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Designing and testing an Adapted Primary Literature-based technology-enhanced environment for learning and instruction of scientific writing in high-school biology

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This thesis summarizes my independent research

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List of abbreviations

APL	Adapted Primary Literature
DBR	Design-Based Research
DP	Design Principle
IMRaD	Introduction Methods Results and Discussion
LMS	Learning Management System
LTW	Learning To Write
PD	Professional Development
PSL	Primary Scientific Literature
SFL	Systemic Functional Linguistics
SRSD	Self-Regulated Strategy Development
SWAR	Scientific Writing Assessment Rubric
SWIM	Scientific Writing Interactive Model
SWS	Scientific Writing Skills
TELE	Technology-Enhanced Learning Environment
WAC	Writing Across the Curriculum
WID	Writing In the Disciplines
WTL	Writing To Learn

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1. Abstract

Developing scientific communication skills has become a major educational goal in science education. Learning how to produce scientific texts is essential to developing an understanding of science and to learning science. However, many issues remain unclear regarding the learning goals and the suitable strategies for implementing writing practices in the science classroom. The main goal of this study is to design and examine a teaching and learning environment which is based on Adapted Primary Literature (APL), aimed at promoting scientific writing skills of high-school biology majors. The initial hypothesis was that APL can serve as an apprenticeship genre for high-school biology students' writing and along with the teachers' mediation and coaching could promote the socialization of high school biology students into the scientific community.

The methodological approach chosen for this research was Design-Based Research (DBR). The study consisted of four phases: In phase I, the students' difficulties and the teachers' challenges in the process of inquiry-based writing in high-school biology classes were identified and characterized; In phase II, the initial design principles (DP) were defined and the prototype of the learning and teaching environment was designed and developed. The environment was named "SWIM" which stands for – "Scientific Writing Interactive Model"; In phase III, three consecutive iterations were performed. In each iteration the SWIM technology-enhanced learning environment (TELE) was implemented in a growing scale (from 2 classes in the first iteration to 41 classes in the third iteration), evaluated and revised, to create the subsequent version; In phase IV a reflection of the design and implementation process was made in order to draw conclusions about learning and instruction of scientific writing in high-school biology classes, to produce the final DP and to outline recommendations for future research.

The findings from the first phase of the study indicated that high-school biology majors are lacking the genre knowledge required for writing an inquiry-project report, including specific scientific writing components students are struggling with, such as: raise criticism, justification of the inquiry, resources and citation, and scientific merit of the hypothesis. In addition, teachers experience difficulties instructing writing of an inquiry-project report, and usually implement an inefficient individual instruction. The results also suggest that reading an APL article (and pointing out the similarities to the inquiry-project report) is not sufficient for facilitating scientific writing skills of high-school biology majors, probably due to focusing on the content rather than on the genre. From the findings of the first phase, I concluded that there is a need for an instructional framework that will exploit the APL as an apprenticeship genre to assist the teachers in instructing the writing process of an inquiry-project report and to address specific scientific writing difficulties the students are experiencing during this writing process.

In the second phase of this DBR, the initial DP of the SWIM-TELE were defined and the prototype (SWIM 1.0) was developed accordingly. These DP are founded on the basis of genre-oriented pedagogy, and enabled the implementation of the SWIM environment according to the sociocognitive apprenticeship framework. The high-level conjecture about the SWIM-TELE was that inquiry-based writing in high-school biology requires genre knowledge that can be gained by using APL as an apprenticeship genre. This conjecture was embedded in the environment in different elements. These elements enable mediating

apprenticeship processes that may result in the improvement of students' scientific writing skills.

The findings from the three iterations in the third phase of the research indicate that following the implementation of the SWIM-TELE the students' scientific writing skills and writing strategies had improved. The students also gained appreciation for writing in science and self-efficacy for writing, as well as a better understanding of the biological concepts underlying their inquiry-project. Based on the results obtained in the first iteration, the SWIM-TELE was revised to integrate a process-oriented pedagogy that better linked the genre knowledge gained to the writing of the students' inquiry-project reports. The results also show that in classes in which the SWIM-TELE was implemented, the teachers applied the genre-process pedagogy by sociocognitive apprenticeship process using the APL-based elements and process-based features embedded in the environment for this process.

