG analysis is based on the English grammar, the APL articles were initially translated to English by a professional translator.

5.3.1.3 Sampling

All articles were carefully read in full, and then two or three paragraphs from each section of the PSL and APL articles were sampled for the analysis. The popular article about the edible vaccines was analyzed as a whole. The total length (number of words) of the analyzed texts was similar for each set of articles, namely, the edible vaccines set and the anthrax set (Table 5.1). Thus, differences in the frequency of lexicogrammatical items that might arise during the analysis could not be due to text length.

Table 5.1: Number of words in sampled paragraphs for each text

	PSL		APL		Popular[a]	
	No. of sampled paragraphs	No. of words	No. of sampled paragraphs	No. of words	No. of sampled paragraphs	No. of words
Edible vaccine texts						
Introduction	2	209	2	229	Full article analyzed	
Methods	2	216	2	183		
Results	2	294	3	197		
Discussion	2	332	2	336		
Total	**8**	**1051**	**9**	**945**		**1134**
% of analyzed text		**~14%[b]**		**~20%[c]**		**100%**
Anthrax texts						
Introduction	2	249	2	221		
Methods	1	159	2	160		
Results	2	191	2	168		
Discussion	1	158	2	163		
Total	**6**	**757**	**8**	**712**		
% of analyzed text		**~30%[a]**		**~39%[b]**		

[a] The popular article is not divided into sections like the PSL and APL articles.
[b] Without figures and references which appear separately from the article's narrative.
[c] Without figures which appear separately from the article's narrative.

It should be noted that reading the whole text enabled us to reflect on the differences between the texts as found in the analysis, and to ensure that they are not only a result of text sampling. For example, in analyzing the terms in the sampled paragraphs, we took into consideration the ways in which these terms appeared and were explained throughout the entire text.

5.3.2 Systemic Functional Grammar (SFG)[1]

Texts were analyzed using the Systemic Functional Grammar (SFG) as an analytical tool which is grounded in the Systemic Functional Linguistics (SFL) framework (Halliday & Matthiessen, 2014). SFG provides an in-depth, systemic comparison of selected lexicogrammatical items in texts, and enables to characterize the grammatical

[1] The SFG analysis including clause segmentation as well as the linguistic analysis of the texts was validated by Prof. Zohar Livnat, Head of the Hebrew and Semitic languages Dept. Bar-Ilan University, Israel.

choices made by the writer of the text, by focusing on selected grammatical and semantic features. In other words, SFG is the way to analyze discourses from an SFL perspective. Previous SFG analysis of discourses has shown that different text genres are composed of different linguistic features. These features can reflect the text's different social functions (Fang, 2005; Fang & Schleppegrell, 2010; Halliday, 1993a; Parkinson, 2001).

One of the most notable dimensions of language is its compositional structure. Language is built of large units that consist of smaller units. Thus, there is a scale of rank in the grammar of every language that can be represented as: clause, phrase, word and morpheme- each consists of one or more units of the rank below, and when linked together they can form word groups in one clause, clause complexes, and eventually the whole text (Halliday & Matthiessen, 2014). Accordingly, texts were analyzed at the word, clauses and the whole text levels, each time highlighting specific linguistic features which characterize the language of science. In the first part of the analysis, the texts were analyzed at the level of words and clauses. In the second part of the analysis, the connection between clauses, paragraphs and sections in the article was analyzed, in order to get a more coherent picture of the text as whole. Texts were analyzed for five features: informational density, abstraction, technicality, authoritativeness and hedging. Texts were scanned and analyzed several times, each time highlighting a specific lexicogrammatical item.

Detailed examples of the analysis are presented in the following sections. For full analysis, see Appendix 3).

5.3.2.1 Clause segmentation

Initially, all texts were segmented into clauses. The clause is the basic unit for analysis in SFG. Minimally, a clause has a verbal group, and one or two nominal groups. It may also have a prepositional phrase (Halliday & Matthiessen, 2014).

When several clauses a linked to one another by some kind of logico-semantic relation they form clauses complexes. Clause boundaries are marked with // for simple clause or with /// for clause complex. Embedded clauses are marked with [[ ]]. Embedded groups are marked with [ ].

Embedded clauses are considered as parts of the nominal group or prepositional phrase in which they are included, and they function as groups in the clause (downgraded). Therefore, embedded clauses are not considered in the total number of clauses in the text, since they are non-ranking clauses and are analyzed as part of the clause and not in their own right.

Clauses and clause-complexes were numbered by using a superscript number at the beginning of each clause. Clauses within the clause complex were added a letter to indicate the number of related clauses in the clause complex. Thus, the number before the following clause indicates that this is the third clause (c) in the first clause complex of the “text:

[1c]//causing severe acute diseases///

Examples of clause segmentation are presented below. For full clause segmentation see Appendix 4.

The following paragraph, taken from the PSL article, is comprised of six clauses:

> [1a]///Mucosal- and gut - associated lymphatic tissues represent unique architecture of the immune system [1b]//and provide a major site of entry for many gastrointestinal, respiratory and urogenital infections, [1c]//causing severe acute diseases///. [2a]///This [compartment of the immune system] constitutes a first line of defense [2b]//by providing [antigen-specific local IgA, systemic antigen-specific immunoglobulins and generation of cytotoxic T cells]///. [3]//Advantages of oral plant-based vaccines have been described previously.//

The following paragraph, taken from the popular article, is comprised of eight clauses:

> [1a]///Scientists began altering potatoes two years later because [1b]//“mice like raw potatoes [1c]//and the turnaround time from seed to potato is relatively short,” [1d]//says Arntzen///. [2]//“Raw is the key”//. [3a]///Many plants could carry antigens, [3b]//but the final vaccine must be produced in fruits or vegetables [[that can be processed and eaten raw]]//. [4]//Cooking breaks down the proteins [[that provoke the needed immune response]]//.

The clause segmentation was validated by a linguistic expert until 100% agreement on the segmentation was reached between the two coders.

5.3.2.2 Analysis of lexicogrammatical items in the texts

The abovementioned linguistic features of scientific writing were analyzed: informational density, abstraction, technicality, authoritativeness (Fang, 2005) and hedging (Hyland, 1998). Each linguistic feature in the text was realized by one or more lexicogrammatical items. The texts were systematically scanned several times; each time, a different lexicogrammatical item was identified and analyzed.

The informational density of each text was analyzed by calculating its lexical density value.

Lexical density is a measure of the density of information in a particular text, and it can be measured as the number of content words per clause (Halliday, 1993b). Texts with high lexical density values are considered to be more difficult to read than those with lower lexical density values (Halliday, 1993b). The lexical density was analyzed by identifying and quantifying all content words (nouns, verbs, adjectives, and some adverbs) in each clause, and calculated by dividing the total number of content words by the number of ranking clauses in each text, following Halliday (1993b). Examples of the lexical density analysis are presented in Table 5.2 and Table 5.3.

Table 5.2: Analysis of lexical density in the paragraph taken from the PSL article (Davoodi- Semiromi et al., 2010). Content items are underlined.

Clause (n=6)		**Content items**
1a	Mucosal- and gut-associated lymphatic tissues represent unique architecture of the immune system	10
1b	and provide a major site of entry for many gastrointestinal, respiratory and urogenital infections	8
1c	causing severe acute diseases	4
2a	This compartment of the immune system constitutes a first line of defense	6
2b	by providing [antigen-specific local IgA, systemic antigen-specific immunoglobulins and generation of cytotoxic T-cells]	12
3	Advantages of oral plant-based vaccines have been described previously	7
Total		**47**
Lexical density (content items/clauses)		**7.83**

Table 5.3: Analysis of lexical density in the paragraph taken from the popular article (Guynup, 2000). Content items are underlined.

Clause (n=8)		**Content items**
1a	Scientists began altering potatoes two years later because	5
1b	mice like raw potatoes	4
1c	and the turnaround time from seed to potato is relatively short	6
1d	says Arntzen	2
2	Raw is the key	2
3a	Many plants could carry antigens	3
3b	but the final vaccine must be produced in fruits or vegetables [[that can be processed and eaten raw]]	8
4	Cooking breaks down the proteins [[that provoke the needed immune response]]	7
Total		**37**
Lexical density (content items/clauses)		**4.63**

Abstraction in the text was analyzed by identifying and quantifying the nominalizations. The level of nominalization was calculated by dividing the total number of nominalized words by the number of ranking clauses in each text. Examples of the nominalization analysis are presented in Table 5.4.

The identification of nominalizations in the texts was validated by a linguistic expert until 100% agreement was reached.

Table 5.4: Abstraction analysis- nominalizations identified in each of the analyzed paragraphs

	PSL article (n=6)	**Popular article (n=8)**
	Entry Infections Defense Generation	Response
No. of nominalizations	**4**	**1**
Level of abstraction (nominalizations/clauses)	**0.67**	**0.13**

Technicality in the texts was analyzed by identifying and quantifying all of the technical terms in each clause. The total number of technical terms and terminological variance (i.e., the number of different technical terms) were quantified. The level of technicality of the texts and the "technical load" (namely the average number of technical terms per clause, and the average number of different technical terms per clause), were calculated by dividing the total number of technical terms by the number of ranking clauses in each text, and by dividing the number of different technical terms by the number of ranking clauses in each text, respectively (Table 5.5).

Table 5.5: Analysis of technicality in the paragraph taken from the PSL article (Davoodi- Semiromi et al., 2010). Technical terms are underlined.

Clause (n=6)		**Terms (total)**	**Terms (variance)**
1a	<u>Mucosal</u>- and <u>gut-associated lymphatic tissues</u> represent unique architecture of the <u>immune system</u>	3	
1b	and provide a major site of entry for many <u>gastrointestinal</u>, <u>respiratory</u> and <u>urogenital infections</u>	3	
1c	causing severe acute diseases	0	
2a	This compartment of the <u>immune system</u> constitutes a <u>first line of defense</u>	2	
2b	by providing [<u>antigen-specific local IgA</u>, <u>systemic antigen-specific immunoglobulins</u> and generation of <u>cytotoxic T-cells</u>]	3	
3	Advantages of <u>oral plant-based vaccines</u> have been described previously	1	
Total		**12**	**11**
Technicality (Technical terms/clauses)		**2.00**	**1.83**

For example, in the paragraph taken form the PSL article there are 12 technical terms in total, but 11 different terms, since the term "immune system" is repeated twice in the paragraph (see Table 5.5).

Next, a bottom-up analytical approach was taken to identify the different types and features of the technical vocabulary in each of the three text genres, by comparing the technical terms appearing in each genre. In addition, field-specific terms were identified and quantified. Terms were classified as highly technical if they were unfamiliar from everyday life or do not appear in the secondary-school biology curriculum. Highly technical terms were identified and quantified. Three out of the 12 technical terms found in the PSL paragraph are highly technical terms (in clause 2b, "antigen-specific local IgA", "systemic antigen-specific immunoglobulins" and "generation of cytotoxic T-cells"). For more examples of technical terms coding see Table 5.6.

This analysis was validated by two other researchers, and the level of agreement between raters reached 95%.

Table 5.6: Analysis of technicality in the paragraph taken from the PSL article (Davoodi- Semiromi et al., 2010). Technical terms are underlined.

Term	Coding
Adjuvant (AJV) mice	Highly technical
Antigen spesific CTB-IgA	Highly technical
Binding site	School
Chloroplast-derived CTB malarial proteins	Highly technical
Cholera	Popular
Cholera toxin (CT)	School
CTB-IgM	Highly technical
Expression (genes)	School
First line of defense	School
Germs	Popular
IL-17A	Highly technical
Immune system	Popular
Lungs	Popular
Operon	School
Protein synthesis	School
Ribosomes	School
Virus	Popular
Vibrio cholerae	Highly technical

Authoritativeness in the text was analyzed by identifying passivation and human participation in the texts. For passivation analysis, clauses were classified as having an active or a passive verb. All clauses displaying a passive action with no "visible" actor, and clauses with acting human participants were identified and then quantified. To analyze human participation, clauses with human actors (the scientists themselves or other scientific authority over the scientific activity) were identified. The level of passivation and the presence of human participants in the texts were calculated as the percent of clauses with a passive activity or a human participant in the text. Analysis of passivation and human participation is presented in Table 5.7 and Table 5.8.

Table 5.7: Analysis of passivation and human participation in clauses taken from the PSL article paragraph (Davoodi- Semiromi et al., 2010). Passivations are underlined.

Clause (n=6)		Passive clause (Yes/No)	Human participation (Yes/No)
1a	Mucosal- and gut-associated lymphatic tissues represent unique architecture of the immune system	No	No
1b	and provide a major site of entry for many gastrointestinal, respiratory and urogenital infections	No	No
1c	causing severe acute diseases	No	No
2a	This compartment of the immune system constitutes a first line of defense	No	No
2b	by providing [antigen-specific local IgA, systemic antigen-specific immunoglobulins and generation of cytotoxic T-cells]	No	No
3	Advantages of oral plant-based vaccines have been described previously	Yes	No
Total		**1**	**0**
% of clauses		**16.7%**	**0.0%**

Table 5.8: Analysis of passivation and human participation in clauses taken from the popular article paragraph (Guynup, 2000). Passivations are underlined. Human participation is marked in bold.

Clause (n=6)		Passive clause (Yes/No)	Human participation (Yes/No)
1a	**Scientists** began altering potatoes two years later because	No	Yes
1b	mice like raw potatoes	No	No
1c	and the turnaround time from seed to potato is relatively short	No	No
1d	**says Arntzen**	No	Yes
2	Raw is the key	No	No
3a	Many plants could carry antigens	No	No
3b	but the final vaccine must be produced in fruits or vegetables [[that can be processed and eaten raw]]	Yes	No
4	Cooking breaks down the proteins [[that provoke the needed immune response]]	No	No
Total		**1**	**2**
% of clauses		**12.5%**	**25%**

The identification of passivation in the texts was validated by a linguistic expert until 100% agreement was reached.

Hedging in the text was analyzed by identifying hedges and categorizing them into different types of hedging, following Hyland (1996) (See Figure 5.3).

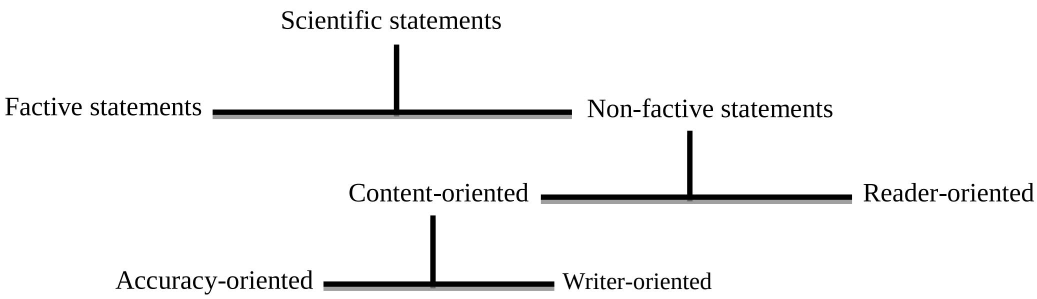

Figure 5.3: Categorization of scientific hedges (Hyland, 1996)

All clauses with hedges were identified and classified as either content-oriented or reader-oriented hedges. Content oriented hedges were further classified as writer-oriented or accuracy-oriented hedges (Hyland, 1996). The hedge type in each text was validated by a linguistic expert and the level of agreement was 100%.

5.3.2.3 Statistical analysis of lexicogrammatical items

A Chi-square test, followed by a Bonferroni post-hoc comparison test were conducted on the quantitative data of the text analyses. Chi-square test showed a highly significant difference between the three text genres. However, it was not clear which text genre contributes most to this difference. Thus, a Bonferroni post-hoc comparison test, which compares two text genres at a time (PSL-APL, APL-popular and PSL popular), was conducted. Since there were three couples, a significant difference was determined if $p<0.016$ ($p<0.05/3$).

5.3.2.4 Types of processes in the text (semantic relations)

For analyzing the semantic relations which reflect the message of the text (experiential representations), processes in the text were identified and classified.

Processes in the text are reflected in the verbal group of the clauses. All clauses were classified according to six process types as presented below (following Halliday & Matthiessen, 2014). There are three major process types (Figure 5.4 - Figure 5.6):

a. Material processes of doing and happening in the real world:

[5a]//*Vibrio cholerae*	**secretes**	a 86-kDa toxin…//
Actor	**Process: Material**	Participant (scope)

Figure 5.4: An example a Material process in clause 5a taken from the PSL article.

b. Mental processes of sensing, thinking and feeling in our conscious and imagination:

[35]//In the current study	we	observed	[high level of] CTB-IgA	only in ORV-CTB mice but not in SQV…//
Circumstances	Senser	**Process: Mental**	Phenomenon	circumstances

Figure 5.5: An example of a Mental process in clause 35 taken from the PSL article.

c. Relational processes of classifying and identifying (being and having).

[6a]//Mucosal- and gut-associated lymphatic tissues	represent	unique architecture of the immune system//
Carrier	**Process: Relational** (Attributive process)	Attribute

[7a]//This compartment of the immune system	constitutes	a first line of defense//
Identified	**Process: Relational** (Identifying process)	Identifier

Figure 5.6: Examples of Relational processes in clauses 6a and 7a taken from the PSL article.

In addition, there are another three subsidiary process types that are located at each of the boundaries of the major process types described above (Figure 5.7 - Figure 5.8):

d. Verbal processes of saying (between mental and relational),

[34]//Many advantages [of oral plant derived vaccines…	were discussed	previously//
Verbiage [with an embedded group]	**Process: Verbal**	circumstances

Figure 5.7: An example of a Verbal process in clause 34 taken from the PSL article.

e. Existential processes of existing (between relational and material).

[51]//[Thus]	there is	a real need to develop a low-cost, multivalent vaccine…//.
	Process: Existential	Existent [with embedded group]

Figure 5.8: An example of an Existential process in clause 51 taken from the APL article.

f. Behavioural processes of acting out of consciousness (between material and mental), such as laughing and sleeping. This process type was not found in any of analyzed texts.

The process analysis was validated by another researcher and the level of agreement between researchers was 70%. It should be noted, that in the first round of validation the second researcher was learning the analysis method. After a long discussion and another round of validation, the level of agreement was 90%, and after another discussion, the level of agreement reached 100%. Each of the process types was quantified, and its proportion in the text (%) calculated for each text genre.

5.3.3 Cohesion analysis

Cohesion is the semantic relation between an element in the text, and some other element that is crucial to the interpretation of it (Halliday & Hasan, 1985). Cohesion is a characteristic of the text, whereas coherence is a characteristic of the reader's mental representation of the text content (Graesser et al., 2004). The main goal of the cohesion analysis was to characterize the different cohesive ties in the PSL and the APL article, in order to understand the contribution of different cohesive ties to the cohesion and coherence of the texts. Comparing the original PSL paragraphs with the APL paragraphs enabled me to evaluate the changes in cohesive ties that were made in the APL article by the APL adaptors.

In general, cohesion analysis was conducted at three organizational levels: cohesion within the paragraphs (between sentences), cohesion between paragraphs, and cohesion between article sections. The analysis organizational level was done by identifying larger segments in the paragraphs (one or more sentences), that have a role in connecting ideas from different paragraphs and also sentences or paragraphs that explicitly make connections between the different sections.

The cohesion analysis had two main phases: first, a quantitative analysis of the linguistic features based on the computational automatic tool: Coh-Metrix (Graesser et al., 2004) was conducted. Second, a qualitative analysis of selected paragraphs was conducted by sampling 1-2 paragraphs from each section of the articles. The qualitative analysis was aimed to deeply understand the changes made in the APL article regarding the cohesion and coherence of the text that cannot be analyzed by the computational tool. In addition, triangulation between the two analyses was aimed to validate the results regarding the texts' cohesion.

5.3.3.1 Unit of analysis

Cohesive relations have in principle nothing to do with sentence boundaries. The location of one element which is connected to another element is not determined by the grammatical structure (Halliday & Hasan, 1976). According to Halliday and Hasan (1976) the cohesive ties between sentences stand out more clearly because they are the only source of texture, whereas within the sentence there are structural relations as well. Also, the expression of the semantic unity of the text lies in the cohesion among the sentences of which it is composed. Therefore, for the qualitative cohesion analysis, sentences (i.e. clause complexes) were chosen to be the unit of analysis. This unit of analysis is also in alignment with the sentence segmentation calculated by Coh-Metrix analysis tool.

5.3.3.2 Computer analysis of text characteristics: Coh-Metrix

Coh-Metrix is an automated linguistics tool that analyzes multiple characteristics and levels of language-discourse of texts (McNamara et al., 2005). The Coh-Metrix tool analyzes texts on over a 100 measures of cohesion, language, and readability. Its modules use lexicons, part-of-speech classifiers, syntactic parsers, templates, corpora, latent semantic analysis, and other components that are widely used in computational linguistics (Graesser et al., 2004). Unlike basic word counting systems, Coh-Metrix relies on more sophisticated methods of natural language processing, such as syntactic parsing and cohesion computation, to capture higher-level language characteristics (Graesser et al., 2014; Graesser et al., 2011; Graesser et al., 2004). Coh-Metrix was previously tested as a measure of cohesion, and was found to successfully distinguish between low- and high-cohesion texts (McNamara et al., 2010). Since Coh-Metrix was found particularly valid for distinguishing between two versions of the same text, I conducted the analysis on parallel paragraphs taken from the PSL and the APL only (for the full analysis see Appendix 5).

It was previously found that there are several unique variables that capture the differences between the high- and low-cohesion by Coh-Metrix, and these are briefly presented below (McNamara et al., 2010):

a. Co-referential (noun, argument and stem) overlap: high cohesion text contains words and ideas that overlap across sentences, and the entire text. These indexes represent the average number of sentences, out of all the sentences in the analyzed text, that have noun, argument and stem overlap from one sentence back to the previous sentence (adjacent) and from one sentence to all sentences in a paragraph (all sentences). Noun overlap occurs when a noun from one sentence overlaps with the same noun in another sentence. Argument overlap occurs when there is overlap between a noun in one sentence and the same noun (in singular or plural form) in another sentence. It also occurs when there are matching personal pronouns between two sentences. Stem overlap occurs when a noun in one sentence is matched with a content word (i.e., nouns, verbs, adjectives, adverbs) in a previous sentence that shares a common lemma (e.g., tree/treed; mouse/mousey; price/priced) (Graesser et al., 2004)

b. LSA (Latent Semantic Analysis) sentence to sentence: LSA (Landauer, 2007) provides measures of semantic overlap between sentences. This index represents how conceptually similar each sentence is to the next sentence. (Graesser et al., 2004)
c. Causal ratio: this index represents the use of connectives in the text. Connectives provide explicit cues to the types of relations between ideas in a text (Halliday & Hasan, 1985). Coh-Metrix provides an incidence score (occurrence per 1000 words) for all connectives. Causal connectives cue the reader that there is a causal connection between two text segments in the text. The causal ratio index represents the ratio of causal particles (may be conjunctions, transitional adverbs, and other forms of connectives) such as since, so that, because, the cause of, and as a consequence, to causal verbs (on the basis of WordNet).(Graesser et al., 2004).
d. Word concreteness: This is an index of how concrete or non-abstract a word is (on the basis of human ratings) (Graesser et al., 2004).
e. Word frequency: this index represents the average word frequency for content words. This is important because word frequency greatly influence text processing and understanding (Graesser et al., 2004; McNamara et al., 2010).

Texts (from the edible vaccines set) were inserted into Coh-Metrix, and all the data from the analysis was saved and transferred to an Excel worksheet for further analysis. In the second phase of the analysis, cohesive relations in sampled paragraphs were qualitatively analyzed.

The quantitative analysis for cohesion may give a general idea about the cohesive ties in a given text. However, some cohesive ties cannot be subjected to an automated analysis since making these connections requires the reader to have some knowledge about various lexical relations. This type of cohesion is a part of the lexical cohesion called collocation. Collocation is considered problematic since it is achieved through the association of items that regularly re-occur (Halliday & Hasan, 1976). Although Coh-Metrix linguistic tool has some aspects of collocation analysis such as LSA, this type of cohesion cannot be conducted with computerized tools alone, since it rests on the readers' knowledge and on a deep understating of the discipline in which the text was written (Myers, 1991).

Articles were carefully read in full, and then parallel paragraphs from the PSL and APL articles (that were previously analyzed by Coh-Metrix) were analyzed. The paragraphs were segmented into sentences. One sentence may have one, or more than one clause, namely a clause complex (Halliday & Matthiessen, 2014).

Cohesion can be expressed partly through grammar and partly through vocabulary (i.e. grammatical cohesion vs. lexical cohesion, Halliday & Hasan, 1976). Since I was specifically interested in lexical cohesion in the text, and more specifically in collocation ties, I narrowed my analysis to lexical cohesion analysis only. Following Myers (1991), I analyzed the connections between lexical items in PSL and APL articles by searching for two or more lexical items that are connected through a lexical cohesive tie (i.e: reiteration or collocation ties). Lexical items that appear in both texts were identified, analyzed, and compared to reveal differences between lexical items connections in the PSL and in the APL article.

5.3.3.3 Statistical analysis of cohesive relations

Effect size (Cohen's d) was calculated for each variable, and then a Kruskal-Wallis test was conducted on each variable chosen for the cohesion analysis. Significance was determined if $p<.05$.

5.4 Results

5.4.1 Systemic Functional Grammar (SFG) analysis of lexicogrammatical items

5.4.1.1 Lexicogrammatical analysis of Edible vaccines articles

Initially, the three texts were segmented into clauses. The popular article was found to have the highest number of clauses (n=126), the PSL article the least (n=70), and the APL article an intermediate number (n=84). The five key linguistic features of scientific writing were analyzed, each realized by one or more lexicogrammatical items: informational density, technicality, abstraction, authoritativeness and hedging (Table 5.9). These results are part of an article, recently submitted (Ariely et al., Appendix 6).

Informational density

A decrease in lexical density values was found going from the PSL, to the APL and to the popular article (8.45, 6.16 and 4.95 respectively, Table 5.9). The PSL was found to be significantly more lexically dense compared to the APL article (p=.0025), and the APL article was found to be significantly more lexically dense than the popular article (p=.0010).

Table 5.9: Statistical analysis of lexicogrammatical features in the three texts (Edible vaccines)

Linguistic features	Lexicogrammatical items		Text genre			χ^2 (2, n = 280) (all texts)	Bonferroni post hoc comparison test[c]		
			PSL (n = 70)	**APL (n = 84)**	**Popular (n = 126)**		**PSL-APL χ^2 (1, n = 154)**	**APL-Popular χ^2 (1, n = 210)**	**PSL-Popular χ^2 (1, n = 196)**
Informational density	Lexical density[a]	Content words	592	518	624	34.857 ***	*p* =.0025	*p* = .0010	*p* < .0001
		Lexical density value	**8.45**	**6.16**	**4.95**				
Abstraction	Nominalizations[a]	Nominalizations	79	63	38	38.211 ***	*p* =.0289	*p* < .0001	*p* < .0001
		Nominalizations per clause	**1.13**	**0.75**	**0.30**				
Technicality	Terms (total)[a]	Number of total terms	192	170	110	67.002 ***	*p* = .1654	*p* < .0001	*p* < .0001
		Terms per clause	**2.74**	**2.02**	**0.87**				
Authoritativeness	Passivation[b]	Clauses with passive verbs	33	24	14	31.522 ***	*p* = .0175	*p* = .0013	*p* < .0001
		% of clauses with passive verbs	**47.1%**	**28.6%**	**11.1%**				
	Human participation[b]	Clauses with human participants	6	6	46	34.841 ***	*p* = .7419	*p* < .0001	*p* < .0001
		% of clauses with human participants	**8.6%**	**7.1%**	**36.5%**				

[a] Kruskal–Wallis test (2, n=280).
[b] Chi-square test (2, n=280), ****p*< .0001.
[c] Light gray cells mark significant difference of *p*< .016, dark gray cells mark significant difference of *p*< .0001.

Abstraction

A decrease in the average number of nominalizations per clause was found, going from the PSL to the APL and to the popular article (1.13, 0.75 and 0.30 respectively, Table 5.9). Although the average number of nominalizations was lower in the APL article than in the PSL article, it was not significantly different (*p*=.0289). The PSL and the APL articles were found to have significantly more nominalizations per clause compared to the popular article (*p*<.0001, Table 5.9).

Technicality

A decrease in the average number of technical terms per clause was found, going from the PSL to the APL and to the popular article (2.74, 2.02 and 0.87 respectively, Table 5.9. Although the average number of terms per clause was lower in the APL article than in the PSL article, it was not significantly different (*p*=.1654). However, the PSL and APL articles were found to have significantly more technical terms per clause compared to the popular article (*p*<.0001, Table 5.9). Analysis of terminological-variance (i.e., the number of different technical terms), revealed a decrease in the number of different terms going from the PSL to the APL and to the popular article (115, 82 and 63, Table 5.9). However, it was found that the text technicality is affected not only by the differences in the number of terms and their variance, but also by the features and changes made to the terms of each text genre. In general, the APL article had simpler terms than the PSL article, having less taxonomies, and the popular article had simpler terms than the APL article. Some terms in the APL article and in the popular article were replacements for those in the PSL article, consisting of more familiar terms (from the syllabus or from everyday life. Some terms were found in the PSL article but not in the APL article or in the popular article, and vice versa (see Table 5.10 for examples).

Table 5.10: Examples of the way technical terms appear in each of the three text genres.

PSL	APL	Popular
Chloroplast-derived CTB malarial proteins*	(Malarial) proteins	Proteins
Systemic antigen-specific immunoglobulins*	(Malarial) Antibodies	Antibodies
Oral plant-derived vaccines	Edible vaccines	Edible vaccines
Plasma membrane receptor	Receptor	-
Spectinomycin resistance*	Antibiotic resistance	-
Spectinomycin*	Antibiotic Spectinomycin*	
-	Intestine	Guts

* Examples of field specific technical terms, classified as highly technical. Other technical terms are classified as either known from the biology curriculum or from everyday life.

In addition, more than half of the technical terms in the PSL article were found to be field-specific, and classified as highly technical. In the APL article 11% of all technical terms were field-specific terms, and the popular article had only one technical term classified as field specific (1.6%, Table 5.11).

Table 5.11: Proportion of highly technical, field-specific terms in the three texts

Text genre	Number of different technical terms (total)	Highly technical terms	
		Number	%
PSL	115	61	53%
APL	82	9	11%
Popular	63	1	1.6%

However, field-specific terms in the APL article and in the popular article were thoroughly explained throughout the text. This was not found to be the case for the field-specific terms in the PSL article, which were not explained at all. For example, in the PSL article, there was no explanation of what spectinomycin is (classified as a highly technical term), or how it is connected to the ribosome. However, in the APL article, there was an explanation for spectinomycin – what it is, how it works, and why it was used in the experiment (Figure 5.9). The same was found be true for the professional research methods. For example, the ELISA method was not explained in the PSL article. However, in the APL article, detailed explanations were provided for each step of the method, including illustrations.

"The native plastid ribosomal operon promoter (Prrn) was used to drive expression of the aadA gene from the GGAG ribosome binding site for spectinomycin resistance." (Results section, PSL article)

"In order to sort the cells in which the transgenic DNA was inserted into their chloroplasts, cells are grown in sterile conditions in the presence of the antibiotics spectinomycin. This antibiotic prevents protein synthesis in the chloroplast by interfering with ribosomes activity". (Methods section, APL article)

Figure 5.9: Examples of references to highly technical terms in the PSL and the APL articles

Authoritativeness

Almost half of the clauses in the PSL article (47.1%) were written in a passive voice. In the APL and the popular articles passivation value was found to be lower (28.6% of and 11.1% respectively, Table 5.9). Although the passivation value found in the APL article was lower than in the PSL article, it was not significantly different (p=.0175). However, a significant difference was found between the passivation values of the PSL and the APL articles compared to the popular article (p=.0013 and p<.0001 respectively, Table 5.9). In addition, both the PSL article and the APL article had a small proportion of clauses with human participation (8.6% and 7.1% respectively), while the popular article had a relatively high proportion of such clauses (36.5%, Table 5.9). No significant difference was found between the proportion of human participation in the APL article and that in the PSL article (p=.7419). However, a highly significant difference was found between the human participation values of the PSL and the APL articles compared to the popular article (p<.0001,Table 5.9).

Hedging

All three text genres were found to have hedging. Moreover, different types of hedging were present in all text genres. In the PSL article, most hedges were found to be content-oriented, in both writer-oriented and accuracy-oriented categories. Some reader-oriented hedges were found in the PSL article as well (Table 5.12).

Table 5.12: Examples of hedging (bold) in clauses taken from the PSL article.

Clause	Hedge type
These data **suggest** that induction of intestinal IgA may require certain components of the gut immune system	Writer oriented
the mortality rate is **estimated** to be 100, 000–150, 000 deaths annually	Accuracy oriented
However, IL-17A **is unlikely** to play a role in this system	Accuracy oriented, reliability hedge
It should be noted that IgA titres repeatedly and reproducibly observed in ORV-CTB mice in this study were much higher than those reported in previous studies	Reader oriented
Our data show that only serum CTB-IgG1 and not -IgG2a, -IgG2b, -IgG3 or -IgM conferred immunity against CT challenge in SQV mice	Reader oriented

In the APL article, most hedges were also found to be content-oriented, with most of these being accuracy-oriented hedges. Reader-oriented hedges were also found in the APL article (Table 5.13).

Table 5.13: Examples of hedging (bold) in clauses taken from the APL article.

Clause	Hedge type
Inserting the genes and integrating them into the plant chloroplast genome **may** serve as a solution to both of these problems	Accuracy oriented, reliability hedge
These results **indicate** [[that exposure to the fusion antigen increased the immune response against each one of the antigens.]]	Reader oriented & Writer oriented
It is likely that in this case the high expression level of the fusion antigen contributed in enhancing the immune response against the two antigens.	Accuracy oriented, reliability hedge
We **suspect** that…	Reader oriented
One of the methods for creating a vaccine with low production cost is creating an edible vaccine…	Reader oriented

A focus on the reader-oriented hedges shows that in the PSL and APL articles, these hedges are aimed to signal the reader as to the personal responsibility of the writers for what is being written. In the popular article, unlike the PSL and APL articles, the content-oriented hedges are all accuracy hedges, and the reader-oriented hedges are aimed at removing the writer's responsibility for what is written, giving full authority to the researcher or to the scientific community (Table 5.14).

Table 5.14: Examples of hedging (bold) in clauses taken from the popular article.

Clause	Hedge type
Although his dream **may** still be a few years away	Accuracy oriented, reliability hedge
according to a study published in the July issue of the Journal of Infectious Diseases	Reader oriented
that kills **approximately** three million infants each year	Accuracy oriented, reliability hedge
WHO **estimates**	Accuracy oriented, reliability hedge & reader oriented
But the **scientists believe**	Reader oriented

Thus, the reader-oriented hedges in the PSL and APL articles have similar goals, but in the popular article, hedges have a different goal. These differences reflect the writer's aim of reporting research findings of others (scientists) to the general public, while not taking personal responsibility for the scientific ideas that are being reported.

5.4.1.2 Lexicogrammatical analysis of Anthrax articles

Initially, the two texts the PSL, and APL articles were segmented into clauses. The APL article was found to have a higher number of clauses (n=61) than the PSL article (n=52). The five key linguistic features of scientific writing were analyzed, as previously described, each realized by one or more lexicogrammatical items: informational density, technicality, abstraction, authoritativeness and hedging (Table 5.15).

<u>Informational density</u>

The lexical density value was found to be higher in the PSL article (p=.056), and lower in the APL article (8.08 and 5.85 respectfully, Table 5.15)

<u>Abstraction</u>

The level of abstraction in the texts was analyzed by calculating the average number of nominalizations per clause. The total number of nominalizations in the text, as well as the average number of nominalizations per clause was found to be higher in the PSL article (0.94), compared to the APL article (0.94 and 0.48 respectively, Table 5.15), but not significantly so (p=.063).

Table 5.15: Statistical analysis of lexicogrammatical features in the two texts

Linguistic features	Lexicogrammatical items		Text genre		χ^2 (1, n = 113)
			PSL (n = 52)	APL (n = 61)	
Informational density	Lexical density[a]	Content words	420	357	*p*=.056
		Lexical density value	**8.08**	**5.85**	
Abstraction	Nominalizations[a]	Nominalizations	49	29	*p*=.063
		Nominalizations per clause	**0.94**	**0.48**	
Technicality	Terms (total)[a]	Number of total terms	187	144	*p*=.009
		Terms per clause	**3.60**	**2.36**	
Authoritativeness	Passivation[b]	Clauses with passive verbs	21	12	*p*=.186
		% of clauses with passive verbs	**34.4%**	**23.1%**	
	Human participation[b]	Clauses with human participants	3	2	*p*=.521
		% of clauses with human participants	**5.8%**	**3.3%**	

[a] Kruskal–Wallis test (1, n = 113).
[b] Chi-square test (2, n = 113).
Gray cells mark significant difference of $p < .05$

Technicality

The technicality of the three texts was calculated as the number of technical terms (total) and as the average number of technical terms per clause (Technical "load"). The PSL article had a significantly higher number of technical terms (*p*=.009), and a higher technical "load" of 3.6 terms per clause on average. The APL article was found to have fewer technical terms and a lower technical "load" of 2.36 terms per clause on average (Table 5.15). In addition, the average number of different technical terms (variance) per clause, in each text, was also calculated. The analysis of terminological variance revealed that the PSL article has a higher number of different technical terms and 2.42 different terms per clause on average, the APL has fewer different terms and 1.05 different terms per clause (Table 5.16).

Table 5.16: Technical term values (variance) in the three text genres

Text genre	N (clauses)	Number of different terms (variance)	Mean terms per clause
PSL	52	126	2.42
APL	61	64	1.05

The analysis of term types revealed that a large proportion of the technical terms in the PSL article were field-specific, and classified as highly technical (53.2%). The APL article had a low proportion of field-specific terms (18.7%, Table 5.17).

Table 5.17: Proportion of highly technical, field-specific terms in the three texts

Text genre	Number of different technical terms	Number of highly technical terms	The level of highly technical terms (%)
PSL	126	67	53.2%
APL	64	12	18.7%

Interestingly, when comparing the technical terms of the PSL article to the technical terms in the APL article, many of the terms are unchanged. It seems that in the adaptation process of this APL article, the number of terms, which was significantly lower in the APL article has contributed mostly to the reduced technical load of the APL article.

<u>Authoritativeness</u>

Authoritativeness in the two texts was analyzed by identifying human participation, and passivation. The PSL article passivation level was found to be higher compared to the APL article (34.4% and 24.1% respectively, Table 5.15) but not significantly so (p=.186). In addition, both the PSL article and the APL article had a small proportion of clauses with human participants (5.8% and 3.3% respectively, Table 5.15). Kruskal-Wallis test revealed that there is no significant difference between the proportion of human participants in the APL article and that in the PSL article (p=.521).

<u>Hedging</u>

Both text genres were found to have hedging. In the PSL article, most hedges were found to be content-oriented, in both writer-oriented and accuracy-oriented categories. Some reader-oriented hedges were found in the APL article as well (Table 5.18 and Table 5.19).

Table 5.18: Examples of hedging (bold) in clauses taken from the Anthrax PSL article.

Clause	Hedge type
The efficacy of PVI in blocking the action of anthrax toxin in vivo **suggests** that it, or another inhibitor developed by a similar approach, could be a useful therapeutic…	Writer oriented
a specific inhibitor of the toxin's action **might prove** a valuable adjunct…	Accuracy oriented, reliability hedge
We hypothesize that the YWWL sequence may bind to PA63 at this site…	Accuracy oriented, reliability hedge

Table 5.19: Examples of hedging (bold) in clauses taken from the Anthrax APL article.

Clause	Hedge type
another inhibitor developed by a similar approach, **may** serve as	Accuracy oriented, reliability hedge
the activity of the anthrax toxin in animal models **suggests**	Writer oriented
It is thus **reasonable to assume…**	Accuracy oriented, reliability hedge
co-injection of the inhibitor in small doses (amounts) **could delay** the onset of symptoms	Reader oriented

5.4.1.3 A comparison of lexicogrammatical items in the "edible vaccines" and "anthrax" articles (PSL vs. APL)

The APL articles of the edible vaccines and anthrax were written by two different researchers for two different student populations. A comparison between the edible vaccine articles and the anthrax articles reveals common features of the PSL articles and in the adaptation of the texts to APL articles. In both PSL articles the lexical density, technicality, nominalizations and passivation were high, and in both APL articles a decrease was found in all analyzed lexicogrammatical features (Figure 5.10 and Figure 5.11).

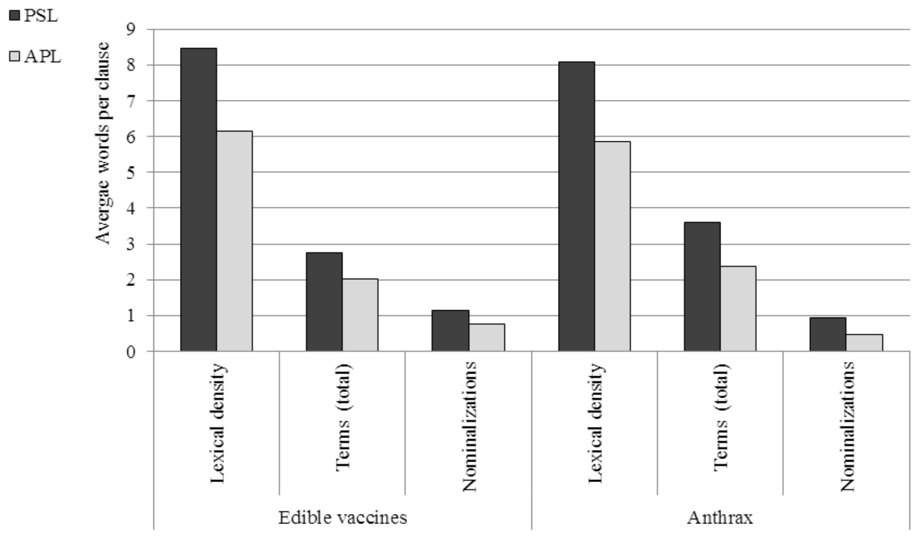

Figure 5.10: Comparisson between the lexicogrammatical items; Lexical density, Terms and Nominalizations, in the edible vaccines articles (PSL and APL) and the anthrax article (PSL and APL).

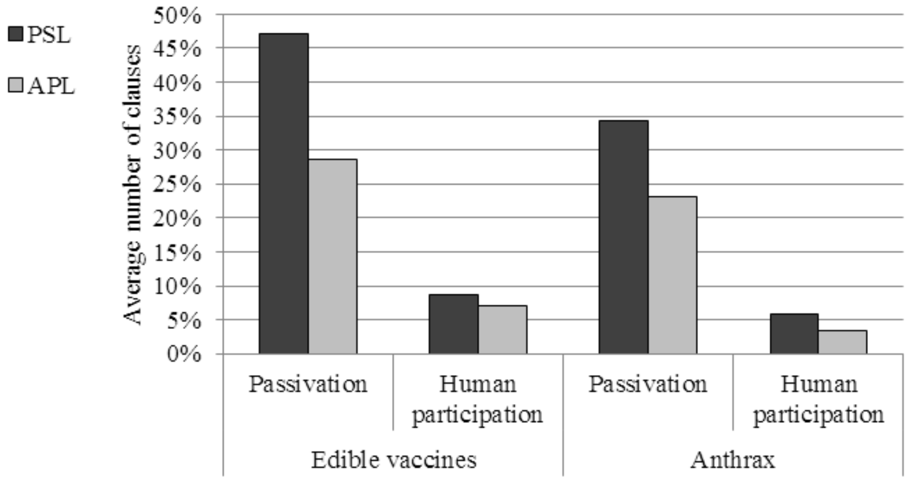

Figure 5.11: Comparison between the lexicogrammatical items; passivation and human participation, in the edible vaccines articles (PSL and APL) and the anthrax article (PSL and APL).

In addition, hedging in the PSL and APL articles was found to have similar goals, which may reflect the APL writer's attempt to preserve the original function of the hedging as presented in the original PSL article, thereby keeping the language and reasoning as authentic as possible. While in the APL article, hedging signals the personal responsibility of the presented data, in the popular article hedging functions to remove personal responsibility from the writers and give full authority to the scientific community.

5.4.2 Systemic Functional Grammar (SFG) of process analysis of Edible vaccines articles

The sampled clauses of the three texts (n=113) were classified according to six processes (Material, Mental, Relational, Verbal, Existential and Behavioural). The proportion of each process was analyzed for each text (Table 5.20).

Table 5.20: The proportion of process types (out of all processes) in the three articles

	PSL	APL	Popular
Material	38.6%	59.0%	62.7%
Mental	11.4%	4.8%	8.7%
Relational	42.9%	32.5%	23.0%
Verbal	4.3%	1.2%	5.6%
Existential	2.9%	2.4%	0.0%
Behavioural	0.0%	0.0%	0.0%

The most common processes in all three texts were found to be Material (actions of doing and happening) and Relational (actions of classifying and identifying). The next most common process was Mental, and the Verbal and Existential processes had very low representation in all the texts. The Behavioural process was not identified at all in any of the texts. A closer look into the processes analysis reveals an increase in the Material processes, and a decrease in the Relational processes when comparing the PSL article to the APL article and to the popular article (Table 5.20).

In addition, the analysis of processes in the different sections of the APL and PSL articles revealed some differences between them (Table 5.21). Differences in the Material processes were found in the Introduction, Results and Discussion sections of the articles. In the introduction section of the APL article there were two times more Material processes. In the Results section almost three times more Material processes and in the discussion almost six times more Material processes. In addition, differences in the Relational processes were found in the Methods and the Results sections. In the Methods section of the APL article there were 15.8% relational processes, but no relational process was found in the Methods section of the PSL article. However almost half (44.4%) of the processes found in the results section of the PSL article were relational, but no relational process was found in the results section of the APL article. Some differences in the Verbal processes were identified in the Introduction, Results and Discussion sections of the articles.