As the conjectures of the SWIM-TELE were verified, I argue that: a) the SWIM teaching and learning environment with its underlying genre (APL-based) and process elements together with the technological support, enabled the teachers to apprentice their students by modeling, coaching and fading, using APL as an apprenticeship genre, b) Eventually, these processes enabled students to develop scientific writing skills, including genre knowledge and writing strategies as well as gaining self-efficacy for writing in science and appreciation for the important roles writing holds in science.

This research shows for the first time that APL can be used for instructing scientific writing. By exploiting the APL as an apprenticeship genre, the teachers can advance their students awareness of the language of the discipline and thus facilitate the enculturation of their students into the scientific discourse community.

This research also shows that effective instruction of scientific writing of high-school biology students should be based on integrated genre-process pedagogy. In addition to the construction of genre knowledge by the students, the writing instruction process should also include the teaching of writing strategies and self-regulation procedures along with extensive and productive feedback and collaboration.

Taken together, a SWIM instructional model was designed to claim that knowledge and expertise are distributed and shared between the teacher, the students and the SWIM-TELE. This distribution enables the apprenticeship process and eventually the socialization of the students into ways of knowing and understanding within the discipline.

תקציר

פיתוח מיומנויות תקשורת מדעית הפך ליעד עיקרי בהוראת המדעים. לימוד מיומנויות כתיבה של טקסט מדעי חיוני לפיתוח הבנה של מדע ולמידת מדע. עם זאת, בעיות רבות עדיין אינן ברורות באשר למטרות הלמידה ולאסטרטגיות המתאימות להטמעת כתיבה בלימודי מדע. המטרה העיקרית של מחקר זה היא לעצב ולבחון סביבת הוראה ולמידה המבוססת על ספרות ראשונית מעובדת (Adapted Primary Literature - APL), שמטרתה קידום מיומנויות כתיבה מדעית של תלמידי ביולוגיה בתיכון. ההשערה הראשונית הייתה כי APL יכול לשמש כסוגה שוליינית ללימוד כתיבה מדעית בביולוגיה בתיכון ויחד עם התיווך וההכוונה של המורה יקדם את החיברות של תלמידי הביולוגיה בתיכון לתוך הקהילה המדעית.

הגישה המתודולוגית שננקטה הייתה מחקר מבוסס עיצוב (Design-Based Research - DBR). המחקר כלל ארבעה שלבים: בשלב א', זוהו ואופיינו קשיי התלמידים והמורים בתהליך הכתיבה של עבודת החקר בכיתות ביולוגיה בתיכון; בשלב השני, עקרונות העיצוב הראשוניים הוגדרו והאבטיפוס של סביבת הלמידה וההוראה תוכנן ופותח. הסביבה נקראה מכ"ם לביוחקר, כאשר מכ"ם מייצג - "מודל כתיבה מדעית"; בשלב השלישי, בוצעו שלוש חזרות רצופות של הפעלה בכיתות. בכל איטרציה סביבת הלמידה הוטמעה בקנה מידה הולך וגדל (משתי כיתות באיטציה הראשונה ל-41 כיתות באיטרציה השלישית), הוערכה ותוקנה כדי ליצור את הגרסה המשופרת; ובשלב הרביעי, נעשתה רפלקציה על תהליך העיצוב וההטמעה על מנת להסיק מסקנות לגבי הוראה ולמידה של כתיבה מדעית בביולוגיה בתיכון, לגבש את עקרונות העיצוב הסופיים ולהתוות המלצות למחקר עתידי.