Table 5.21: The proportion of process types in the PSL and APL articles (Edible vaccines)

	Introduction		**Methods**		**Results**		**Discussion**	
	PSL	**APL**	**PSL**	**APL**	**PSL**	**APL**	**PSL**	**APL**
Material	**17.6%**	**35.0%**	94.4%	89.5%	**33.3%**	**84.2%**	**6.3%**	**34.6%**
Mental	5.9%	0.0%	5.6%	0.0%	**22.2%**	**10.5%**	12.5%	7.7%
Relational	64.7%	60.0%	**0.0%**	**15.8%**	**44.4%**	**0.0%**	**68.8%**	**46.2%**
Verbal	**11.8%**	**0.0%**	0.0%	0.0%	0.0%	5.3%	6.3%	0.0%
Existential	5.9%	5.0%	0.0%	0.0%	0.0%	0.0%	6.3%	3.8%
Behavioural	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Three main differences between the APL and the PSL articles were identified. First, there is a difference in the proportion of Material processes in the Introduction, Results and Discussion sections of the APL and the PSL articles. The Introduction and the Discussion sections of the APL article contain more Material processes compared to these sections in the PSL article. Second, there is a difference in the proportion of Relational processes in the Methods section of the APL and the PSL articles. Third, there is a difference in the proportion of Verbal processes in the introduction section of the APL and the PSL article.

5.4.2.1 Process analysis of Anthrax articles

The sampled clauses in the two texts (n=113) were classified according to six processes (Material, Mental, Relational, Verbal, Existential and Behavioural). The proportion of each process was analyzed for each text.

The most common processes in all three texts were found to be Material (actions of doing and happening) and Relational (actions of classifying and identifying). The next most common process was Mental, and the Verbal and Existential processes had very low representation in all the texts. The Behavioural process was not identified at all in any of the texts (Table 5.22).

Table 5.22: The proportion of process types (out of all processes) in the two articles

	PSL	APL
Material	59.6%	78.7%
Mental	3.8%	3.3%
Relational	30.8%	16.4%
Verbal	0.0%	0.0%
Existential	5.8%	1.6%
Behavioural	0.0%	0.0%

A closer look into the processes analysis reveals an increase in the Material processes, and a decrease in the Relational processes when comparing the PSL article to the APL article (Table 5.23). Similar to the edible vaccines articles, here too, similar differences between the APL and the PSL articles were identified.

Table 5.23: The proportion of process types in the PSL and APL articles (Anthrax)

	Introduction		Methods		Results		Discussion	
	PSL	APL	PSL	APL	PSL	APL	PSL	APL
Material	**55%**	**69.2%**	100%	91.7%	73.3%	83.3%	**0.0%**	**81.8%**
Mental	0%	7.7%	0%	0.0%	6.7%	0.0%	12.5%	0.0%
Relational	**35%**	**19.2%**	**0%**	**8.3%**	13.3%	16.7%	**87.5%**	**18.2%**
Verbal	0%	0.0%	0%	0.0%	0.0%	0.0%	0.0%	0.0%
Existential	**10.0%**	**3.8%**	0%	0.0%	6.7%	0.0%	0.0%	0.0%
Behavioural	0.0%	0.0%	0%	0.0%	0.0%	0.0%	0.0%	0.0%

Differences in the Material processes were found mostly in the Introduction and Discussion sections of the article. In the Introduction section of the APL article there were more Material processes, and in the Discussion there were almost no Material processes in the PSL, but in the APL most of the processes were Material (81.8%).

In addition, differences in the Relational processes were found mostly in the Introduction and the Discussion sections. In the Introduction section of the PSL article there were two times more relational processes compared to the APL. In the Discussion section almost all processes of the PSL article (87.5%) were Relational, compared to 18.2% in the APL article. In this article no Verbal or Behavioral processes were found.

5.4.2.2 A comparison of processes in the "edible vaccines" and "anthrax" articles (PSL vs. APL)

The APL articles of the edible vaccines and anthrax were written by two different researchers for two different student populations. A comparison between the edible vaccine articles and the anthrax articles reveals a similar trend in the proportion of processes in the PSL articles compared to the APL articles. In all of the articles analyzed, the most common processes were found to be Material and Relational. The proportions of other processes (Mental, Verbal and Existential) were found to be low in all the articles. Behavioural process was not found in any of the analyzed articles. When comparing the PSL artice to the APL article it was found that in both APL articles the proportion of Material processes is higher, and the proportion of Relational processes is lower, compared to the PSL article (Figure 5.12).

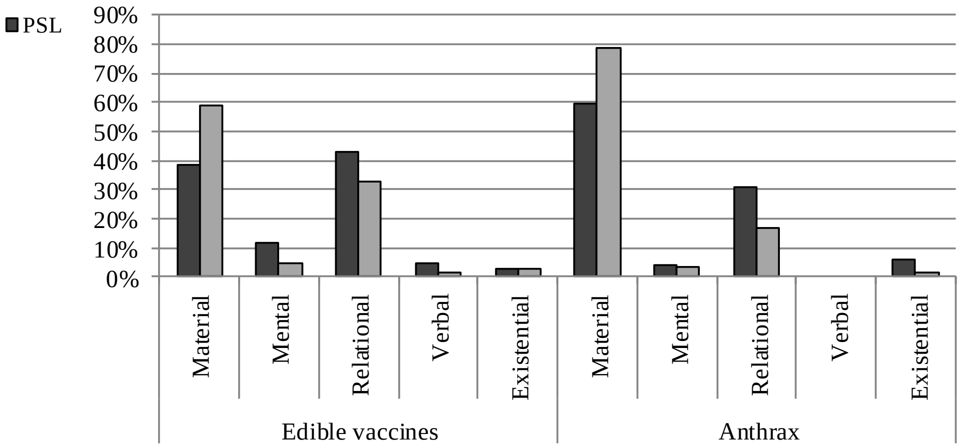

Figure 5.12: Comparison between the proportion of processes, in the edible vaccines articles (PSL and APL) and the anthrax article (PSL and APL).

Three main differences between the APL and the PSL articles were identified. First, a difference was found in the proportion of Material processes in the Introduction, Results and Discussion sections of the APL and the PSL articles. The Introduction and the Discussion sections of the APL article contain more Material processes compared to these sections in the PSL article. In addition, the APL article was found to have a higher proportion of Material processes in the Results section.

Second, a difference was found in the proportion of Relational processes in the Methods section of the APL and the PSL articles.

Third, a difference was found in the proportion of Verbal processes in the introduction section of the APL and the PSL article.

Taken together, the differences in the semantic relations (i.e, processes) can help to understand the changes made in the APL article in the adaptation process, and reflect the different writers' goals, and will be discussed in the discussion of this thesis.

5.4.3 Cohesion analysis of the Edible vaccines articles

In order to get a quantitative assessment of the text cohesiveness, sampled paragraphs from two of the texts were analyzed using Coh-Metrix automated linguistic tool. Parallel paragraphs from the PSL and the APL articles were subjected to the analysis (which consisted ~45% and ~65% of the full articles, respectively). Table 5.24 presents descriptive and cohesion statistics for the PSL and the APL paragraphs.

Table 5.24: Coh-Metrix indexes for parallel sections taken from the PSL and the APL articles

	PSL article (n=11)		APL article (n=11)				
Variable	Mean	(SD)	Mean	(SD)	Diff.[a]	χ^2(1, n = 11)[b]	Effect[c]
Descriptive indexes							
No. of words	321.73	(126.23)	296.18	(110.87)	25.55	0.16	0.22
No. of Sentences (total)	15.91	(5.84)	11.00	(4.1)	4.91	4.35*	0.97
Words per sentence	20.50	(3.82)	26.88	(3.97)	-6.38	8.94**	1.64
Sentences per paragraph	8.32	(2.29)	5.54	(2.27)	2.78	6.28*	1.22
Flesch Reading Ease	31.90	(14.82)	33.94	(7.08)	-2.04	0.05	0.18
Flesch-Kincaid Grade Level	13.90	(2.81)	15.20	(1.91)	-1.30	1.48	0.54
CELEX word frequency	2.77	(0.10)	2.93	(0.08)	-0.16	10.15**	1.77
Content word concreteness	412.03	(42.38)	428.39	(45.01)	-16.36	0.31	0.37
Co-reference indexes							
Noun overlap (adjacent)	0.5	(0.21)	0.85	(0.90)	-0.35	9.61**	0.54
Noun overlap, (all)	0.44	(0.23)	0.72	(0.20)	-0.28	8.39**	1.30
Argument overlap (adjacent)	0.57	(0.23)	0.9	(0.15)	-0.33	8.07**	1.70
Argument overlap (all)	0.50	(0.22)	0.76	(0.19)	-0.26	8.02**	1.26
Stem overlap (adjacent)	0.65	(0.22)	0.89	(0.11)	-0.24	8.26**	1.38
Stem overlap (all)	0.56	(0.20)	0.80	(0.18)	-0.24	6.10*	1.26
LSA indexes							
Adjacent sentences to sentence	0.36	(0.16)	0.48	(0.09)	-0.12	7.43*	0.92
Sentence to text (all sentences)	0.30	(0.12)	0.47	(0.10)	-0.17	9.33**	1.54
Adjacent paragraphs	0.55	(0.30)	0.43	(0.31)	0.12	0.68	0.39
Connective incidences							
Causal	22.41	(12.28)	26.00	(13.41)	-3.59	0.18	0.28
Adversative	12.66	(8.75)	6.40	(5.78)	6.26	3.65	0.84
Additive	52.28	(18.05)	30.95	(14.60)	21.33	7.61*	1.30
Temporal	14.17	(13.54)	10.61	(6.64)	3.56	0.004	0.33
Causal index							
Causal ratio	0.20	(0.20)	0.34	(0.32)	0.12	0.68	0.52

[a] Diff. = the difference between the PSL paragraphs (mean) and the APL paragraphs (mean).
[b] Kruskal-Wallis test, *p<.05, **p<.005
[c] Effect = effect size using Cohen's d.

These statistics shows that although the number of words (total) is not significantly different, the paragraphs taken from the APL article were significantly shorter and had less sentences ($p<.05$). Regarding cohesion indexes, the APL article was found to have significantly more co-references of all types (noun, argument and stem; $p<.005$). In addition, the APL article was found to have higher values in LSA indexes (semantic overlap) between adjacent sentences ($p<.005$) and in all the text ($p<.05$), but not between paragraphs.

When analyzing the connective incidences, it was found that the causal and temporal and adversative connectives values in the APL article are not significantly different, however the additive connectives were found to be significantly lower in the APL article compared to the PSL article ($p=0.05$). The causal ratio (casual particles to causal verbs ratio) was found to be higher in the APL article, however not significantly so.

5.4.3.1 Combined factors to assess cohesion in texts

It was previously found that there are three unique variables; co-reference (specifically noun overlap), LSA and causal ratio, that can be considered direct indexes of cohesion (McNamara et al., 2010). The summary of these three factors is presented in Figure 5.13. As shown in Figure 5.13, the APL was found to have significantly higher values of co-referential noun overlap ($p<.005$), and LSA ($p<.05$), and also a higher value of causal ratio, meaning that there are more causality ties in the APL article, but not significantly so.

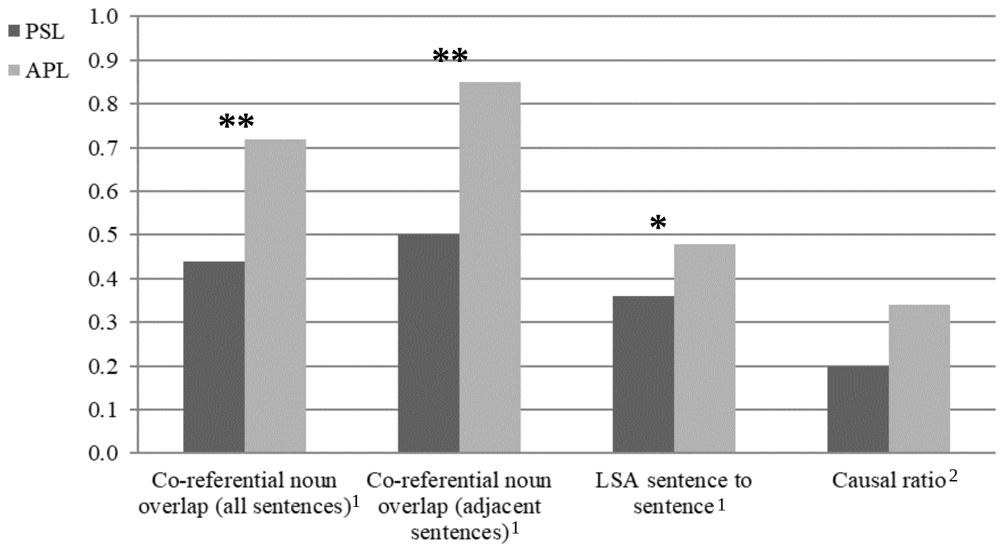

Figure 5.13: values of unique variables that are considered indexes of cohesion.

1- Number of sentences out of all sentences

2- Causal particles to causal verbs ratio

5.4.3.2 Qualitative analysis of cohesion in the texts

Following Myers (1991), I focused the qualitative analysis on the connection between lexical items in PSL and APL articles. For this analysis I re-read the articles and searched for two or more lexical items that are connected through a lexical cohesive tie (i.e. reiteration or collocation ties). I specifically searched for lexical items that appear in both texts, in order to analyze the differences between them.

I found that in the APL article, some relations between lexical items are introduced explicitly, by adding information or defining specialized terms. This was done in the text itself, or in footnotes. For example, in the following sentences taken from the Introduction section of the PSL article, the lexical items 'cholera disease' and 'Vibrio cholerea' are connected, and 'Malaria disease' and Plasmodium falciparum are connected in a collocation cohesive tie.

> "Cholera is one among the top three diseases listed by the World Health Organization… […]. Vibrio cholerae secretes an 86-kDa toxin that is made up of two subunits…"
> "Malaria is also a devastating global health problem in tropical and subtropical areas of over 100 countries. Plasmodium falciparum is the most virulent species with approximately 500 million cases, 1 million deaths annually … […]

However, in order to understand how they are connected one needs to have some knowledge. Vibrio cholerae is in fact the bacteria causing the cholera disease. Moreover, a specialist reader will automatically realize that Vibrio cholerae is written in italics, and that this is the proper way to write the organisms' taxonomic names in science. Hence, Vibrio cholerae is the name of the cholera causing bacteria.

In the APL article the connection between these lexical items is specifically stated (marked in bold):

> "Cholera is a severe infectious disease, claiming 100,000-150,000 victims worldwide every year. **The disease is caused by the bacteria Vibrio cholera**…"
> "Malaria is a severe infectious disease as well… […] **Malaria is caused by the single-cell parasite called Plasmodium**, which is carried in the saliva of the female Anopheles mosquito…"

By adding this information, the APL adaptors connected the two lexical items and thus the connection between them is apparent, making the text more coherent for non-specialist readers.

Another example taken from the Introduction section is the connection between the lexical items: MSP1, erythrocytes and blood. MSP1 and erythrocytes are connected in a collocation tie, while erythrocytes and blood are connected in a meronymy cohesive tie (erythrocytes are blood components). In order to understand this paragraph one must know that the Plasmodium falciparum is a parasite that penetrates the red blood cells (erythrocytes), and gradually destroys them as part of its reproductive cycle. One must also know the mechanism of infection in order to relate MSP1 to the parasite infection mechanism. These connections are clear for experts (i.e. the scientists in the field of research) and therefore are not made explicit in the PSL article:

> "Currently, there is no licensed vaccine for prevention of malaria. Current clinical trials are under way investigating several blood-stage candidates such as apical membrane antigen-1 (AMA1), merozoite surface protein-1 (MSP1) and erythrocyte surface antigen..."

However, this information is added in the APL article (marked in bold):

> "Malaria is caused by the single-cell parasite called Plasmodium, which is carried in the saliva of the female Anopheles mosquito. **The parasite enters the human body when bitten, then into the red blood cells, reproduces inside them, is released into the bloodstream and then the cells rupture, and the cycle repeats. The MSP1 protein (Merozoite Surface Protein-1) is found on the surface of the parasite's cell membrane and is apparently necessary for the penetration of the parasite into the red blood cells**…"

It should be noted, that "the parasite" in the second sentence is a reference tie (grammatical cohesion) to the previously mentioned 'Plasmodium', which connects the two sentences dealing with Plasmodium and its infection mechanism.

Adding information to connect between lexical items or ideas in the text was also found in the Methods section. For example, in the PSL article there is no explanation about collecting and measuring intestinal water retention for assessing the mice's response to cholera toxin:

> "…mice were challenged with a CT dose of 1.5 lg⁄g of body weight. The mice remained in their cages without food but water ad libitum. The mice were scarified after 14 h and intestinal water retention was collected and measured…"

The connection between cholera toxin and intestinal water retention is apparent to scientists that read this article, but not to non-specialist readers. This connection is made explicit in the APL article (marked in bold):

> **"One of the symptoms of cholera is fluid secretion into the intestine of the infected host. Therefore, measuring the volume of water in the mice intestines serves as an indicator for cholera.** Following exposure to the cholera toxin, the two mouse groups (mice fed with modified and unmodified tobacco plants) received a limitless supply of water, but did not receive food, for 14 hours. Then water was collected from the mice intestines and the water volume was measured…"

Sometimes the word is not defined, but it is marked as a new term, and thereafter it can be used in the text even though readers may not know where the name comes from. For example, the terms 'immunological carrier' and 'biolistic bombardment' in the APL article:

> "…One of the known strategies for attempting to enhance the amount of generated antibodies, is connecting the antigen to an **immunological carrier** which participates in triggering an immune response. However, past efforts to connect a malaria antigen to various immunological carriers did not succeed in raising the immune response level to the antigen…"
>
> "Insertion of the modified DNA into the chloroplast of tobacco and lettuce plants in performed using "**biolistic bombardment**". Biolistcs is used to deliver DNA into the cells of plants using a device called a Gene Gun…"

Sometimes unexplained terms in the text are explained in footnotes, and therefore provide the non-specialist readers with more background information.

Another type of information that is added to the APL article is unique to this text genre, is the detailed explanations of research methods. In the PSL article some methods are not explained, such as ELISA or cloning. However, these methods are thoroughly explained in the APL article, therefore readers can understand the results presented in the articles, and also assess the validity and reliability of the methods used in the experiments presented in the article.

Numerous examples of repetitions in the article were found in the PSL and also the APL article. These repetitions of lexical items (within or between paragraphs) and of sentences and ideas (between paragraphs and sections in the article) were found to be present in both articles. For example, in the Discussion section of the PSL article the opening paragraph is repetitions of ideas previously presented in the Introduction. In the Results section there is some repetition of methods, mainly due to the article's structure in which the experimental procedures are at the end of the article (marked in bold):

> "**To examine functionality of antibody generated in immunized mice against Plasmodium, parasite inhibition assays evaluated the ability of anti-MSP1 antibodies in inhibiting parasite entry into erythrocytes.** We found that the ring stage was the predominant stage of the parasite under microscopic examination..."

However this was not the case for all paragraphs, and the repetition was minimal.

In the APL article, each paragraph in the Results section begins with several sentences repeating the method, in order to connect the relevant method to the results presented in the paragraph (marked in bold):

> **"In order to check whether the antibodies generated in the immunized mice are effective against the Plasmodium parasite, we tested the ability of the antibodies to inhibit the penetration of the parasite into red blood cells. In these experiments human red blood cells were incubated with the parasite and with serum (containing the**

antibodies) from the mice that were fed genetically modified plants (after 10 feedings) or from a number of control groups (Table 1). We found that the antibodies generated in the immunized mice inhibited the penetration of the parasite into the red blood cells in a similar efficacy to that of commercial specific anti-MSP1 antibodies (97.2% and 100%, respectively)…"

5.4.4 Summary and main conclusions from the text analysis

- The analysis of the lexicogrammatical features of an APL article compared to those of PSL and popular articles suggest that the adaptation of the APL article lowers the lexical complexity and increases the readability of the text, making it more readable and probably more suitable for high school students, while at the same time retaining the authenticity of the scientific writing.
- The differences in the semantic relations (i.e, processes) can help to understand the changes made in the APL article in the adaptation process, and reflect the different writers' goals. For example, more Material processes (actions of "doing" and "happenings") in the APL article may reflect the authors aim at making the text less abstract. Repetitions in the APL article also influence the proportion of processes in the text. These repetitions may indicate the authors' goal of making the text more coherent. In addition, an increase in Relational processes in the Methods section of the APL article is characterized by explanations which connect the methods and the results. These explanations help to characterize and identify the stages of the methodological procedure, and are thus realized mainly by Relational processes.
- The cohesion analysis shows that the APL article analyzed in this study is more cohesive and therefore may suggest that the APL article may be more coherent for high school students than the PSL article.

6. Teachers' professional development program

6.1 Introduction

Teacher professional learning is of increasing interest as one way to support the increasingly complex skills students need to learn in preparation for further education and work in the 21st century. Effective professional development (PD) is needed to help teachers learn and refine the pedagogies required to teach these skills (Darling-Hammond et al., 2017).

Developing disciplinary literacy means learning more sophisticated but less generalizable skills and routines. However, by the time adolescent students are being challenged with disciplinary texts, literacy instruction has evaporated altogether or has degenerated into reiteration of general reading strategies (Shanahan & Shanahan, 2008). Indeed, many teachers see texts as no more than a different teaching resource for teaching content knowledge, or as a tool aimed to promote students' intermediate literacy skills (Fang & Schleppegrell, 2008; Shanahan & Shanahan, 2008).

High school science teachers know the content of their disciplines, but they may know only implicitly its literate processes. Teacher candidates take courses in their discipline, but they may not take courses that teach them how experts create knowledge, communicate it and critique it. As a result, many teachers lack a full understanding of the literacy of their own discipline. To teach the literacy of the discipline teachers need to understand it at another level, and break down what has become automatic, into steps or processes that can be explicitly taught (Hynd-Shanahan, 2013). Recognizing the role of language in construing knowledge and value can enable teachers to help students recognize the specialized patterns of language in the texts they read (Fang & Schleppegrell, 2010). This includes the ideas that PSL articles can represent authentic scientific epistemology through their language (Fang, 2005; Halliday, 2004; Parkinson, 2001) and through their structure (Suppe, 1998); that different text genres in the same discipline can reflect different purposes and a different epistemology (Parkinson, 2001); and that different disciplines have different criteria to assess reliability and to accept what counts as evidence (Fang, 2012; Shanahan & Shanahan, 2012).

To optimize classroom learning around the epistemology of scientific texts, teachers need a sophisticated understanding of the nature of scientific texts (and of non-scientific texts), as well as how they are used authentically by the scientific community. Functional language analysis recognized that disciplinary texts are constructed in patterns of language, and offers teachers a set of practical tools for engaging students in systematically analyzing the language patterns and discussing the meanings of these patterns in disciplinary texts (Fang, 2012). Thus, to promote their students' disciplinary literacy teachers should be knowledgeable of both disciplinary content and disciplinary language, since it is through participation in discipline specific practices (such as reading, writing, talking, etc.) that disciplinary knowledge is used, shared, critiqued, refined and expanded (Fang, 2012).

Based on these assumptions I developed a professional development program for in-service high school teachers. This PD is a new model for teachers' PD which emphasizes the linguistic, semantic and structural features of different scientific text genres, and on scientific reading and writing skills.

6.2 Goals and research questions

The goal of the teachers' course, that was developed in the course of this part of my study, was to develop and assess a genre-based grammar approach for promoting disciplinary literacy among high school biology teachers. I chose to apply the cognitive apprenticeship framework in general, and specifically the APL article as an apprenticeship-genre.

I hypothesized that reading and analyzing scientific texts, and eventually writing an APL article are 'ways of doing' by which teachers can participate and learn about the 'ways of knowing' in the scientific community (i.e. promoting their disciplinary literacy). I also hypothesized that this enculturation will enable teachers to use scientific texts to promote their students' disciplinary literacy.

My research questions in this part of my study were:

a. How do the teachers conceive the role of scientific texts in their teaching, and do their conceptions regarding the use of texts develop throughout PD?
b. How does the teachers' disciplinary literacy develop throughout the professional development program?
c. How do teachers conceive their role in developing their students' disciplinary literacy, and do their conceptions develop throughout the PD?

6.3 Research context

Knowledge of genres has an important consciousness-raising potential for teachers, with significant implications for both their understanding of writing and their professional development.

The context of this study was a 26h professional development course entitled "Science Literacy". This course was given as part of a special M.Sc. program for science teachers, The Rothschild-Weizmann Program for Excellence in Science Education at the Weizmann Institute of Science. In this program teachers participate in advanced courses related to their main field of teaching, courses in pedagogy, and courses in science education research. The current course was aimed to promote the teachers' pedagogical and disciplinary knowledge and to develop the teachers' scientific literacy by reading, writing, interacting with and learning about disciplinary texts. The program's curriculum ran for 2h per week during the first semester of the 2016-2017 academic year.

6.4 Course design principles and rationale

The objectives of teachers' development at any stage in professional career is to support teachers in making changes to elements of their existing knowledge and skills, and to support them in changing their existing beliefs about science and about teaching, where these seem needed. The material that forms the substance of professional development is the knowledge and skills that a science teacher has to possess in order to support significant learning of their students (Gilbert, 2010). According to Gilbert (2010), professional development is the development of "repertoire of beliefs, knowledge and skills, that enable a sense of being a teacher of science to be exercised in everyday classroom practice" (p.277).

The professional development program (PD) developed in the course of this study was aimed at shaping teachers' understanding of scientific texts as a tool for teaching about how knowledge is accumulating in the discipline in secondary school. Drawing on the theoretical frameworks of social constructivism and SFL I developed and taught a science literacy course for in-service biology teachers. Accordingly, I applied the cognitive apprenticeship approach and used genre-based grammar pedagogy. It should be noted, that three rounds of the course were previously conducted and changes were made in the course, until it reached its final version. In this thesis I present and analyze the fourth and final version of the course.

As previously described, theories of situated cognition view learning as enculturation, an act of taking on the behaviors and world view of a culture or knowledge domain that may be achieved through engaging in the authentic activities of the culture (Brown et al., 1989). The socialization into the community of practice occurs through apprenticeship thorough which a newcomer learns its ways of knowing by participating in the ways of doing that define a community (Brown et al., 1989; Lave & Wenger, 1991).

Based on the cognitive apprenticeship framework I used the research article as a model for scientific reasoning and learning about the scientific epistemology, and the APL-genre as an apprenticeship genre for learning about the unique linguistic and semantic features of scientific texts. Learning in a cognitive apprenticeship occurs through legitimate peripheral participation, a process in which newcomers enter the periphery and gradually move toward full participation (Lave & Wenger, 1991). Accordingly, teachers were considered as newcomers in the field of professional scientific writing, and were given a chance to participate in professional writing by adapting an APL article while taking into consideration the proper ways of writing and communicating the message in scientific texts.

The course had four parts. A summary of the course structure is presented in Table 6.1.

Table 6.1: Structure of the course "Science literacy"

	Course topics	Specific topics covered in the course	Time allotted
Part 1	Introduction to disciplinary literacy	• The epistemology of science • The different epistemologies of different disciplinary texts • Disciplinary literacy vs. basic & intermediate literacy • The scientific argument	6 h
Part 2	Scientific text genres	• Scientific text genres- different writers, different audiences • Adapted Primary Literature (APL)	2 h
	The scientific research article (including APL)	• The article's structure (IMRD), and the structure and role of each section in the article. • The unique linguistic features of the scientific article	6 h
Part 3	Adapting a research article	• Workshop: adapting a scientific research article for secondary school students.	8 h
Part 4	Summary & reflection	• Teaching strategies for using texts in class • Reflection on the adaptation process and relevance to biology teaching	4 h
	Total		**26 h**

for elaborated course plan and materials, see Appendix 7.

In the first part of the course (6 hours) was aimed at introducing the teachers with the theoretical framework that is relevant for understanding the concept of disciplinary literacy. The teachers were taught the epistemology of science and much focus was given on eliciting teachers' views about teaching using texts, and on how their views about students' understanding of NOS aspects.

In the second part of the course (8 hours) I applied a genre-based grammar pedagogy which focuses on the manner through which different language processes or genres in writing are coded in distinct and recognizable ways (Knapp & Watkins, 1994). To my knowledge, this is the first time that this approach is applied in a teachers' development program in Israel. As I applied a genre-based grammar pedagogy, I used the PSL article as a model for scientific writing, while asking the teachers to compare the PSL to a popular article, and reflect on the differences between the texts. According to the genre-based pedagogy, teachers first reflected on the texts as whole, and specifically in relation to their purpose, audiences and message. Then we "zoomed-in" to the sections and paragraphs in each texts, while reflecting on how each section in the text is structured and organized so as to make the text more effective as written communication. Also, we discussed how all the parts are used to serve the purpose of the language users (i.e. the argumentative structure of the article). Finally, texts were analyzed grammatically while reflecting on the grammar of the article from a functional view. Namely, learning about the grammar was not concerned with the rules of correct language, but with the ways grammar functions to communicate experience and knowledge. At the end of these sessions, teachers were introduced with the APL genre, and discussed the similarities and differences of this article compared to a PSL article and a popular article.

I conceived my role in the first two parts of the course as assisting to the teachers with expert knowledge (i.e., coaching, Collins et al., 1988). I maintained focus on the goal, determined when learner exploration is fruitless and when a learner is ready to move onward, while helping and guiding the teachers through the new content knowledge and discourse.

In the third part of the course (8 h), the teachers adapted a PSL article for their students. The writing sessions were collaborative, each teacher contributed to the discourse and to the adaptation of the article. In this part the APL article served as an apprenticeship genre. At this point, teachers were expected to understand the disciplinary features that are communicated in scientific texts. Although the PSL and APL have different audience and purposes, what PSL and APL have in common; their structure, the way the shared way of knowing is represented, the language and the reasoning in the articles, make the APL article a legitimate apprenticeship-genre.

The adaptation workshop was aimed to help the teachers use knowledge about scientific texts and about disciplinary literacy, for adapting an article to be read by their students. During the workshop the teachers were encouraged to reflect on the changes they made in the PSL article, on the features they chose to leave unchanged, and to discuss their decisions with the group.

The last part of the course (4 h) was dedicated to a summary of the course, implementation strategies for using APL articles in class, and reflections about the course and their professional development.

6.5 Methodology

6.5.1 Population

The population of this study consisted of six in-service secondary school biology teachers participating in the above-described professional development program. All six teachers held a B.Sc. degree in Biology at the time the study was conducted. The teachers' professional experience is summarized in Table 6.2.

Table 6.2: The professional experience of the six teachers that participated in this study

	Teachers (pseudonyms)	Years of teaching experience	Gender
1	Liz	8	Female
2	Owen	5	Male
3	Nasrin	4	Female
4	Nathan	5	Male
5	Ruth	30	Female
6	Sarah	8	Female

6.5.2 Data collection, sampling and data analysis

Data were collected during the 13-weeks semester. All lectures, group discussions, focus group sessions, and workshops were recorded using a digital tape recorder. Written assignments given throughout the course were collected as well. Data analysis began after all data were collected. All transcripts were thoroughly read, and were initially divided into sections. Each section consisted of a relatively large proportion of the discourse (between several participants), around a specific topic or activity. For example, when teachers were asked to report about a teaching experience, the whole discourse, of all the teachers reporting about their experience, was considered as one section.

Microanalysis was applied to transcripts that were prepared from the audio files, and the discourse between the teachers was analyzed. The qualitative data analysis was conducted through an iterative process of reading the discourse and the teachers' assignments. Initially, all data were read, and each section in the discourse was classified according to a short description of what was happening in that section. At first, bottom up categories emerged from the first part of the data (lessons 1-3). Then, a top down analysis with the emerged categories was conducted on the rest of the data.

6.6 Results

6.6.1 Teachers' development regarding the use of text and NOS

In this section I attempt to answer the first research question: How do the teachers conceive the role of scientific texts in their teaching, and do their conceptions regarding the use of texts develop throughout PD?

Two activities at the beginning of the course (lessons 1-2) were aimed to elicit the teachers' views about the goals for teaching biology and about the goals for teaching using text. In the first lesson, the teachers were asked to rate their teaching goals, taken form the Israeli high school biology curriculum (Israeli Ministry of Education, 2011), going from the most important to the least important goal. I encouraged teachers to add any other goal they found important. I then asked the teachers to report what were their top three goals and why. Focusing on the three most important goals enabled me to know what goals the teachers perceive as the most important ones in their teaching, which may be implying more strongly on their orientation. The 18 goals that teachers reported to be most important to them were then classified into five categories. The categories and their distribution are presented in Table 6.3.

Table 6.3: Distribution of teachers' views about their teaching goals at the beginning of the course

	Goal	Number of teachers mentioning this goal as one of their top three goals
1	Learning content knowledge	3
2	Increasing students' motivation and interest	1
3	Acknowledging the influence and relevance of biology to the students' lives	6
4	Learning about the nature of science	4
5	Developing high-order thinking skills	4

The distribution of the teachers' goals shows that among the teachers' most important goals for teaching, there are disciplinary, epistemic goals (goals 3, 4, and 5).

In the second lesson, I asked the teachers to tell about a successful teaching experience in which they used texts. Teachers were asked to describe their experiences, the texts they used, their goals for using the texts, and the outcomes of that experience. At the end of the course (lesson 13) teachers were asked again the same questions regarding a future activity with a text. Nineteen sub-categories emerged from the data regarding the teachers' goals for teaching using texts (12 at the beginning of the course and another 7 at the end). These categories were classified to four major categories, (1) teaching content knowledge; (2) teaching procedural knowledge; (3) teaching epistemic knowledge; and (4) general pedagogy (Figure 6.1).

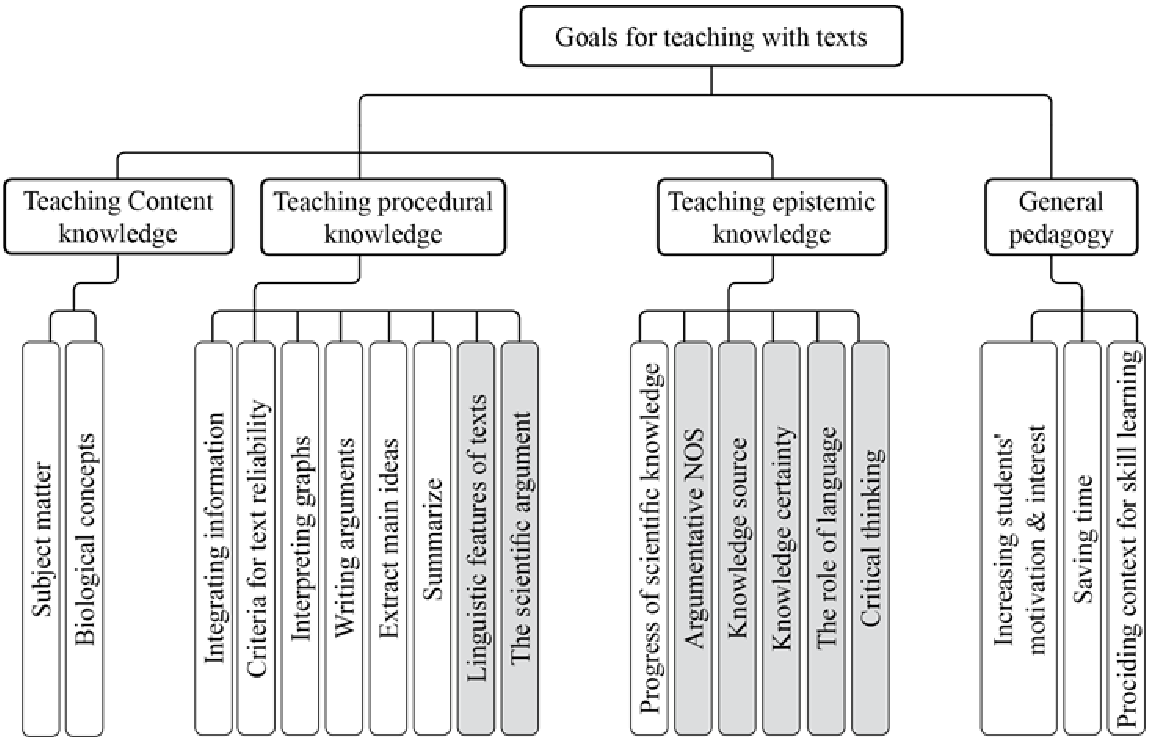

Figure 6.1: Emerging categories for the teachers' views about their teaching goals when teaching with texts. Categories that emerged at the beginning of the course are marked in white, and categories that were added at the end of the course are marked in grey.

Comparing the goals for teaching science with the goals for teaching using texts shows that at the beginning of the course there was little alignment between the teachers' general goals (beliefs about purposes of learning science) and their goal for teaching using text. Namely, although the teachers reported that epistemology and high-order thinking skills were most important to them, these were not mentioned by them as their goals when teaching using text:

Nasrin: *"I asked my students to read several scientific articles, to summarize them, and to present them to the whole class"*

Ruth: *"they [students] read two texts from the textbook, and I asked them to find a key sentence that is common to both texts. It was supposed to be the surface-area to volume ratio…"*

Liz: *"…I do not use texts unless there is some skill I can teach from it [the text]… so when I teach how to interpret graphs, for example, the text provides the context for the graph, so it will not be out of context…"*

The fact that the text has had little alignment with the teachers' general goals for teaching biology suggests that at the beginning of the course teachers did not view texts as tools fit to achieve their goals for teaching science, and they were not familiar with strategies for teaching using texts aimed at teaching about the nature of science, or high-order thinking skills. However, as the analysis and the data presented in Figure 6.1 suggest, by the end of the course teachers expanded their views that texts can be used for various instructional strategies. Seven categories were added to the teachers' goals, out of which, five were goals for learning epistemic knowledge and two were goals for learning procedural, disciplinary knowledge. At the end of the course, all the teachers added disciplinary-specific, and epistemological knowledge to their goals for teaching using text:

Liz: *"…I would like to bring an APL article and a popular article, so they [students] would see the difference between the writing of a research article compared to the writing of a popular article. I want them to be more critical to what they are reading… [by acknowledging] the use of scientific concepts and other criteria such as the epistemology or the argument in the article…"*

This shift was also apparent in the teachers written assignments. During the course I encouraged teachers to write about their thoughts as the course progressed:

Sarah: *"…I now realize how important it is to be familiar with our own discipline. Each discipline has its own ways of creating knowledge and to assess the knowledge… when students will be able to read knowledge [in the discipline] they will also be able to understand that knowledge… when Moriah gave us the exercise to read different disciplinary texts… then I understood how I do not understand other texts, or why they are written this way, even though I basically know how to read…"*

Owen: *"… I started to think about the concept "science" what does it mean? How is the knowledge created in science, and how I, as a teacher, reflect the progression of scientific knowledge to my students… I find myself saying things in the classroom that I have never said before, like what I am teaching you now, is true for now…I suddenly ask my students to claim claims, and to give evidence for what they argue…"*

Looking at the data from a disciplinary literacy point of view reveals that by the end of the course, teachers, emphasized less the teaching of a generalizable (across content areas) set of reading skills for use in subject matter classes, and emphasized more the unique tools that experts in a discipline use to participate in the research work of that discipline (Shanahan & Shanahan, 2012). In other words, the expansion of the teachers' views represents a shift in teachers' orientation from an intermediate literacy view of teaching biology using texts, to a more disciplinary literacy view of teaching biology using texts.

In the following section I attempt to answer the second research question: How does the teachers' disciplinary literacy develop throughout the professional development program?

During the course, dealing with the nature of science and scientific epistemology elicited teachers' epistemic knowledge and disciplinary literacy. In addition, it elicited discussions about the instructional strategies for teaching the nature of science (NOS) in class. Three categories emerged regarding the teaching of NOS (Figure 6.2): (1) views about learning of NOS; (2) views about NOS teaching strategies; and (3) students' difficulties regarding NOS.

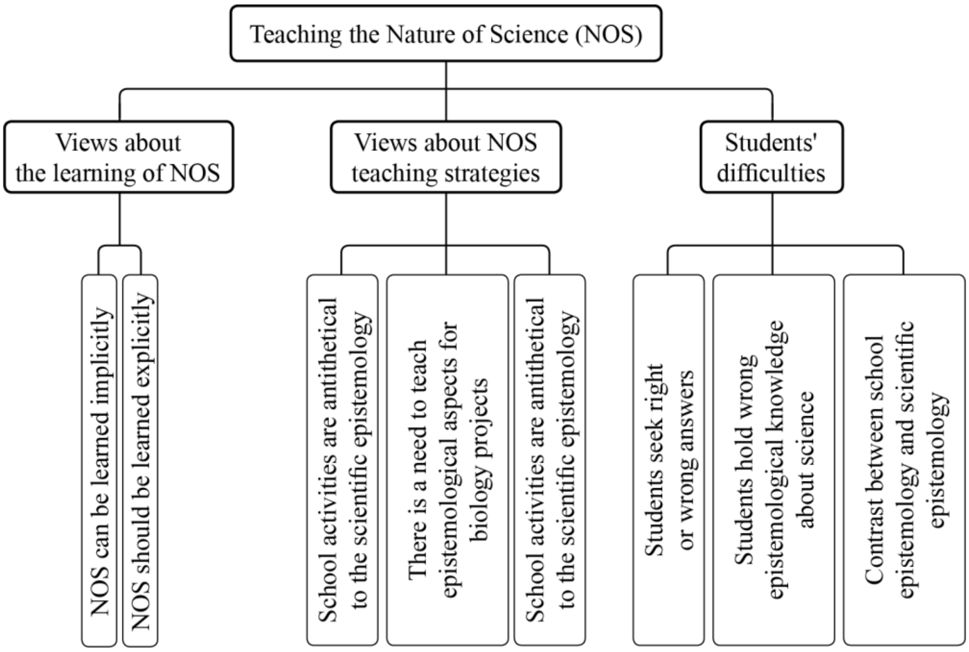

Figure 6.2: Emerging categories of teachers' views about teaching the Nature of Science (NOS)

At the beginning of the course teachers viewed the learning of NOS as implicit, and were surprised to reveal that their students did not show a high epistemic understanding in some aspects of the scientific epistemology.

Sarah: *"[regarding the uncertainty of science]"...you are doing it [teaching NOS], and you don't know that you are doing it... if students are reading some articles that you brought to class, it gets in, between* *the… you say in class this is true until something else [new theory] will come, and that's it! You do it again and again- I consider it closed…"*

This may also explain the weak connection between the teachers' goals for teaching using text, and the teachers' general teaching goals. As long as NOS was viewed as knowledge that can be learned implicitly, the teachers saw no need for specific strategies to teach NOS, and therefore, the text was not considered as a relevant tool for this purpose.

The discussions about teaching strategies for NOS elicited the teachers' reflection on the ways NOS is reflected in school science. During these reflections teachers came to the understanding that school science is often antithetical to the epistemology of science:

Nathan: *"…in school there is a right answer and a wrong answer, and also in the school laboratory, when writing the conclusion, I will get points if I write this, but not if I write that… but actually I can think of several conclusions for their results…I think that in the school essence there is right and wrong…and that is very problematic…"*

Liz: *"yes, it is problematic. This is what we teach them…"*

During the discussions and reflections, the idea that NOS should be taught explicitly, and the need for specific strategies to teach NOS emerged:

Sarah: *"…I actually have to give a lesson about the ways scientific knowledge is built! There is no connection between the fact that I teach how to build an argument, and their [the students'] ability to argue scientifically and to justify their arguments, or their understanding of science and how arguments are justified…"*

…

Nathan: *"… you know, this is something we need to do. To build an exercise… some kind of research article that we can work with…*

As the course progressed the NOS and the scientific epistemology were viewed as an important knowledge for learning about the discipline and for developing high-order thinking skills (an important teaching goal for many of the teachers). Accordingly, teachers were now open to consider strategies that are aimed to explicitly teach students this kind of knowledge. At this point, I introduced to the teachers the new strategy for teaching with texts (as presented in the Rationale of this report): structure-oriented text analysis and language-oriented text analysis.

When presenting the teachers with the linguistic features of the research article, teachers started to reflect on the role of language in their class, in their teaching and about the importance of language for learning about the discipline. Teachers were enthusiastic and stated that they have never thought about language this way:

Liz: *"Wow! This is amazing! I have never thought about it like this, but this is true!*

Ruth: *"so… we need to teach this [language] as a skill [for reading texts]…"*

Nathan: *"language is the only tool we have to explain, or to prove, that I understood something…"*

I also found evidence that teachers understand and realized the role language has in construing meaning and reasoning in the text, as the course progressed:

Ruth: *"In order for students to relate to the article and understand it, we need to make it less dense, and to include few technical terms. Or we should give an explanation about terms inside the text. We should find the right dose between distance and objectivity in the text. On one hand, too much distance will alienate the students and on the other, no objectivity will damage the text's epistemology and authenticity… "*

Nasrin: *"I think the APL article should be less informationally dense, because not everything is relevant to the students. New technical terms should be explained, and information about them should be added in the article. Concerning the Abstraction, I think it should be lowered and teachers should guide their students how to analyze it…"*

Liz: *"If needed we can use verbs instead of Nominalizations… however I think we should keep the Authoritativeness because that is how we can reflect better the scientific argument…"*

Owen [answering Liz]: *"…we should be very careful with eliminating Nominalizations and using verbs instead! ... I think we should keep some kind of ratio between nominalizations and verbs, so that on the one hand we retain the scientific language, and on the other hand we won't scare the students… also, eliminating the nominalizations will damage the texts' authoritativeness and objectivity, and can damage the second goal that you mentioned [the scientific argument]…"*

6.6.2 Some insights from the professional development program

Darling-Hammond et al. (2017) identified seven characteristics of effective PD, and concluded that it should: (1) be content focused, (2) incorporate active learning, (3) support collaboration, (4) use models and modeling of effective practice, (5) provide coaching and expert support, (6) offer opportunities for feedback and reflection, and- (7) be of sustained duration.

Reflecting on the PD, I find that all the above mentioned characteristics were expressed in the course. First, the course was focused on epistemology and language. Second, applying the cognitive apprenticeship approach and using the APL article as an apprenticeship genre enabled teachers to be active in their learning, supported their collaboration, and was effective in modeling to the teachers the practice of reading and writing in their discipline. The APL adaptation enabled me to progress through the stages of cognitive apprenticeship from modeling and coaching (mostly at the beginning of the course) until fading. The APL adaptation along with a critical analysis of scientific texts, enabled me to make a clear explication of thinking – in the community of science, and as an expert APL adaptor. Fading occurred by the end of the course when the teachers were able to adapt the APL by themselves, and reflect critically on their adaptation process, from a linguistic, disciplinary perspective.

6.6.3 Summary and main conclusions from the teachers' development program

- The expansion of the teachers' views represents a shift in teachers' orientation from an intermediate literacy view of teaching biology using texts, to a more disciplinary literacy view of teaching biology using texts.
- Teachers made new connections between scientific language and scientific epistemology.
- Teachers understood and realized the role language has in construing meaning and reasoning in the text.
- Teachers were able to use language and other stylistic and rhetorical features in order to critically assess different scientific texts.
- Teachers were able to adapt an APL article, and to reflect on the adaption process from an "expert" point of view, taking into their consideration structural and linguistic features to reflect different aspect of NOS that they found important.

7. Using scientific texts to promote students' epistemological understanding and critical reading skills

7.1 Introduction

"Argumentation – the making of reasoned claims which are supported by data or evidence – is a specific form of discourse that can help students view science as an epistemological and social process in which knowledge claims are generated, adapted, reorganized, and, at times, abandoned…" (Evagorou & Osborne, 2010, p.154).

In our daily life we hear and read confusing messages from the media, and these messages should be evaluated; their source needs to be considered, their context, their agreement or disagreement. This evaluation will enable us to know what to think and how to act, and this evaluative stance is at the heart of critical thinking (Hynd, 1999). The ability to make evaluative judgments about the validity of science-related media reports and their implications on people's lives and the society was recently accepted as an important aspect for developing students' argumentation skills and critical thinking (National Research Council (NRC), 2012). Thus, the underlying concern of critical thinking is making reasoned judgments, and argumentation constitutes a significant aspect of it (Bailin & Battersby, 2009).

The characteristics of argumentation in different domains is different, because it bears domain norms according to which people reason (Schwarz, 2009). When students understand how knowledge is created in a discipline, they know that knowledge is always being constructed and reconstructed, and that the "truth" known by the discipline is a result of social influences and balances of power. Scientists understand these relations because they have a great deal of disciplinary knowledge. However, most students do not (Hynd, 1999). Therefore, one aspect of disciplinary literacy requires a focus on how evidence is used to construct explanations. Thus, students should understand the criteria used in science to evaluate evidence, and to recognize the standard genres of science to infer meaning from scientific texts (Osborne et al., 2004; Schwarz, 2009). The more students understand how information was created in a discipline in the first place, the more likely they are to view it with a critical eye (Hynd, 1999).

Developing students' critical thinking is one of the widely accepted goals of science education (Erduran & Jiménez-Aleixandre, 2008; National Research Council (NRC), 2012; Osborne, 2010; Simon et al., 2006). The competence to comprehend and follow arguments of a scientific nature is a crucial aspect of scientific literacy in its fundamental sense (Simon et al., 2006). However, in order to examine scientific claims and arguments critically, one needs insights into scientific criteria for judging claims and arguments (Kolstø et al., 2006). Scientists use argumentation to make justified claims about the world, and other scientists criticize and assess these claims (National Research Council (NRC), 2012; Osborne, 2010). Thus, being literate in a discipline means having both deep knowledge of disciplinary content and deep understanding of the ways of making meaning in the discipline (Fang, 2012, 2013; Shanahan & Shanahan, 2012). The practice of argumentation requires the use of criteria for the selection and evaluation of evidence, the creation of counter-arguments and the provision of justification (Driver et al., 2000; Erduran & Jiménez-Aleixandre, 2008). In other words, having an understanding of the epistemology of science is crucial for being disciplinary literate. It was previously argued that developing students' conceptual and epistemic knowledge requires them to engage in common practices of science, and that separation of concept learning from practices requiring use of knowledge does not promote meaningful learning (Duschl & Grandy, 2013). Reading and analyzing PSL is an authentic scientific cognitive activity, and scientists spend much of their time learning about other scientists' research through reading of research articles (Chinn & Malhotra, 2002). Activities with text are as much part of what scientists do as are observation, measurement and calculation (Norris & Phillips, 2008). As such, reading scientific texts may provide students with insights into the nature of science and scientific epistemology (Yarden et al., 2015).

7.2 Goals and research questions

The goal in this part of the research was to assess the use of two contradictory texts on students' critical thinking and NOS understanding.

My research questions were:

a) Whether and how engaging in an argumentation activity, using two contradictory articles, promotes students' ability to critically asses a popular article?

b) Does the genre of the contradictory articles (APL or popular) influence students' ability to critically assess a popular article?

c) Whether and how engaging in an argumentation activity, using two contradictory articles promotes epistemology understanding? And does the genre of the contradictory articles (APL or popular) influence such understanding?

My initial hypothesis as described (p. 23) was that APL can serve as an apprentice-genre for high-school science students. This hypothesis was further reinforced by the text analysis as presented in chapter 5 of this research. Moreover, there is a strong link between epistemic discourse and the practice of argumentation since argumentation places great emphasis on the use of evidence for supporting or rejecting a theory or idea (Driver et al., 2000; Erduran & Jiménez-Aleixandre, 2008). Therefore, I expected the critical thinking and epistemological understanding of students who read APL articles will improve more than that of students who read popular articles.

7.3 Methodology

7.3.1 Strategy

7.3.1.1 Using contradictory texts to facilitate evidence-based argumentation

Designing conditions in which students spontaneously express multiple voices in science is difficult. Often, students know that there is generally one legitimate answer, and many would not risk to concur with an answer expressed by their teacher or by a strong student (Schwarz, 2003).

A prerequisite for studying the effects of argumentation on content learning is to elicit productive argumentative discussions. However, this is not an easy feat. Simply telling students to conduct a critical discussion is often not enough. Providing students with textual resources that convey contradictory viewpoints can increase the likelihood that they discuss and explore the differences between them (Asterhan & Schwarz, 2016). Therefore, engagement with texts presenting contradicting sources can provide students with motivation for broadening perspectives.

Evidence-based argumentation is defined as making a claim that is supported by evidence. This is an essential practice to nearly all disciplinary knowledge creation and when situated inside the discourse practices of academic disciplines, argumentation tasks have shown to build students disciplinary knowledge and reasoning (Litman et al., 2017; Osborne et al., 2004).

7.3.1.2 Texts chosen for the activity

I chose two contradictory research articles that describe the effects of the herbicide atrazine on frogs' reproductive system and sexual development as a platform for this research. One article gives evidence that atrazine is safe for use (Kloas et al., 2009), and the other article gives evidence that atrazine is not safe for use (Hayes et al., 2002). Both articles deal with topics that are not studied in 10^{th} grade, in order to minimize the possibility that differences in comprehension will occur due to different learning styles, different instruction, and eventually differences in students' previous knowledge on these topics. On the basis of these two articles I wrote two versions of each PSL articles; one version was an APL article (Appendix 8), and the second version was a popular article (Appendix 9). Students in each class were divided into two groups. One group received two contradictory APL articles about the use of atrazine, and the other group received two contradictory popular articles about the use of atrazine. The students read the contradictory articles and then participated in a debate. For the debate, each group (the APL group and the popular article group) was randomly divided into two groups: one was instructed to speak in favor of using atrazine, and the other group was instructed to speak against the use of atrazine. Students were asked to fill an epistemological understanding questionnaire (Appendix 10) before, and after the intervention, in order to assess possible changes in students' views. In addition, students were asked to read and criticize a popular article, taken from the local media (Appendix 11) before and after the intervention.

Since the language and structure of APL articles are more epistemologically authentic, these articles, as opposed to popular articles may offer students some insights into the context of justification (Osborne, 2009). Therefore, I hypothesized that reading the APL articles (and not the popular articles) will contribute more to the promotion of students' epistemological views, and also to their ability to criticize a scientific text. Since it was previously argued that the texts that most students will encounter in their future lives are media reports (Osborne, 2009), I asked all students in both groups to criticize a popular article in the pre- and post-questionnaires.

7.3.2 Population

10^{th} grade students from three different classes in the same school (n=93) participated in the experiment. The school is an urban high-school in a central city in Israel. Classes were chosen by convenient selection and represent medium-high socioeconomic status. Ten students, who missed parts of the intervention, or one of the tests, were excluded from the analysis. Thus, the final sample in this research was n=83 (48 females and 35 males).

Biology class grades were obtained for all students that participated in the experiment. From the grades obtained I learned that the average biology class grade for students in the popular articles group was 83.1, and the average biology class grade for students in the APL articles group was 86.7, out of a maximum score of 100. A two-tailed unpaired t-test was used to compare between the biology achievements of students in the popular articles and the APL articles group. No significant difference was found in the students' achievements in the two groups (p=.14).

7.3.3 Materials

7.3.3.1 Epistemological understanding of science questionnaire

A 32-item questionnaire (Braun & Nückles, 2014), was translated to Hebrew (Appendix 10) and administered at pre- and post-test to the students (n=83).

Score reliabilities (Cronbach's α) obtained from the three dimensions of the 32-item questionnaire[1] (certainty, source and justification) ranged from .64 to .71. Score reliabilities (Cronbach's α) obtained from the five dimensions of the item in the questionnaire[3] ranged from 0.31 (constructive NOS) to 0.68 (argumentative NOS). Therefore, the constructive NOS category was omitted from the analysis (Table 7.1).

Table 7.1: Reliability scores of the epistemological understanding of science questionnaire (post)

	Category	Cronbach's α	Sub-category	Cronbach's α
1	Certainty (10 items)	0.71	Ambiguity (4 items)	0.66
			Tentativeness (6 items)	0.53
2	Source (5 items)	0.64	Explanatory NOS	0.64
3	Justification (12 items)	0.69	Argumentative NOS (5 items)	0.68
			Constructive NOS (7 items)	0.31

Although the reliability scores are not high, they are consistent with the original reliability scores previously published (Braun & Nückles, 2014), except for the tentativeness category which has a lower reliability score, and the constructive NOS category which was excluded from the analysis. It should be noted, that the students in this study are younger than the students in the original study, and that the questionnaire was translated to Hebrew. These changes may lead to lower reliabilities. Therefore, I chose to proceed with the analysis with four categories: Ambiguity, Tentativeness, Source and Argumentative NOS. Nonetheless, since the internal consistencies of the ambiguity, source and argumentative NOS categories are questionable (α=.66, .64 & .68 respectively), and the tentative category is poor (α=.53), the results presented here should be taken with caution.

[1] Items 7, 8, 10, 19 & 31 of the original questionnaire were excluded from the analysis since they lowered the reliability scores. Thus, a total of 27 items were analyzed.

The questionnaires were given to the students a few days prior to the intervention and a few days after the intervention. The time between the pre- and post-questionnaires was approximately six weeks.

7.3.3.2 The popular articles questionnaires

The students were given a short popular article (Har-Noi, 2014) as a pre-test, and a second, different popular article (Shauli, 2013) as a post-test (Appendices 8 and 9). Both articles were similar in length and in style, and were based on real articles published in popular websites. The first article deals with the importance of breakfast, stating that eating breakfast is not necessary. The second article deals with organic fruit, stating that they are not healthy.

Students were asked to read the articles and then to answer the following questions:

- Did the article strengthen or weaken your opinion about breakfast / organic fruit? Please elaborate why.
- Do you have any criticism about the article you have just read?
- What information would help you make a decision about eating or not eating breakfast / organic fruit?

7.3.4 Procedure

Subjects participated in the experiment as part of their regular biology class. The research had three parts: pre-questionnaire, intervention and post-questionnaire (Table 7.2).

Table 7.2: Overview of procedures

Procedure	**Minutes**
General instructions	5
Pre-test:	
Epistemological understanding of science questionnaire	20
Popular article questionnaire	25
Intervention:	
Recognizing and questioning non-scientific arguments	135
Reading articles	50-60
Debate	30-40
Post-test:	
Epistemological understanding of science questionnaire	20
Popular article questionnaire	25
Total	**310-320 (~7 lessons)**

I taught all the lessons in all the three classes. Each class was randomly divided into two groups, and each group was randomly assigned two articles (two APL or two popular articles). I gave the students some general instructions, and after the students completed the pre-questionnaire, all students in all the groups (n=83) participated in three lessons (i.e. the intervention, see Table 7.2) in which I taught about common fallacies of scientific arguments. The students received a fake popular article stating that eating white rice is not healthy (Garty, 2012), in the rest of the article the author reveals the fallacies in each of the statements presented in the article, thus, demonstrating the ways one can refute the argument presented in the article. I modeled to the students the ways in which arguments can be questioned, and also discussed with them the legitimacy of questioning arguments presented in the media. Next, student watched a six-minutes interview with an M.D. arguing that consuming milk products is unhealthy. This short video was published as part of an online article dealing with non-scientific arguments, and the ways to recognize and question these kinds of arguments (Garty, 2013). Again, I asked the students to ask critical questions about the arguments presented by the M.D., and then I summed up the discussion from both activities.

After the abovementioned lessons, each class was randomly divided into two groups. Each group was randomly assigned to read either two contradictory APL articles or two contradictory popular articles. We read the articles together, part by part, and I reassured that the content and the procedures in the articles are clear to the students. During the reading, students summarized the main ideas from each text, thus the differences between the contradictory articles became apparent to them.

After reading the articles, groups were divided again into two groups, each group included six to eight participants. One group was assigned to talk in favor of the use of atrazine, and the other was assigned to talk against the use of atrazine. Groups were divided and assigned randomly. Each group (for and against) was asked to prepare itself for a debate about the use of atrazine. The groups were given time for discussion, and then each group chose one or more presenter to present the group in the debate. It should be noted, that the goals for having the debate was to promote the students' critical reading by having them look deeply into the two articles, and finding their strengths and weaknesses. Therefore, it was not a "classic", "by the book" debate, but rather a discussion with the following rules:

- Groups present their ideas in turns.
- In each turn, the presenter has exactly one minute to present an idea or a claim.
- When the presenters speak, no one is allowed to interrupt them.
- Groups are allowed to ask for time-off for consulting, and reorganizing their thoughts.

Several days after completing the debate, students were given the post-questionnaire.

7.3.5 Data analysis

7.3.5.1 Epistemological understanding of science questionnaire

Responses to the items were to be provided on a six-point scale ranging from “do not agree at all” to “agree completely”. The scores of the negative items were reversed. Initially, the answers to the pre-test questionnaires of the two groups (popular articles and APL articles group) were compared using the two-tailed unpaired t-test procedure. Next, students’ answers to the pre- and post-test were compared for each group separately, using the one-tailed paired t-test procedure.

7.3.5.2 Popular articles questionnaires

Responses to the three questions in the questionnaire were collected. Answers were analyzed by identifying critical questions that students asked about each article. Since I found that most of the students repeated their answers in the three questions of the questionnaire, I analyzed the answers of the three questions as one. Namely, an answer was categorized as having criticism if it had a critical question in either one of the three questions. Repeated criticism in the same questionnaire was categorized only once for each answer.

Students’ answers to the questionnaires were categorized according to the types of criticism which correlate with arguments fallacies and critical questions (following Walton, 2008), into five categories: Causality, Generalization, Authority, Relevance and- No criticism or Irrelevant answer. (For a detailed rubric of analysis see Appendix 12). Twenty percent of the data and the rubric were given to two researchers for validation, one of which is researching argumentation as part of his Ph.D., including critical questions and argumentation fallacies. The agreement on the categorization at the beginning was ~85%, and after discussion reached ~95%. Examples of students’ answers according to the different categories are presented in Table 7.3.

Table 7.3: Examples of the categorization of students' answers to the pre- and post-questionnaires

Type of criticism		Example of a student's answer
Questioning causality	Questioning the link between variables	They didn't take into consideration the growing environment. They [the fruit] were all grown in the same soil. Maybe the soil contains unhealthy substance. They didn't compare it to other fruit that are grown in a different soil"
	Questioning vagueness	What do they mean when they say that it [eating organic fruit] is not healthy? What do they mean by healthy?
	Questioning the methods presented in the article	There is no information about the groups in the experiment or about the control. They just gave us the facts, so we can't really know what they [the researchers] did in their experiment." "The sample is too small"
Questioning generalization	Questioning the ability to generalize from the results in the article to the whole population	The research was done on three types of fruit only. This is not enough to draw a conclusion about other kinds of fruit" "They tested only people who are overweight, but it says nothing about people with normal weight.
Questioning authority	Questioning the expert opinion presented in the article	It [the article] didn't say who is the professor [who conducted the research] and if she is an expert in agriculture. For what I know she can be a literature professor" I would like to know if other scientists also agree with the article's claim.
	Questioning the authority of the article itself	There is no information about the original article, and where it was published. Maybe it wasn't even reviewed"
Questioning the relevance to the conclusion	Questioning the relevance of data or evidence presented in the article to the conclusion or main argument	"they say in the title that these vegetables are not healthy, but the article is all about the ecological damage from growing organic vegetables" Maybe not eating breakfast is fine when you test cholesterol after three weeks, but it says nothing about the way you feel during the day, or about your ability to concentrate"
No criticism or irrelevant answer		"I have no criticism" "If I do not eat breakfast I feel very weak"

7.4 Results

7.4.1 Epistemological understanding of science questionnaire

No significant difference was found between the groups in the pre-questionnaire, in all categories. A significant improvement in student's understanding of the argumentative NOS was found in both groups ($p<.005$), and a significant improvement in the understanding of tentativeness was found in the APL article group ($p<.05$). No differences were found in students understanding of ambiguity and explanatory NOS in both groups (Figure 7.1).

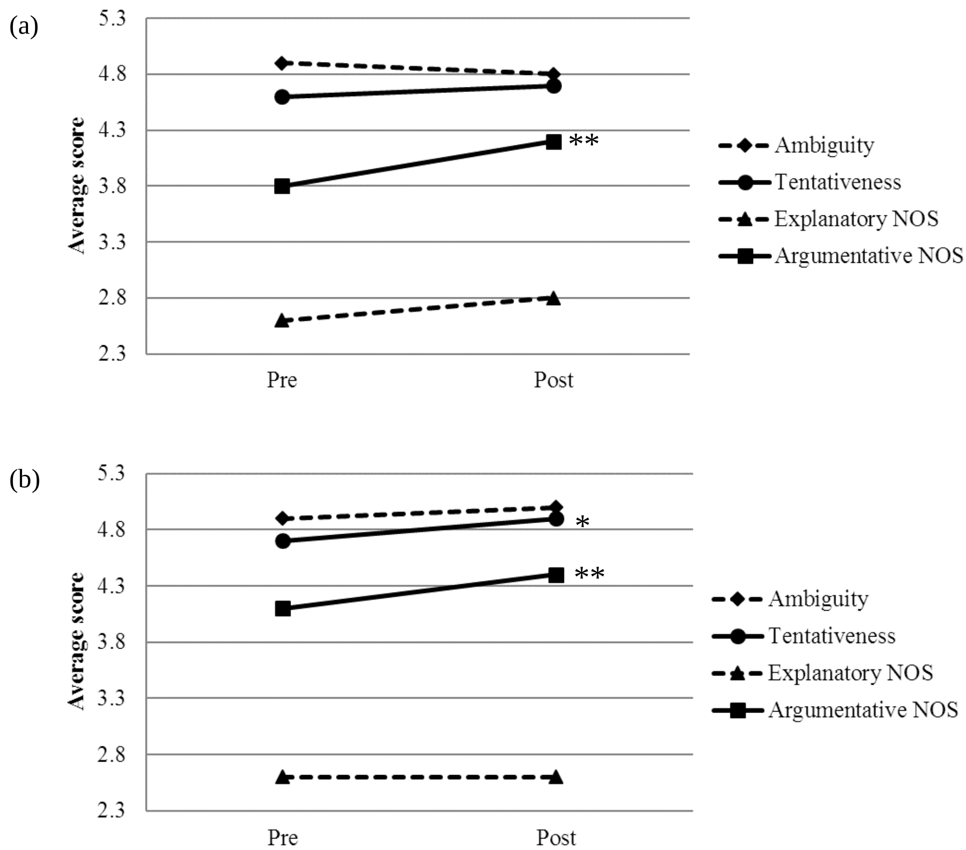

Figure 7.1: Changes in students' understanding of the ambiguity, tentativeness, explanatory NOS and argumentative NOS, in the popular articles group (a), and in the APL articles group (b).
*$p<.05$, **$p<.005$.

7.4.2 Popular article questionnaire

In both groups students' ability to criticize the popular article improved significantly. In the popular articles group, the total number of critical items was 19 in the pre-questionnaire, and 23 students out of 37 (62% of students) did not answer or had no relevant criticism. In the post-questionnaire the total number of critical items was 53, and only 12 students out of 37 (32% of students) did not answer or had no relevant criticism.

In the APL articles group, the total number of critical items was 24 in the pre-questionnaire, and 26 students out of 46 (57% of students) did not answer or had no relevant criticism. In the post-questionnaire the total number of critical items was 87, and only 8 students out of 46 (17% of students) did not answer or had no relevant criticism. The distribution of types of criticism is presented in Table 7.4.

Table 7.4: The distribution of types of criticism in students' answers in the pre- and post-test.

Type of criticism	**Popular articles group (n=37)**				**APL articles group (n=46)**			
	Pre-questionnaire		Post-questionnaire		Pre-questionnaire		Post-questionnaire	
Causality	5		22		5		31	
Generalization	14	45%	13	82%	17	48%	26	92%
Authority	0		16		1		29	
Relevance	0		2		1		1	
No criticism (out of total criticism)	23	55%	12	18%	26	52%	8	8%
Total criticism items*	**42**		**65**		**50**		**95**	

* Some students wrote more than one criticism in their answer.

It was found that in both the popular group and the APL group the students provided significantly more fallacies in the post-questionnaire compared to the pre-questionnaire. Thus, students' ability to criticize the popular articles significantly improved (Figure 7.2 and Figure 7.3).

A closer look on students' ability to criticize the articles shows that in both groups students' ability to criticize the causality and authority of the articles improved, but the APL group showed a bigger improvement than the popular group in both items. In addition, an increase in students' ability to criticize generalizations in the articles was found in the APL group but not in the popular group (Figure 7.2 and Figure 7.3).

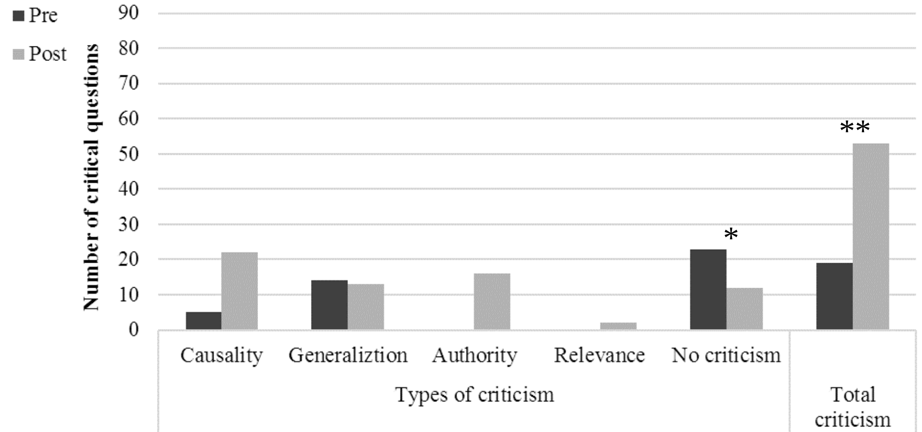

Figure 7.2: Number of critical questions categorized by the type of criticism, and the total number of critical questions asked by the students in the popular articles group. *p<.05 **p<.001

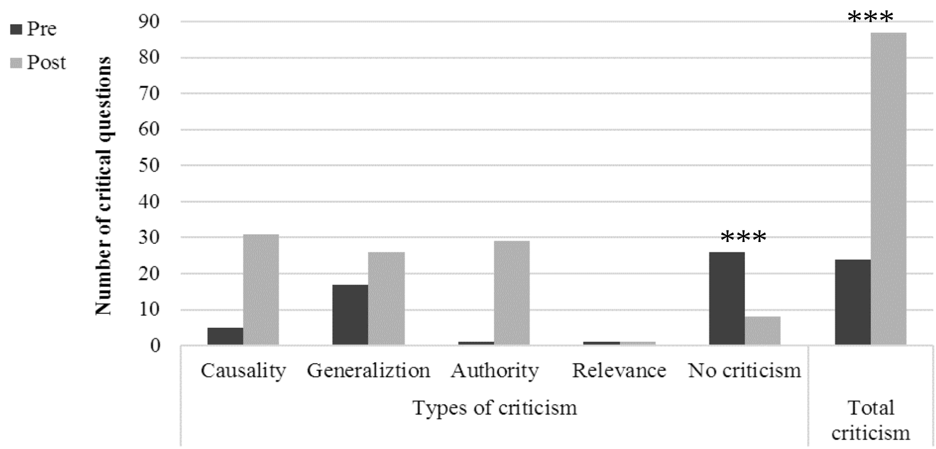

Figure 7.3: Number of critical questions categorized by the type of criticism, and the total number of critical questions asked by the students in the APL articles group. ****p*<.0001

It should be noted, that when comparing the pre-questionnaire of the popular articles group and the pre-questionnaire of the APL articles group, no significant difference is found between the groups. However, when comparing the post-questionnaire of the popular articles group and the post-questionnaire of the APL articles group, a significant difference was found between groups (*p*<.05, Figure 7.4). Thus, the ability of students who read the APL article to criticize a popular article significantly improved their ability compared to students who read popular articles.

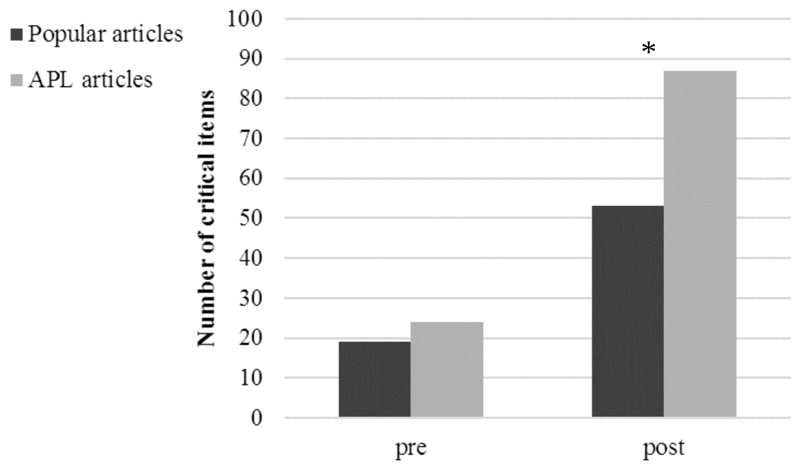

Figure 7.4: Comparison between the pre- and post-questionnaire of the popular articles and APL articles groups. *p<.05

7.4.3 Summary and main conclusions from the two contradictory texts intervention

- Using contradictory texts may promote student's understanding of some NOS aspects such as the argumentative nature of science.
- Using contradictory texts may promote student's critical reading skills, and specifically their ability to find fallacies in the text argument.
- Reading two contradictory APL articles was found to have better outcomes regaring students' critical reading of a popular article compared to students who read two contradictory popular articles.
- APL articles hold more potential for improving students' epistemological understanding of science than popular articles.

8. Discussion

In this study I conducted a linguistic analysis and a comparison of different scientific text genres. I also designed and taught a professional development program with a strong emphasis on the structural and linguistic features of scientific articles and their connection to scientific epistemology, which was mostly based on findings from the texts' analysis. I also designed an intervention for high school students based on two contradictory scientific texts of different genres (APL and popular), aimed at promoting students NOS understanding and critical thinking skills.

The analysis of the linguistic features of an APL article compared to those of PSL and popular articles suggests that the adaptation of the APL article lowers the lexical complexity and increases the readability of the text, making it more readable and probably more suitable for high school students, while at the same time retaining the authenticity of the scientific writing. The quantitative analysis and the qualitative analysis of the cohesive ties in PSL and APL articles show that several grammatical and lexical relations increase the APL articles' cohesion and therefore increasing text's coherence.

In the teachers' professional development program, I found a shift in teachers' orientation from an intermediate literacy view of teaching biology using texts, to a more disciplinary literacy view. In addition, teachers reflected on the role of NOS in their teaching and on NOS as an important knowledge for learning about the discipline and for developing high-order thinking skills. Moreover, teachers found the language of science to be a practical tool for learning and understanding the reasoning and the epistemology of science. During the course, the teachers were able to use a linguistic perspective to discuss and assess scientific texts, and to reflect on their teaching, their discourse with students, and also on the APL they adapted during the course.

In the contradictory texts research, I found a significant improvement in students' views of the argumentative aspect of NOS and in students' ability to criticize popular texts. Differences were found between students who read two contradictory APL articles and students who read two contradictory popular articles. For example, students' ability to criticize a popular article was found to improve more in the APL group compared to the popular group. In addition, improvement in students' understanding of the tentativeness of scientific knowledge was found in the APL group as well.

In the following sections I will discuss the pedagogical affordances of APL articles in light of the linguistic analysis and the teachers PD and contradictory-texts activity. First, I discuss the APL as an apprenticeship-genre and the way it is adapted to students' reading skills and cognitive abilities. I focus my discussion on the functionality of the APL language compared to the language of a PSL and a popular article, as it was found in the SFL analysis. Second, I discuss new ways to promote disciplinary literacy, to use APL as an apprenticeship-genre and as a tool for promoting teachers' disciplinary literacy, as well as views regarding the use of texts in their class. Next, I discuss ways to promote students' disciplinary literacy and specifically their NOS understanding and critical thinking by using contradictory texts. Finally, I discuss teaching implications for adopting a more disciplinary view for teaching using texts in general, and APL articles in particular.

8.1 APL as an apprenticeship-genre

8.1.1 The unique linguistic features and semantic relations of the APL article

8.1.1.1 The linguistic features of the APL article

High school students are not scientists, and they should be considered as inexperienced readers when it comes to scientific texts. Thus, they are incapable of reading PSL articles. Therefore, these articles are adapted to match students' reading skills and cognitive abilities (Yarden et al., 2001).

The SFL analysis of the APL article compared to the PSL and popular articles, that was carried out in the course of this study, revealed that the informational density, technicality, abstraction and authoritativeness values are lower in the APL articles compared to the PSL articles. Hedging in the PSL and APL articles was found to have similar goals, which may reflect the APL writer's attempt to preserve the original function of the hedging as presented in the original PSL article, thereby keeping the language and reasoning as authentic as possible. In contrast, when comparing the APL article to the popular article, the technicality, abstraction and authoritativeness values, as well as the lexical density value, were found to be significantly higher in the APL article, and hedging was found to have different goals. While in the APL articles, hedging signals the personal responsibility of the presented data, in the popular articles hedging functions to remove personal responsibility from the writers and give full authority to the scientific community (Hyland, 1998; Parkinson, 2001). Similarly, when comparing the PSL to the popular article, the technicality, abstraction, authoritativeness values and the lexical density value were significantly higher in the former, and their hedging was found to have different goals.

The linguistic features of PSL and popular articles found in this study, as well as the differences between them, are consistent with previous studies on scientific text genres (Fang, 2005; Halliday, 1993b; Lemke, 1990; Livnat, 2010a, 2010b; Myers, 1989; Parkinson, 2001; Parkinson & Adendorff, 2004). However, the linguistic features of the APL articles, as well as the comparison of the linguistic features of the APL, PSL and popular articles, are reported here for the first time.

The APL article's lexis, while abstract and technical, was found to be less abstract and less technical than that of the PSL article, with simpler technical terms taken mostly from the high school biology curriculum in Israel. First, the significantly lower lexical density values of the APL article compared to the PSL article, suggest that the APL article is easier to read. Also, less technical terms, the use of familiar and simpler technical terms, and using more verbs and less nominalizations, may each contribute to the text's reading easibility by lowering the cognitive load when reading the article.

Second, both the APL and PSL articles were found to be depersonalized; however, the APL article was found to have less passivation than the PSL article. Active constructions are considered more interesting and engaging than passive constructions (Parkinson, 2001). Thus, the decrease in passivation in the APL article may reflect the writer's effort to make the APL article more engaging for students and less impersonal.

Third, some knowledge gaps in the article, especially regarding the technical terms or research procedures are filled in the APL article, thus making it more coherent for students to read. However, since the APL article reflects the syntactic structure of the discipline, it may still have informational gaps, making their reading more challenging for students, compared to the popular article.

8.1.1.2 The semantic relations of the APL article

The differences in the semantic relations (i.e., processes) can help to understand the changes made in the APL article in the adaptation process, and reflect the different writers' goals. Material, Mental and Relational are the main types of processes in the English transitivity system. They are the most frequent types with Material and Relational being significantly more frequent than Mental (Halliday & Matthiessen, 2014). Previous analysis of process types in different scientific text genres show that scientific texts have mostly Material and Relational processes (Parkinson, 2001;

Parkinson & Adendorff, 2004). The process analysis presented in this study is consistent with these findings. The process analysis of the APL articles, as well as a comparison of the APL, PSL and popular articles, are reported here for the first time.

First, the Introduction and the Discussion sections of the APL article were found here to contain more Material processes compared to these sections in the PSL article. In the APL articles the information in the Introduction and Discussion sections helps the readers understand what cholera does or how the treatment that is given is affective. These are actions of "doing" and "happening" and they are realized by Material processes. There are less explanations of this kind in the PSL article, and this can explain the higher proportion of Material processes in these sections. Second, there is a difference in the proportion of Verbal processes found in the Introduction sections of the APL and PSL articles. In the PSL article the introduction section is aimed mainly to review the research made in the specific field, and this is mainly realized by Verbal processes (for example: "have been described previously", "have been recently reported"). However, the Introduction section of the APL article is aimed to introduce the students to the content knowledge of a specific scientific domain and to provide explanations and definitions which are relevant to the experiments presented in the article. Third, there is a high proportion of Material processes in the Results section of the APL. It was found that the APL article includes repetitions of the methodological procedures that are presented in the Methods section of the article. These repetitions do not exist in the original PSL article. Since the methods section is characterized with a high proportion of Material processes, the repetitions of the methodological procedures in the results section of the APL article lead to a higher proportion of Material processes in this section. Theses repetitions may also increase the cohesion of the article, making it more coherent for students. Finally, there are Relational processes in the methods section of the APL article. APL article is characterized by explanations which connect the methods and the results. These explanations help to characterize and identify the stages of the methodological procedure, and are thus realized mainly by Relational processes. These explanations are absent in the original PSL article. These explanations can contribute to the cohesion of the text as well.

8.1.1.3 Cohesion and coherence of the APL article

The quantitative and qualitative analyses of the cohesive ties in the PSL and the APL articles show that several grammatical and lexical relations increase the APL articles' cohesion. Cohesion is a characteristic of the text, whereas coherence is a characteristic of the reader's mental representation of the text content (Graesser et al., 2004). The cohesive devises in the language cue the reader on how to form a coherent representation. The coherence relations are constructed in the mind of the reader and depend on the skills and knowledge that readers bring to the situation, such as knowledge about the subject matter and adequate linguistic and discourse cues (Graesser et al., 2004). Thus, coherence is a psychological construct, whereas cohesion is a textual construct. Therefore, it should be noted, that the PSL article is cohesive, and include numerous cohesive ties. However, non-specialist readers find this text non-coherent since they lack knowledge which is critical for understanding and connecting between ideas in the text. PSL articles are written for scientists and therefore their authors can assume that their readers have the relevant knowledge to properly connect (lexically) items in the text (Myers, 1991). APL adaptors cannot assume that readers (i.e., high school students) have the relevant knowledge of lexical relations. Therefore, some of the relations should be introduced either explicitly or implicitly. According to Halliday and Hasan (1976), "it is the continuity provided by cohesion that enables the reader or listener to supply all the missing pieces, all the components of the picture which are not present in the text but are necessary to its interpretation" (p. 299). Thus, by providing the readers with the missing information, by defining terms and marking new terms used in the text, by elaborating about the methods, by repeating some of the sections in the article, by increased lexical and semantic overlapping, and more causal relations - APL authors increase the text cohesion, thus, making it more coherent for non-specialist readers.

8.1.2 The functionality of the APL language

In the PSL articles linguistic features reflect scientists shared beliefs. These texts have evolved certain grammatical features, figures of speech and rhetorical patterns, which reflect on the scientist' worldview and reasoning (Lemke, 1990; Martin, 1993). The scientific discourse in PSL articles combines theoretical technicality with reasoned argument, each relying on grammar's power of condensing extended meanings in a highly structured and nominalized form (Halliday & Matthiessen, 2014).

In contrast to PSL articles, popular articles are produced in different social contexts, and have different communicative functions (Goldman & Bisanz, 2002). Accordingly, popular articles share linguistic features that reflect the context and purpose of the genre, focusing on people and what they say or think (Parkinson & Adendorff, 2004).

APL articles aim to represent science realistically to non-scientists, and to promote important aspects of high school students' scientific literacy that are harder to achieve using textbooks or popular articles. It has been claimed that the APL article is somewhat closer to the PSL article than to the popular article, since it represents the structure, claims, content and uncertainty that are found in the PSL article (Yarden et al., 2015). The results obtained from the linguistic analysis strengthen this claim. The APL article analyzed in this study was found to construe specific realms of scientific knowledge and beliefs, in a form that is more readable and interpretable to students.

A comparison of the attributes characterizing the PSL, APL and popular articles in eight different dimensions is presented in Table 8.1. The authors and the target audience of APL articles are different from those of PSL articles. However, APL and PSL articles are similar in the main text type, the organizational structure, the content and the presentation of science. Two new attributes were added to the previously published table (Yarden et al., 2015): the main purpose of each genre and the functionality of the language in each text genre (Table 8.1). Concerning the latter, the PSL and APL articles share the same function of construing specific realms of scientific knowledge and beliefs, but the adaptations in the APL article’s language make the text less complex and, thus, probably more appropriate for high school students. Since linguistic features can reflect beliefs about knowledge, this finding suggests that the APL article may serve as an apprentice-genre and be used as a tool for learning the unique features of the scientific language and reasoning. This is not the case for popular articles which are different from both PSL and APL articles in all parameters, including the functionality of language (Table 8.1).

Table 8.1: Various attributes characterizing three text genres: PSL, APL and popular articles, following Yarden et al. (2015). New attributes: main purpose and functionality of language[a]

	PSL	**APL**	**Popular**
Main purpose	Having claims accepted by the scientific community (Hyland, 1998; Myers, 1989)	Enable the use of scientific research articles in schools, as a model of scientific reasoning and communication (Yarden et al., 2001)	Communicating scientific findings to nonscientists (Norris & Phillips, 1994)
Authors	Scientists (Myers, 1989; Yore et al., 2004a)	Science educators and scientists (Norris et al., 2009b; Yarden et al., 2001)	Science journalists (Nwogu, 1991)
Target audience	Scientists (Myers, 1989; Yore et al., 2004a)	Students (Yarden et al., 2001)	General public (Nwogu, 1991)
Main text type	Argumentative (Hyland, 1998; Jiménez-Aleixandre & Federico-Agraso, 2009; Suppe, 1998)	Argumentative (Norris et al., 2009b)	Varying (Expository, Narrative, Argumentative) (Jiménez-Aleixandre & Federico-Agraso, 2009; Penney et al., 2003)
Organizational structure	Canonical (Suppe, 1998; Swales, 2001)	Canonical (Baram-Tsabari & Yarden, 2005; Yarden et al., 2001)	Non-canonical (Nwogu, 1991)
Content	Evidence to support conclusions (Suppe, 1998)	Evidence to support conclusions (Falk & Yarden, 2009; Yarden et al., 2001)	Facts with minimum evidence (Jiménez-Aleixandre & Federico-Agraso, 2009)
Presentation of science	Uncertain (Suppe, 1998)	Uncertain (Falk & Yarden, 2009; Yarden et al., 2001)	Various degrees of certainty (Penney et al., 2003)
Functionality of language	Construing special realms of scientific knowledge and beliefs (Fang, 2005)	**Construing specific realms of scientific knowledge and beliefs in a form that is more readable and interpretable to students**	Reporting about new scientific findings in a form that is interpretable by nonscientists (Norris & Phillips, 1994; Parkinson, 2001)

[a] The results obtained from this study are marked in **bold**

8.2 Towards a disciplinary view of using scientific text

In the last years reading has become accepted as one of the practices needed in order to become literate in science (Ford, 2009; National Research Council (NRC), 2012; Norris & Phillips, 2003; Phillips & Norris, 2009; Yore, 2000). Nonetheless, there are many challenges involved in meeting the literacy demands in high schools; texts are underused in science classrooms (Wade & Moje, 2001; Wellington & Osborne, 2001), and much focus is given on generalized literacy strategies, resulting in many students that are lacking the disciplinary literacy skills necessary to succeed in secondary schooling (Fang & Schleppegrell, 2010). Norris and Phillips (2008) argue that reading in science can be best taught as an inquiry process, which requires an active construction of new meanings, contextualization, and the inferring of authorial intentions (Haas & Flower, 1988; Norris & Phillips, 2008). However, reading is often perceived by students (and their teachers) as a process of recognizing words and locating information in the text, and difficulties in reading scientific texts are perceived as difficulties to understand the text's vocabulary (Norris & Phillips, 2003).

As previously presented, reading APL articles was previously found to help students improve their understanding of inquiry, active learning and integration of knowledge (Falk & Yarden, 2009). Moreover, reading APL articles has been found to improve students' understanding of the nature of scientific inquiry, their ability to criticize scientific research, compared to students who read a popular article (Baram-Tsabari & Yarden, 2005; Norris et al., 2012). APL articles were also found to be useful in promoting students' understanding of scientific and mathematical reasoning and argument, and for introducing modern science into the school (Norris et al., 2009b). In addition, following the use of an APL article students' level of inquiry thinking and uniqueness was improved (Brill & Yarden, 2003).

The abovementioned studies about the use of APL articles in class, strongly suggest that these texts may improve students' scientific literacy and reasoning about science. Nonetheless, the results obtained from this study imply that the language of the APL article, although adapted to match high school students' cognitive skills and knowledge, can still be challenging for students to read and comprehend. It was shown that readers with a low level of background knowledge benefit more from coherent and explicit texts (such as popular articles), while for readers with an adequate background knowledge coherence gaps can stimulate constructive activities which are better for learning

(McNamara et al., 1996). These findings may explain the benefits that students gained when reading an APL article. In addition, differences in texts' authoritativeness may influence students' ability to criticize the text, since the writers' goal is different, and it reflects on the way information is communicated to the readers.

Still, students face many challenges when reading disciplinary text. For example, Brill et al. (2004) analyzed the reading strategies of two students while they were reading an APL article, and found that although the students applied some previously acquired well-established reading comprehension strategies, the students encountered some major difficulties in comprehending the article. Readers need specific skills for understanding science texts (Fang et al., 2006), Thus, although basic literacy skills, such as perceptual and decoding skills, are necessary for all reading tasks, they cannot be generalized and applied to all texts, especially as one progresses to those of a more specialized disciplinary nature (Shanahan & Shanahan, 2008).

8.2.1 Rethinking the use of texts in class

8.2.1.1 Towards a disciplinary view of teaching using texts

Teachers that operate on the notion that there is nothing particularly distinctive about the genres in which science is communicated may fail to mentor their students in the necessary literacy practices which would help them read in science (Osborne, 2014).

The distinctive quality of scientific language lies in "the wording" as a whole. Technical terms, for example, are not in themselves, difficult to master, however teachers focus on technical terms since "vocabulary is much more obvious and easy to talk about". Knowing the vocabulary of science without understanding how it is used, or why, has little value for understanding science, or becoming literate in science (Osborne, 2002). Thus, readers need specific skills for understanding science texts other than dealing with the specialized vocabulary. Accordingly, education programs should support students in acquiring the facility of science language and the ability to use and comprehend the full range of science text and representations (Gee, 2004).

Based on these assumptions and on the results obtained here from the texts' analysis, I designed a unique professional development program for in-service biology teachers, that can serve as a model for teachers' professional development towards reaching a mastery of teaching disciplinary literacy.

Eylon and Bagno (2006) suggested a three staged model of teachers PD. In the first stage teachers should realize the need to introduce some innovation in the particular topic. In this stage teachers are enabled to identify problems encountered by them- as learners, and by their students- through diagnosis. In the second stage teachers are introduced with new instructional strategies, leading teachers though a process of successive refinement of goals and means, an approach taken by curriculum developers. In this stage teachers design an instruction unit based on expert consultation, critique by peers, and observation of other strategies used by colleagues. In the third stage, teachers evaluate the instruction that they have developed and report about their evaluation to participants and other colleagues (Eylon & Bagno, 2006). Following this model of PD, I suggest a model for using a genre-based grammar pedagogy to reach a mastery of teaching disciplinary literacy (Table 8.2).

Table 8.2: A model for teachers' professional development towards reaching a mastery of teaching disciplinary literacy (following Eylon & Bagno, 2006).

Teachers as learners (Stage I)	Teachers were taught the epistemology of science, and read several disciplinary texts. Teachers also diagnosed their students' epistemological understanding with a questionnaire (Part 1 of the course).
Teachers as curriculum developers (Stage II)	A genre-based grammar approach for learning about scientific texts. Teachers were introduced to the APL article, and to new teaching strategies which emphasize the language of science and its connection to scientific epistemology (Part 2 of the course).
	Teachers adapted an APL article to meet their needs as they were defined and refined during the course, and refined the adaptation mainly through group discussions and peer critique. The APL was also used as an apprenticeship-genre (Part 3 of the course).
Reflection (Stage III)	Teachers reflected on the APL article that they have adapted and planned a minimodule for teaching using the APL article (Part 4 of the course)

Teachers should be prepared to facilitate sophisticated epistemological discourse in order for their student to engage in such a discourse. For this, teachers need to have sophisticated epistemological understanding (Sandoval & Morrison, 2003). However, many of them do not (Lederman, 1992). Engaging in scientific reasoning requires a body of epistemic knowledge which needs to be taught explicitly (Kind & Osborne, 2017). Therefore, teachers were explicitly taught the epistemology of science and the ways it is reflected in the text structure and language of scientific articles.

In addition, teachers practiced the writing of an APL article. The APL in this respect was used as an apprenticeship-genre. According to Brown et al. (1989), engaging in an authentic activity is the only way learners can gain access to the standpoint that enables practitioners to act meaningfully and purposefully. Biology teachers are not scientists; they cannot be expected to write an authentic PSL article. However, since the APL and

PSL articles were found to have several shared features, writing an APL article was considered to be a legitimate peripheral participation (Lave & Wenger, 1991), enabling the teachers to engage in the kinds of writing that full participants (i.e., scientists) do.

The objectives of teachers professional development programs are to support teachers in making changes to elements of their existing knowledge and skills, and to support them in changing their existing beliefs about science and about teaching, where these seem needed (Gilbert, 2010). Accordingly, one of the major goals of the PD reported here was to provide teachers with knowledge about the technicality and functionality of scientific text, and also about the epistemology of science. But more importantly, the goal was to promote teachers' understanding of scientific texts by explicitly connecting between the language and epistemology. Having an understanding of "the structure of the genres and the grammar of technicality" (Martin, 1993) allows teachers to shift their focus from solely the article content to the language of the article as well. This knowledge provided the teachers with a new tool to assess disciplinary texts, and to understand these texts in a whole different level.

Evidence from the discourse analysis suggests that teachers expanded their views about the use of text in their class, and shifted towards a more disciplinary view for teaching using texts. Specifically, teachers were able to connect the language of science and the epistemology of science to critically assess different scientific text genres, and use the language of science to reflect on their own teaching and on the APL that they adapted during the course. At the beginning of the course teachers reported they use text to promote intermediate literacy skills (Shanahan & Shanahan, 2012, p.7). During the course, teachers adopted a more disciplinary view for teaching with text, and used the newly acquired knowledge about epistemology and language to critically assess various scientific texts, and to think about new ways to promote disciplinary literacy. This change in the teachers' views may seem small and local, but it is significant. Despite the importance of language in learning science, most biology teachers typically view their job as teachers of content, and typically prioritize content coverage rather than on reading or language instruction in their content area (Fang, 2005). Knowledge of genres has an important consciousness-raising potential for teachers. Becoming more aware of the ways meanings are created, teachers can better reflect on their own writing and that of their students. They can also make decisions about teaching methods and materials to use, and approach current instructional paradigm with a more critical eye (Hyland, 2007). In this respect I conclude that the scientific literacy course was effective.

Nonetheless, Darling-Hammond et al. (2017) define an effective professional development as “structured professional learning that results in changes in teacher practices and improvements in student learning outcomes” (p. 2). I cannot state if and how the teachers that participated in the course changed their practices, or if their students’ learning outcomes improved. My insights regarding the teachers’ development and course effectivity are based on the teachers’ reports during the course, and on their written assignments throughout the course. This should be further analyzed in order to assess the full effectivity of this PD.

8.2.1.2 Using APL articles to promote NOS understanding and critical thinking

One aspect of disciplinary literacy requires a focus on how evidence is used to construct explanations. Thus, students should understand the criteria used in science to evaluate evidence, and to recognize the standard genres of science to infer meaning from scientific texts (Osborne et al., 2004; Schwarz, 2009). PSL articles convey epistemological assumptions scientists operate with. Popular articles are different in their epistemological assumptions. Thus, it was previously suggested that PSL articles hold more potential for improving students' epistemological understanding of science (Braun & Nuckles, 2014). APL articles were found to improve students' understanding of the nature of science, and the ability to criticize scientific research, compared to students who read a popular article having the same scientific content (Baram-Tsabari & Yarden, 2005). However, it is popular articles that the overwhelming majority of students will need to read critically in their lives, and therefore they should be taught how to read such texts critically (Osborne, 2009). Unfortunately, students were found to have severe difficulties to interpret correctly popular articles, which resulted in their inability to critically assess the texts they read (Norris & Phillips 1994).

Based on the abovementioned data, I designed an intervention aimed at promoting students' NOS understanding and critical thinking skills. In this intervention all the students participated in lessons about argument fallacies, and then one group of students read and debated about two popular articles, and a second group of students read and debated about two APL articles. The advantage of a discourse-based model is that it acknowledges the role of social interaction in the construction of argument (Felton & Kuhn, 2001). Students were asked to read and criticize a popular article and to answer a NOS questionnaire, prior to the intervention, and following the intervention. Students in both groups showed a significant improvement of the argumentative NOS component in the NOS questionnaire. The APL group also improved in the understanding of the tentative nature of scientific knowledge. It was previously found that the understanding of argumentative NOS of students who read a PSL article and an APL articles was improved compared to students who read a popular article (Braun & Nuckles, 2014). However, no difference was found in other components of epistemology examined here. Namely, the absence of significant differences in the other dimensions of epistemological understanding can be explained by the initial level of students' understanding which was relatively high at the pre-questionnaire. In addition, epistemological understanding is considered as a more or less independent belief and therefore can change according to the context and grain size of the selected texts in the intervention (Sandoval & Morrison, 2003). Finally, developmental models of personal epistemology consider changes in beliefs about knowledge and knowing to occur over years of schooling (e.g., Schommer et al., 1997). Thus, the effect of the short intervention on one dimension of epistemology can be considered remarkable. It was previously found that epistemological beliefs and cognitive dispositions predicted acceptance of scientific knowledge in controversial scientific topics (Sinatra et al., 2003). Thus, changes in epistemology may be pointing to changes in students' cognitive dispositions, i.e., the students' tendency or openness to accept an epistemic change.

The improvement in students' argumentative NOS in both groups and the significant improvement in students' critical thinking in both groups suggest that engaging with contradictory articles of any kind may have a positive effect on students' epistemological understanding and on their ability to assess claims made in the popular article. From a social constructivist perspective, argumentative dialogue provides an ideal context for knowledge building. When students explore their diverging views on a topic, they engage in a host of activities that socially scaffold knowledge construction by producing questions, statements and objections that prompt each other to clarify claims, provide evidence and rebut counterclaims (Felton & Kuhn, 2001). In addition, it may be possible that the first part of the intervention, in which students were taught about fallacies and the ways to recognize them had an impact on their ability to criticize the popular article in the post-questionnaire. Still, it was found that students who read two contradictory APL articles in the second part of the intervention improved significantly more than students who read two contradictory popular articles. These results suggest that although engaging with contradictory articles and debate has a significant effect on students' ability to criticize popular articles, the genre of the text also influence the students' ability to evaluate evidence. Students who engaged with two APL articles showed greater improvement in their ability to criticize a popular article. From the SFL perspective, epistemological assumptions encoded in rhetorical and stylistic features can be assumed to vary by genre (Fang, 2005, 2013; Halliday, 1993b), and hence it may explain the differences found between the APL and popular groups. Moreover, it is possible that if students are presented with research articles, they can gain a clearer view of what is actually involved in the original research and what was left out in the popular article. "Comprehending why ideas are wrong matters as much as understanding why other ideas might be right" (Osborne, 2010, p.464). Thus, students must know what they don't know to assess a popular article.

Coping with contradictory information is an important skill in the 21st century. Preparing students to life as citizens requires students to learn how to assess sources of information, authority of authors, and the general quality of texts.

8.3 Research implications- taking the language into account

It takes more than learning the content of a particular text to truly understand it (Hynd-Shanahan, 2013). Disciplinary enculturation requires the learning of the language patterns that construct the knowledge, values, and worldview of the discipline. Science is a socially situated practice in which scientists' values for what counts as good questions, appropriate methods, and good answers are constructed and negotiated within particular scientific disciplines and communities (Sandoval & Morrison, 2003). Such practices are inherently epistemic, based on ideas about what kind of knowledge is valued. Based on the socio-cultural perspective and cognitive apprenticeship- to learn science is to be apprenticed into the reasoning and discursive practices of particular scientific communities. Such an apprenticeship is inherently epistemic, necessarily including the development of standards for evaluating both knowledge claims and the methods for generating them (Sandoval & Morrison, 2003).

Many scholars call for literacy instruction that would better support the reading of disciplinary texts (Alvermann & Rush, 2004; Biancarosa & Snow, 2004; Fang & Schleppegrell, 2010; Hynd-Shanahan, 2013; Moje, 2008; Osborne, 2014; Pearson et al., 2010). Using APL articles as an apprenticeship genre, for learning scientific reasoning and communication, can promote teachers' and students' disciplinary literacy. However, for the latter, instruction should focus on the ways knowledge is created and communicated in the specific discipline while taking the language into account

(Hynd-Shanahan, 2013; Moje, 2008). Although content is clearly important, using APL articles to teach only content knowledge reflects, in my opinion, a misunderstanding of the goals of science teaching. APL articles should be used to develop students' disciplinary literacy, as a *tool* for learning its unique features, and the reasoning that is reflected in the way the articles are written—*no matter what the content*.

The selection of text materials for science teaching is an important implication drawn from this study. Teachers and science educators, who wish to adapt PSL articles for classroom use, should be aware to the form of language they use when adapting the article, and be careful with the extent to which they are popularizing the texts. SFL analysis may serve as a useful tool for evaluating the functionality of language in the adapted texts. Reading APL articles may be a suitable resource for promoting disciplinary literacy. However, since APL articles require that students have some background knowledge, the right timing for using the adapted text, and the purpose for using the adapted text during instruction should be carefully considered. Nevertheless, popular articles are valuable resources as well. Popular articles are simpler, more available to science teachers, and they make the science more accessible to students (Parkinson & Adendorff, 2004). They were also found to be more appealing and motivating to read than APL articles (Baram-Tsabari & Yarden, 2005). However, popular articles may have a different influence on students' epistemological understanding and critical reading skills. Nonetheless, the improvement in students' understanding of NOS and critical thinking skills of students who read two contradictory popular articles imply that teachers who find the APL articles too challenging for their students' can still benefit from this activity. Still, for disciplinary literacy to develop, students should be able to decode and interpret more complex forms of text, to recognize the nature and function of genres specific to the discipline, and "to use author intent as a frame for a critical response" (Osborne, 2014).

Thus, I suggest integrating APL and popular articles in science instruction. The popular article may fill some informational gaps for students who lack the prior knowledge required for understanding the content of the APL article, and it may also improve students' attitudes towards reading scientific texts. However, to promote students' disciplinary literacy teachers must also highlight the structural and linguistic differences between these scientific text genres, and discuss with their students how these differences reflect the context and communicative purposes of the genre. Recognizing discipline-specific ways of using language can promote students scientific epistemology understanding, and may enable them to better read and evaluate texts in the discipline (Fang, 2012).

Is it the science teacher's job to teach her students how to read scientific texts? My answer to this question is undoubtedly – Yes! In this respect, every teacher is a language teacher. To develop students' disciplinary literacy, teachers should teach their students how to read specialized disciplinary texts, and in doing so they must emphasize the specialized linguistic features and their functionality in these texts. Students will not learn to read scientific texts by reading other forms of literature. Students need to be explicitly taught strategies for reading biology texts, and for understanding the tradition of biology investigation, including the way knowledge is created, shared and evaluated by the biology research community (Hynd-Shanahan, 2013).

8.4 Limitations

There are several limitations to this study. First, this study presents an analysis of two set of articles. Thus, it may limit the generalizations that can be drawn from this study with regards to the differences between the three different genres, and especially with regards to the APL genre. The results obtained from the analysis of two APL articles that were written by different authors were similar, thus, hinting that the results presented here are not limited to the specific set of articles that were analyzed in this study. Nonetheless, the results from the analysis presented in this article should be taken with caution, and should not be generalized to all APL articles.

Second, the analysis presented in this study suggests that the adaptations made in the APL article make the text easier to read and comprehend. Nonetheless, it should be noted, that different students have different reading skills, prior knowledge and motivation, all of which were found to influence text comprehension (Oakhill & Cain, 2014).

Third, the results from the teachers' professional development program were obtained from one course, as a case study. This may limit the generalizations that can be drawn from this research. In addition, since a follow-up support of teachers was not carried out, this was a weakness in the PD approach, and in assessing its effectivity.

Finally, this study presents three studies that were carried out using different methodologies, viewing the use of language in various scientific text genres from the perspective of the text, the teachers and the students. At this point in time, the three perspectives may seem not to be completely aligned. But it is my hope that the readers of this thesis will see the promise these three perspectives hold for promoting the acquisition of disciplinary literacy in secondary schools.

9. Some practical ideas and future directions

This section is a part of a book chapter that was accepted for publication (Ariely & Yarden, 2017). The full chapter is presented in Appendix 13.

9.1 Using texts for learning about the unique features of scientific text genres

In the following sections I would like to suggest some practical ideas for using the language of scientific text for learning the reasoning and communication in science.

This following activity is aimed at promoting students' understanding of the different genres of scientific text and their unique linguistic features.

I shall demonstrate with a concrete example that was handed to 11th grade students learning biology, as part of their biology class:

Below are two paragraphs taken from two different scientific texts genres. One is taken from an APL article (Zer-Kavod & Yarden, 2013), and the other is taken from a popular article (Guynup, 2000). Can you tell which is which?

a. Why edible vaccines? The World Health Organization (WHO) has called for new strategies to deliver vaccines. WHO estimates that 10 million children die in developing countries each year from infectious diseases that could be prevented with vaccines. Existing vaccines are expensive and require a semi-skilled person to give the injection, with needles that are hard to come by in developing countries. Reused needles can transmit viruses such as Hepatitis B and C and HIV. Injectable vaccines also require refrigeration. "In some countries, you never know when the electricity is going to go off," says Arntzen.

b. Recently, a few attempts have been made at creating an edible vaccine with plants, by inserting genes into the plant cell and integrating them into the cell nuclear genome. The main problem with these attempts was the low level of expression of engineered proteins in the cell (0.02-0.5% of the total soluble proteins in the cell). Another disadvantage of integrating genes into the cell nuclear genome is the ecological risk inherent in the transition of genes from the transgenic plants to the non-genetically modified plants. Inserting the genes and integrating them into the plant chloroplast genome may serve as a solution to both of these problems, since each plant cell contains hundreds of chloroplasts and each chloroplast has a large number of chloroplast DNA molecules, which increases the expression level.

The first paragraph is taken from the popular article, and the second is taken from the APL article. All the high school students who read these two paragraphs identified correctly the origin of each text, but more interesting were the students' explanations for how they could distinguish between the two genres. Students were able to identify differences in the language of the paragraphs, in the rhetorical structure of the sentences, in the level of technicality and in the texts' authoritativeness. This is interesting because this was done intuitively by the students, before learning anything about the unique features of the scientific language.

In the next stage of the activity, the full texts were presented to the students, and a comparison between research articles and popular articles was made by the students (with the help of the teacher). The differences between the research article and the popular article are apparent to everyone who reads the articles, even though they are implicit. This activity can make the implicit knowledge explicit. By doing so, teachers can help their students to understand and reflect on the different communicative goals of each text genre.

9.2 Using APL articles for learning about the functionality of language

The following teaching and learning activity is aimed at promoting secondary school students' understanding of the language of science as a system for construing meaning in a specific context. In this activity, students are given two paragraphs from an APL article (Zer-Kavod & Yarden, 2013); one was taken directly from the article, and the other one was modified. The paragraphs are essentially identical, except for one grammatical feature which is purposely modified. Students were asked to compare the paragraphs and decide which paragraph is the original one, and which is a 'fake' one. Here I present two different examples, where each is designed to present a different feature of scientific language:

In the following paragraphs, taken from the methods section of the article, can you tell which is the original, and which is the fake one?

a. In order to examine the development of immunity against cholera and malaria, we fed the mice with the genetically modified tobacco plants. We crushed and melted transgenic tobacco leaves expressing the two cholera and malaria proteins, and fed them to the mice. An additional group of mice that we fed with unmodified tobacco leaves served as a control group. There were ten mice in each trial group. We fed the mice with the genetically modified plants ten times for approximately 300 days of the experiment. After administering the last dose of the vaccine, we exposed the mice to the disease agents (the cholera toxin or the Plasmodium parasite) and examined the immune response to the disease.

b. In order to examine the development of immunity against cholera and malaria, the mice were fed with the genetically modified tobacco plants. Transgenic tobacco leaves expressing the two cholera and malaria proteins, were crushed and melted, and were fed to the mice. An additional group of mice fed with unmodified tobacco leaves served as a control group. There were ten mice in each trial group. The mice were fed with the genetically modified plants ten times for approximately 300 days of the experiment. After administering the last dose of the vaccine, the mice were exposed to the disease agents (the cholera toxin or the Plasmodium parasite) and the immune response to the disease was examined.

The second paragraph is taken directly from the APL article, and the first paragraph is the modified one. The difference between the paragraphs lies in the way verbs are used in them. In the first paragraph the verbs are active, and in the second the verbs are passive (e.g. “we fed the mice with the genetically modified tobacco plants” vs “the mice were fed with the genetically modified tobacco plants”). The use of verbs also makes a difference to the presentation of human participation. In the first paragraph the actors (i.e., the scientists) are present, but in the second they are absent. Absence of human actors is an important feature of scientific writing, and it has a function in producing objectivity in the text (Fang, 2005; Schleppegrell, 2002).

Another example is taken from the discussion section of the same APL article.

a. We suspect that the new spatial structure created by fusing the two proteins also contributed to enhancing the immune response against them. It is also possible that the cholera antigen served as an immunological carrier for the malaria antigen and so contributed to enhancing the immune response against it. An elevation in the immune response against the malaria antigen can also explain the effective response of the malaria antigen antibodies in inhibiting the penetration of the parasite into red blood cells.

b. We are sure that the new spatial structure created by fusing the two proteins also contributed to enhancing the immune response against them. It is certain that the cholera antigen served as an immunological carrier for the malaria antigen and so contributed to enhancing the immune response against it. An elevation in the immune response against the malaria antigen definitely explains the effective response of the malaria antigen antibodies in inhibiting the penetration of the parasite into red blood cells.

In the above example, the difference between the paragraphs is in the hedging. The first paragraph is taken directly from the APL article, and the second paragraph is the modified one. The difference between the paragraphs lies in the level of certainty concerning the factuality of statements. In the first paragraph the statements are presented as uncertain by using modal verbs and other types of hedging, while in the second paragraph the statements are presented as certain (e.g. “We suspect that …” vs “We are sure that …”, “It is also possible that …” vs It is certain that …”, “An elevation in the immune response against the malaria antigen can also explain the …” vs. “An elevation in the immune response against the malaria antigen definitely explains the…”). Hedging is a significant communicative resource and a common feature of scientific texts. It allows writers to anticipate possible opposition to claims by expressing statements with precision and caution (Hyland, 1998).

Students who are not familiar with the role of hedging often wrongly assume that hedged statements are hypotheses, when in fact these statements are the conclusions in the article (data not shown).

Thus, by comparing the paragraphs as presented above, teachers can help their students to understand grammatical features in scientific language, and, more importantly, to appreciate why they are important, what their role is, and how the changes in the grammar change the reasoning in the article, and the author’s message.

Finally, using APL articles to emphasize the unique linguistic features and their functionality in the text, may have a positive effect on students’ understanding of scientific reasoning and epistemological understanding, and may also improve students’ scientific writing.

10. References

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. Science Education, 82(4), 417-436.

Alvermann, D. E., & Rush, L. S. (2004). Literacy intervention programs at the middle and high school levels. Adolescent Literacy Research and Practice, 210-227.

Anderberg, E., Svensson, L., Alvegård, C., & Johansson, T. (2008). The epistemological role of language use in learning: A phenomenographic intentional-expressive approach. Educational Research Review, 3(1), 14-29.

Anderson, J. R., Greeno, J. G., Reder, L. M., & Simon, H. A. (2000). Perspectives on learning, thinking, and activity. Educational Researcher, 29(4), 11-13.

Ariely, M., Livnat, Z., & Yarden, A. Authentic scientific texts in the science classroom: Taking the language into account. Submitted.

Ariely, M., & Yarden, A. (2017). Using authentic texts to promote disciplinary literacy in biology (in press). In Teaching Biology in Schools.

Asterhan, C. S., & Schwarz, B. B. (2016). Argumentation for learning: Well-trodden paths and unexplored territories. Educational Psychologist, 51(2), 164-187.

Au, K. H. (1998). Social constructivism and the school literacy learning of students of diverse backgrounds. Journal of Literacy Research, 30(2), 297-319.

Bailin, S., & Battersby, M. (2009). Inquiry: A dialectical approach to teaching critical thinking. In: J. Ritola (Ed.), *Argument Cultures: Proceedings of Ontario Society for the Study of Argumentation*. Paper presented at the OSSA, Windsor, ON.

Baram-Tsabari, A., & Yarden, A. (2005). Text genre as a factor in the formation of scientific literacy. Journal of Research in Science Teaching, 42(4), 403-428.

Bazerman, C. (1988). Shaping written knowledge: The genre and activity of the experimental article in science: University of Wisconsin Press Madison.

Biancarosa, G., & Snow, C. E. (2004). Reading next: A vision for action and research in middle and high school literacy. A report to the Carnegie Corporation of New York. Washington, DC: Alliance for Excellent Education.

Braun, I., & Nuckles, M. (2014). Scholarly holds lead over popular and instructional: Text type influences epistemological reading outcomes. Science Education, 98(5), 867-904.

Brill, G., Falk, H., & Yarden, A. (2004). The learning processes of two high-school biology students when reading primary literature. International Journal of Science Education, 26(4), 497-512.

Brill, G., & Yarden, A. (2003). Learning biology through research papers: A stimulus for question-asking by high-school students. Cell Biology Education, 2(4), 266-274.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. Educational Researcher, 18(1), 32-42.

Carter, M., Ferzli, M., & Wiebe, E. N. (2007). Writing to learn by learning to write in the disciplines. Journal of Business and Technical Communication, 21(3), 278-302.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. Science Education, 86(2), 175-218.

Cirino, P. T., Romain, M. A., Barth, A. E., Tolar, T. D., Fletcher, J. M., & Vaughn, S. (2013). Reading skill components and impairments in middle school struggling readers. Reading and Writing, 26(7), 1059-1086.

Collins, A., Brown, J. S., & Newman, S. E. (1988). Cognitive apprenticeship: Teaching the craft of reading, writing and mathematics. Thinking: The Journal of Philosophy for Children, 8(1), 2-10.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). Effective Teacher Professional Development. Palo Alto, CA: Learning Policy Institute.

Davey, B., & Miller, D. (1990). Topicalization and the processing of expository prose by children: Mediating effects of cognitive styles and content familiarity. Educational Psychology, 10(1), 23-38.

Davoodi-Semiromi, A., Schreiber, M., Nalapalli, S., Verma, D., Singh, N. D., Banks, R. K., et al. (2010). Chloroplast-derived vaccine antigens confer dual immunity against cholera and malaria by oral or injectable delivery, Plant Biotechnology Journal. 8(2), 223-242.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. Journal of Research in Science Teaching, 37(6), 582-601.

Driver, R., Asoko, H., Leach, J., Scott, P., & Mortimer, E. (1994). Constructing scientific knowledge in the classroom. Educational Researcher, 23(7), 5-12.

Driver, R., Newton, P. E., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. Science Education, 84(3), 287-312.

Duschl, R., & Grandy, R. (2013). Two views about explicitly teaching nature of science. Science & Education, 22(9), 2109-2139.

Erduran, S., & Jiménez-Aleixandre, M. P. (2008). Argumentation in Science Education. Florida State University-USA: Spinger, 3-27.

Evagorou, M., & Osborne, J. (2010). The role of language in the learning and teaching of science. In Osborne, J. & Dillon, J. (Eds.), Good Practice in Science Teaching: What Research Has to Say (pp. 135-157): Open University Press.

Eylon, B.-S., & Bagno, E. (2006). design model for professional development of teachers: Designing lessons with physics education research. Physical Review Special Topics-Physics Education Research, 2(2), 020106.

Falk, H., Brill, G., & Yarden, A. (2008). Teaching a biotechnology curriculum based on adapted primary literature. International Journal of Science Education, 30(14), 1841-1866.

Falk, H., & Yarden, A. (2009). “Here the scientists explain what I said.” Coordination practices elicited during the enactment of the results and discussion sections of adapted primary literature. Research in Science Education, 39(3), 349-383.

Fang, Z. (2005). Scientific literacy: A systemic functional linguistics perspective. Science Education, 89(2), 335-347.

Fang, Z. (2006). The language demands of science reading in middle school. International Journal of Science Education, 28(5), 491-520.

Fang, Z. (2012). Language correlates of disciplinary literacy. Topics in Language Disorders, 32(1), 19-34.

Fang, Z. (2013). Disciplinary literacy in science. Journal of Adolescent & Adult Literacy, 57(4), 274-278.

Fang, Z., & Coatoam, S. (2013). Disciplinary literacy: What you want to know about it. Journal of Adolescent & Adult Literacy, 56(8), 627-632.

Fang, Z., & Schleppegrell, M. J. (2008). Langauge and reading in secondary content areas. In Reading in Secondary Content Areas: A Language-Based Pedagogy (pp. 1-17). Ann Arbor: University of Michigan Press.

Fang, Z., & Schleppegrell, M. J. (2010). Disciplinary literacies across content areas: Supporting secondary reading through functional language analysis. Journal of Adolescent & Adult Literacy, 53(7), 587-597.
Fang, Z., Schleppegrell, M. J., & Cox, B. E. (2006). Understanding the language demands of schooling: Nouns in academic registers. Journal of Literacy Research, 38(3), 247-273.
Felton, M., & Kuhn, D. (2001). The development of argumentive discourse skill. Discourse processes, 32(2-3), 135-153.
Ford, D. J. (2009). Promises and challenges for the use of adapted primary literature in science curricula: Commentary. Research in Science Education, 39(3), 385-390.
Garty, E. (2012). Rice- The white lie (In hebrew). Davidson online (http://davidson.weizmann.ac.il/stub-15).
Garty, E. (2013). Non-scientific argument- milk health damage (in Hebrew). Davidson on line (http://davidson.weizmann.ac.il/online/maagarmada/doubt/%D7%95%D7%99%D7%9B%D7%95%D7%97-%D7%9C%D7%90-%D7%9E%D7%93%D7%A2%D7%99-%E2%80%93-%D7%A0%D7%96%D7%A7%D7%99-%D7%94%D7%97%D7%9C%D7%91_).
Gee, J. P. (2001). Reading as situated language: A sociocognitive perspective. Journal of Adolescent & Adult Literacy, 44(8), 714-725.
Gee, J. P. (2004). Language in the science classroom: Academic social languages as the heart of school-based literacy. In Soul, E. W. (Ed.), Crossing Borders in Literacy and Science Instruction: Perspectives on theory and Practice (pp. 13-32). Arlington, VA: NSTA Press.
Gilbert, J. K. (2010). Supporting the development of effective science teachers. In Osborne, J. & Dillon, J. (Eds.), Good Practice In Science Teaching: What Research Has To Say (pp. 274-300).
Glynn, S. M., & Muth, K. D. (1994). Reading and writing to learn science: Achieving scientific literacy. Journal of Research in Science Teaching, 31(9), 1057-1073.
Goldman, S. R., & Bisanz, G. L. (2002). Toward a functional analysis of scientific genres: Implications for understanding and learning processes. In J. Otero, J. A. Le`on & A. C. Graesser (Eds.), The Psychology of Science Text Comprehension (pp. 19-50). Mahwah, NJ: Erlbaum.
Goldman, S. R., & Snow, C. E. (2015). Adolescent literacy: Development and instruction. In Pollatsek, A. & Teriman, R. (Eds.), The Oxford Handbook of Reading (pp. 463-478). New-York: Oxford University Press.
Graesser, A. C. (2007). An introduction to strategic reading comprehension. In McNamara, D. S. (Ed.), Reading Comprehension Strategies: Theories, Interventions, and Technologies (pp. 3-26). New Jersey: Lawrence Erlbaum Associates, Inc.
Graesser, A. C., McNamara, D. S., Cai, Z., Conley, M., Li, H., & Pennebaker, J. (2014). Coh-Metrix measures text characteristics at multiple levels of language and discourse. The Elementary School Journal, 115(2), 210-229.
Graesser, A. C., McNamara, D. S., & Kulikowich, J. M. (2011). Coh-Metrix providing multilevel analyses of text characteristics. Educational Researcher, 40(5), 223-234.
Graesser, A. C., McNamara, D. S., Louwerse, M. M., & Cai, Z. (2004). Coh-Metrix: Analysis of text on cohesion and language. Behavior Research Methods, Instruments, & Computers, 36(2), 193-202.

Greeno, J. (1996). Cognition and Learning. In J. Greeno, A. Collins & L. Resnick (Eds.), Handbook of Research in Educational Psychology: New York: Macmillan.
Greeno, J. G. (1998). The situativity of knowing, learning, and research. American Psychologist, 53(1), 5.
Guynup, S. (2000). Seeds of a New Medicine. Genes, Plants, and Edible Vaccines, J. Craig Venter Institute GNN. Genome News Network, from (http://www.genomenewsnetwork.org/articles/07_00/vaccines_trees.shtml)
Haas, C., & Flower, L. (1988). Rhetorical reading strategies and the construction of meaning. College Composition and Communication, 39(2), 167-183.
Halliday, M., & Hasan, R. (1985). Language, Context, and Text: Aspects of Language in a Social-Semiotic Perspective. Oxford: Oxford University Press.
Halliday, M. A. K. (1978). Language as Social Semiotic: The Social Interpretation of Language and Meaning. Edward Arnold, London.
Halliday, M. A. K. (1993a). General orientation. In Halliday, M. A. K. & Martin, J. R. (Eds.), Writing Science (pp. 2-21). Pittsburgh: University of Pittsburgh Press.
Halliday, M. A. K. (1993b). Some grammatical problems in scientific English. In Halliday, M. A. K. & Martin, J. R. (Eds.), Writing Science: Literacy and Discursive Power (pp. 69-85). Pittsburgh: University of Pittsburgh Press.
Halliday, M. A. K. (1993c). Towards a language-based theory of learning. Linguistics and Education, 5(2), 93-116.
Halliday, M. A. K. (2004). The Language of Science (Collected works of MAK Halliday Vol. 5). New York: Continuum, 135-237.
Halliday, M. A. K., & Hasan, R. (1976). Cohesion in English. London: Longman.
Halliday, M. A. K., & Matthiessen, C. (2014). Halliday's Introduction to Functional Grammar (4th ed.). London and New York: Routledge.
Hayes, T. B., Collins, A., Lee, M., Mendoza, M., Noriega, N., Stuart, A. A., et al. (2002). Hermaphroditic demasculinized frogs after exposure to the herbicide atrazine at low ecologically relevant doses. Proceedings of the National Academy of Sciences, 99(8), 5476-5480.
Hofer, B. K. (2001). Personal epistemology research: Implications for learning and teaching. Educational Psychology Review, 13(4), 353-383.
Holliday, W. G., Yore, L. D., & Alvermann, D. E. (1994). The reading–science learning–writing connection: Breakthroughs, barriers, and promises. Journal of Research in Science Teaching, 31(9), 877-893.
Hurd, P. D. (1998). Scientific literacy: New minds for a changing world. Science Education, 82(3), 407-416.
Hyland, K. (1996). Writing without conviction? Hedging in science research articles. Applied Linguistics, 17(4), 433-454.
Hyland, K. (1998). Hedging in Scientific Research Articles (Vol. 54). Amsterdam and Philadelphia: John Benjamins Publishing.
Hyland, K. (2002). Authority and invisibility: Authorial identity in academic writing. Journal of Pragmatics, 34(8), 1091-1112.
Hyland, K. (2007). Genre pedagogy: Language, literacy and L2 writing instruction. Journal of Second Language Writing, 16(3), 148-164.
Hynd-Shanahan, C. (2013). What does it take? The challenge of disciplinary literacy. Journal of Adolescent & Adult Literacy, 57(2), 93-98.
Hynd, C. R. (1999). Teaching students to think critically using multiple texts in history. Journal of Adolescent & Adult Literacy, 42(6), 428-436.

Israeli Ministry of Education. (2011). Syllabus of Biological Studies (10th-12th grade). In State of Israel Ministry of Education Curriculum Center (Ed.). Jerusalem, Israel http://meyda.education.gov.il/files/Mazkirut_Pedagogit/biology/tochnit17.7.17.doc.

Janick-Buckner, D. (1997). Getting undergraduates to critically read and discuss primary literature. Journal of College Science Teaching, 27(1), 29-32.

Jiménez-Aleixandre, M. P., & Federico-Agraso, M. (2009). Justification and persuasion about cloning: Arguments in hwang's paper and journalistic reported versions. Research in Science Education, 39(3), 331-347.

Kelly, G. J. (2008). Inquiry, activity, and epistemic practice. In Duschl, R. & Grandy, R. (Eds.), Teaching Scientific Inquiry: Recommendations for Research and Implementation (pp. 99-117). Rotterdam: Sense Publishers.

Kelly, G. J., McDonald, S., & Wickman, P.-O. (2012). Science learning and epistemology. In Fraser, B. J., Tobin, K. & McRobbie, C. J. (Eds.), Second International Handbook of Science Education (pp. 281-291). Dordrecht: Springer.

Kind, P., & Osborne, J. (2017). Styles of scientific reasoning: A cultural rationale for science education? Science Education, 101(1), 8-31.

Kintsch, W., & Van Dijk, T. A. (1978). Toward a model of text comprehension and production. Psychological Review, 85(5), 363.

Kloas, W., Lutz, I., Springer, T., Krueger, H., Wolf, J., Holden, L., et al. (2009). Does atrazine influence larval development and sexual differentiation in Xenopus laevis? Toxicological Sciences, 107(2), 376-384.

Knapp, P., & Watkins, M. (1994). Context-text-grammar: Teaching the genres and grammar of school writing in infants and primary classrooms. Broadway, Australia: Text productions.

Kolstø, S. D., Bungum, B., Arnesen, E., Isnes, A., Kristensen, T., Mathiassen, K., et al. (2006). Science students' critical examination of scientific information related to socioscientific issues. Science Education, 90(4), 632-655.

Kyle, W. C. (1995a). Editorial. Scientific literacy: How many lost generations can we afford? Journal of Research in Science Teaching, 32(9), 895-896.

Kyle, W. C. (1995b). Editorial. Scientific literacy: Where do we go from here? Journal of Research in Science Teaching, 32(10), 1007-1009.

Landauer, T. K. (2007). LSA as a theory of meaning. Mahwah, NJ: Lawrence Erlbaum Associates.

Lave, J., & Wenger, E. (1991). Situated Learning: Legitimate Peripheral Participation: Cambridge university press.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. Journal of Research in Science Teaching, 29(4), 331-359.

Lemke, J. L. (1990). Talking Science: Language, Learning, and Values. In. Norwood, New Jersey: Albex Publishing.

Litman, C., Marple, S., Greenleaf, C., Charney-Sirott, I., Bolz, M. J., Richardson, L. K., et al. (2017). Text-based argumentation with multiple sources: A descriptive study of opportunity to learn in secondary English language arts, history, and science. Journal of the Learning Sciences, 26(1), 79-130.

Livnat, Z. (2010a). Impersonality and grammatical metaphors in scientific discourse. The rhetorical perspective. Lidil. Revue de Linguistique et de Didactique des Langues(41), 103-119.

Livnat, Z. (2010b). Rhetoric of the Scietific Article (in Hebrew): Bar-Ilan University.

Martin, J. R. (1993). Literacy in science: Learning to handle texts as technology. In Halliday, M. A. K. & Martin, J. R. (Eds.), Writing Science: Literacy and Discursive Power (pp. 166-202). Pittsburgh: University of Pittsburgh Press.

Mason, L. (2007). Introduction: bridging the cognitive and sociocultural approaches in research on conceptual change: Is it feasible? Educational Psychologist, 42(1), 1-7.

Mayer, V. J. (1997). Guest editorial: Global science literacy: An earth system view. Journal of Research in Science Teaching, 34(2), 101-105.

McConachie, S. M. (2009). Disciplinary literacy: A principle-based framework In McConachie, S. M., Petrosky, A. R. & Resnick, L. B. (Eds.), Content Matters: A Disciplinary Literacy Approach to Improving Student Learning (pp. 15-31). San Francisco, California: Jossey-Bass.

McConachie, S. M., & Petrosky, A. R. (2009). Engaging Content Teachers in Literacy Development In McConachie, S. M., Petrosky, A. R. & Resnick, L. B. (Eds.), Content Matters: A Disciplinary Literacy Approach to Improving Student Learning (pp. 1-13). San Francisco, California: Jossey-Bass.

McNamara, D., Louwerse, M., Cai, Z., & Graesser, A. (2005). Coh-Metrix version 1.4, from http://www.cohmetrix.com/

McNamara, D. S. (2007). Preface. In McNamara, D. S. (Ed.), Reading Comprehension Strategies: Theories, Interventions, and Technologies (pp. xi-xv). New Jersey: Lawrence Erlbaum Associates, Inc.

McNamara, D. S., Kintsch, E., Songer, N. B., & Kintsch, W. (1996). Are good texts always better? Interactions of text coherence, background knowledge, and levels of understanding in learning from text. Cognition and Instruction, 14(1), 1-43.

McNamara, D. S., Louwerse, M. M., McCarthy, P. M., & Graesser, A. C. (2010). Coh-Metrix: Capturing linguistic features of cohesion. Discourse Processes, 47(4), 292-330.

Millar, R., & Osborne, J. (1998). Beyond 2000: Science Education for the Future: A Report with Ten Recommendations: King's College London, School of Education.

Moje, E. B. (2008). Foregrounding the disciplines in secondary literacy teaching and learning: A call for change. Journal of Adolescent & Adult Literacy, 52(2), 96-107.

Muench, S. B. (2000). Choosing primary literature in biology to achieve specific educational goals. Journal of College Science Teaching, 29(4), 255-260.

Myers, G. (1989). The pragmatics of politeness in scientific articles. Applied Linguistics, 10(1), 1-35.

Myers, G. (1991). Lexical cohesion and specialized knowledge in science and popular science texts. Discourse Processes, 14(1), 1-26.

National Academies of Sciences Engineering and Medicine. (2016). Science Literacy: Concepts, Contexts, and Consequences (No. 0309447593). Washington DC: Division of Behavioral and Social Sciences and Education.

National Research Council (NRC). (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas: The National Academies Press.

Norris, S. P., Falk, H., Federico-Agraso, M., Jiménez-Aleixandre, M. P., Phillips, L. M., & Yarden, A. (2009a). Reading science texts—epistemology, inquiry, authenticity—a rejoinder to Jonathan Osborne. Research in Science Education, 39(3), 405-410.

Norris, S. P., Macnab, J. S., Wonham, M., & de Vries, G. (2009b). West Nile Virus: Using adapted primary literature in mathematical biology to teach scientific and mathematical reasoning in high school. Research in Science Education, 39(3), 321-329.

Norris, S. P., & Phillips, L. M. (1994). Interpreting pragmatic meaning when reading popular reports of science. Journal of Research in Science Teaching, 31(9), 947-967.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. Science Education, 87(2), 224-240.

Norris, S. P., & Phillips, L. M. (2008). Reading as inquiry. In R. A. Duschl & R. E. Grandy (Eds.), Teaching Scientific Inquiry: Recommendations for Research and Implementation (pp. 233-262). Rotterdam, NL: Sense Publishers.

Norris, S. P., Stelnicki, N., & de Vries, G. (2012). Teaching mathematical biology in high school using adapted primary literature. Research in Science Education, 42(4), 633-649.

Nwogu, K. N. (1991). Structure of science popularizations: A genre-analysis approach to the schema of popularized medical texts. English for Specific Purposes, 10(2), 111-123.

Oakhill, J. V., & Cain, K. (2014). The development of comprehention skills. In Israel, S. E. & Duffy, G. G. (Eds.), Handbook of Research on Reading Comprehension: Routledge.

Osborne, J. (2002). Science without literacy: A ship without a sail? Cambridge Journal of Education, 32(2), 203-218.

Osborne, J. (2009). The potential of adapted primary literature (APL) for learning: A response. Research in Science Education, 39(3), 397-403.

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. Science, 328(5977), 463-466.

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. Journal of Science Teacher Education, 25(2), 177-196.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. Journal of Research in Science Teaching, 41(10), 994-1020.

Paris, S. G., & Oka, E. R. (1989). Strategies for comprehending text and coping with reading difficulties. Learning Disability Quarterly, 12(1), 32-42.

Parkinson, J. (2001). Popular and Academic Genres of Science: A Comparison, with Suggestions for Pedagogical Applications. Unpublished PhD Thesis: University of Natal, Durban.

Parkinson, J., & Adendorff, R. (2004). The use of popular science articles in teaching scientific literacy. English for Specific Purposes, 23(4), 379-396.

Pearson, P. D., Moje, E., & Greenleaf, C. (2010). Literacy and science: Each in the service of the other. Science, 328(5977), 459-463.

Penney, K., Norris, S. P., Phillips, L. M., & Clark, G. (2003). The anatomy of junior high school science textbooks: An analysis of textual characteristics and a comparison to media reports of science. Canadian Journal of Science, Mathematics and Technology Education, 3(4), 415-436.

Phillips, L. M., & Norris, S. P. (2009). Bridging the gap between the language of science and the language of school science through the use of adapted primary literature. Research in Science Education, 39(3), 313-319.

Ryan, A. G., & Aikenhead, G. S. (1992). Students' preconceptions about the epistemology of science. Science Education, 76(6), 559-580.

Sampson, V., Enderle, P., Grooms, J., & Witte, S. (2013). Writing to learn by learning to write during the school science laboratory: Helping middle and high school students develop argumentative writing skills as they learn core ideas. Science Education, 97(5), 643-670.

Sandoval, W. A., & Morrison, K. (2003). High school students' ideas about theories and theory change after a biological inquiry unit. Journal of Research in Science Teaching, 40(4), 369-392.

Schleppegrell, M. J. (2002). Linguistic features of the language of schooling. Linguistics and Education, 12(4), 431-459.

Schleppegrell, M. J. (2004). The Language of Schooling: A Functional Linguistics Perspective. New Jersey: Lawrence Erlbaum Associates Inc., Publishers.

Schleppegrell, M. J. (2006). The challenges of academic language in school subjects. Report from Nordic conference 7-8 October 2005. Gothenburg, Sweden: Gothenburg University.

Schommer, M., Calvert, C., Gariglietti, G., & Bajaj, A. (1997). The development of epistemological beliefs among secondary students: A longitudinal study. Journal of Educational psychology, 89(1), 37.

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. Science Education, 88(4), 610-645.

Schwarz, B. (2003). Collective reading of multiple texts in argumentative activities. International Journal of Educational Research, 39(1), 133-151.

Schwarz, B. B. (2009). Argumentation and learning. In Mizra, N. M. & Perret-Clermont, A. (Eds.), Argumentation and Education. Theoretical Foundations and Practices (pp. 91-126). Dordrecht, Heidelberg, London & New York: Springer.

Shanahan, C. (2004). Better textbooks, better readers and writers. In Soul, E. W. (Ed.), Crossing Borders in Literacy and Science Instruction: Perspectives on Theory and Practice (pp. 370-382). Arlington, VA: NSTA Press.

Shanahan, T., & Shanahan, C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content-area literacy. Harvard Educational Review, 78(1), 40-59.

Shanahan, T., & Shanahan, C. (2012). What is disciplinary literacy and why does it matter? Topics in Language Disorders, 32(1), 7-18.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. International Journal of Science Education, 28(2-3), 235-260.

Sinatra, G. M., Southerland, S. A., McConaughy, F., & Demastes, J. W. (2003). Intentions and beliefs in students' understanding and acceptance of biological evolution. Journal of Research in Science Teaching, 40(5), 510-528.

Sjostrom, C. L., & Hare, V. C. (1984). Teaching high school students to identify main ideas in expository text. The Journal of Educational Research, 78(2), 114-118.

Snow, C. E. (2010). Academic language and the challenge of reading for learning about science. Science, 328(5977), 450-452.

Suppe, F. (1998). The structure of a scientific paper. Philosophy of Science, 65(3), 381-405.

Svensson, L., Anderberg, E., Alvegård, C., & Johansson, T. (2009). The use of language in understanding subject matter. Instructional Science, 37(3), 205-225.

Swales, J. (2001). Genre Analysis: English in Academic and Research Settings (1990 1st ed). Cambridge, New york and Melbourne: Cambridge University Press.

van Lacum, E., Ossevoort, M., Buikema, H., & Goedhart, M. (2012). First experiences with reading primary literature by undergraduate life science students. International Journal of Science Education, 34(12), 1795-1821.
Wade, S. E., & Moje, E. B. (2001). The role of text in classroom learning: Beginning an online dialogue. In Kamile, M. L., Mosenthal, P. B., Pearson, D. & Barr, R. (Eds.), Handbook of Reading Research (Vol. 3, pp. 609-628): Lawrence Elbaum Associates Inc. Publishers.
Wellington, J. J., & Osborne, J. (2001). Language and Literacy in Science Education. Buckingham: Open University Press.
Wignell, P., Martin, J. R., & Eggins, s. (1993). The discourse of geography: Ordering and explaining the experiental world. In Halliday, M. A. K. & Martin, J. R. (Eds.), Writing Science. Literacy and Discursive Power (pp. 136-165).
Yang, L., & Wilson, K. (2006). Second language classroom reading: A social constructivist approach. The Reading Matrix, 6(3), 364-372.
Yarden, A. (2009). Reading scientific texts: Adapting primary literature for promoting scientific literacy. Research in Science Education, 39(3), 307-311.
Yarden, A., Brill, G., & Falk, H. (2001). Primary literature as a basis for a high-school biology curriculum. Journal of Biological Education, 35(4), 190-195.
Yarden, A., Falk, H., Federico-Agraso, M., Jiménez-Aleixandre, M. P., Norris, S. P., & Phillips, L. M. (2009). Supporting teaching and learning using authentic scientific texts: A rejoinder to Danielle J. Ford. Research in Science Education, 39(3), 391-395.
Yarden, A., Norris, S. P., & Phillips, L. M. (2015). Adapted Primary Literature. Dordrecht, The Netherlands: Springer.
Yore, L. D. (2000). Enhancing science literacy for all students with embedded reading instruction and writing-to-learn activities, . Journal of Deaf Studies and Deaf Education, 5(1), 105-122.
Yore, L. D., Hand, B., Goldman, S. R., Hildebrand, G. M., Osborne, J. F., Treagust, D. F., et al. (2004a). New directions in language and science education research. Reading Research Quarterly, 39(3), 347-352.
Yore, L. D., Hand, B. M., & Florence, M. K. (2004b). Scientists' views of science, models of writing, and science writing practices. Journal of Research in Science Teaching, 41(4), 338-369.
Zer-Kavod, G., & Yarden, A. (2013). Vaccine-The next generation: Development of genetically modified edible plants expressing a combined vaccine for Cholera and Malaria (an APL article). In Gene Tamers - Studying Biotechnology Through Research (In Hebrew, 2nd ed.). Rebovot: Department of Science Teaching, Weizmann Institute of Science.

11. Appendices