מצאי השלב הראשון של המחקר הראו כי לתלמידי ביולוגיה בתיכון חסר ידע על הסוגה אשר נדרש לכתיבת עבודת הביוחקר, כולל רכיבי כתיבה מדעית ספציפיים, כגון: העלאת ביקורת, הצדקת החקר, שימוש וציטוט במקורות מידע, ומתן ביסוס מדעי להשערה. בנוסף, התברר שהמורים חווים קשיים בהוראת כתיבת עבודת החקר ובדרך כלל מיישמים הוראה פרטנית לא יעילה. התוצאות גם מראות כי קריאת מאמר APL (תוך הצבעה על הדמיון לעבודת הביוחקר) אינה מספיקה על מנת לקדם את כישורי הכתיבה המדעית של תלמידי ביולוגיה בתיכון, ככל הנראה בשל התמקדות בתוכן ולא בסוגה. מתוך ממצאי השלב הראשון, הגעתי למסקנה כי יש צורך בפיתוח מסגרת הוראה שתנצל את ה-APL בתור סוגה שוליינית, על מנת לסייע למורים להנחות את תהליך כתיבת עבודת הביוחקר ולטפל בקשיי כתיבה מדעית ספציפיים אשר התלמידים חווים במהלך תהליך כתיבה זה.

בשלב השני של המחקר, הוגדרו עקרונות העיצוב, והאבטיפוס של סביבת המכ"ם לביוחקר פותח על פיהם. עקרונות אלה, המבוססים על פדגוגיה מבוססת סוגה, אפשרו את ההטמעה של הסביבה תוך שימוש בשוליינות סוציו-קוגניטיבית. ההשערה הייתה שכתיבה מבוססת חקר בביולוגיה בתיכון דורשת ידע על הסוגה, שניתן לבנות באמצעות שימוש ב-APL כסוגה שוליינית. סברה זו הוטמעה בסביבה באלמנטים שונים. אלמנטים אלה אפשרו תהליכי שוליינות מתווכים, שעשויים לגרום לשיפור מיומנויות הכתיבה המדעית של התלמידים.

מהממצאים משלוש החזרות בשלב השלישי של המחקר עולה כי בעקבות הטמעת מכ"ם לביוחקר בכיתות, מיומנויות הכתיבה המדעית ואסטרטגיות הכתיבה המדעית של התלמידים השתפרו. בנוסף, הערכת התלמידים לכתיבה במדע והמסוגלות העצמית שלהם לכתיבה עלו, כמו גם הבנה טובה יותר של המושגים הביולוגיים העומדים בבסיס פרויקט החקר שלהם. בהתבסס על התוצאות שהושגו באיטרציה הראשונה, סביבת המכ"ם לביוחקר עודכנה על מנת לשלב פדגוגיה מבוססת תהליך, שתקשר טוב יותר את הידע על הסוגה שהתלמידים בנו לתהליך כתיבת עבודות החקר שלהם. עוד עולה מהתוצאות כי בכיתות בהן סביבת המכ"ם לביוחקר הוטמעה, המורים יישמו את הפדגוגיה המשולבת סוגה-תהליך, באמצעות תהליך השוליינות הסוציו-קוגניטיבי, תוך שימוש באמלנטים מבוססי APL וכלים מבוססי תהליך המוטמעים בסביבת הלמידה.

מכיוון שההשערות לגבי הסביבה מכ"ם לביוחקר אומתו, אני טוענת כי: א) סביבת הלמידה מכ"ם לביוחקר עם האלמנטים מבוססי הסוגה (APL) והתהליך העומדים בבסיסה, יחד עם התשתית הטכנולוגית, אפשרו למורים לחנוך את תלמידיהם על ידי תהליכים של הדגמה, הדרכה ושחרור תוך שימוש ב- APL כסוגה שוליינית, ב) בסופו של דבר, תהליכים אלה אפשרו לתלמידים לפתח מיומנויות כתיבה מדעית, כולל ידע סוגה ואסטרטגיות כתיבה וכן העלאת המסוגלות העצמית שלהם לכתיבה במדע והערכת התפקיד החשוב של הכתיבה במדע.

מחקר זה מראה לראשונה כי ניתן להשתמש ב-APL על מנת להנחות כתיבה מדעית בביולוגיה בתיכון. באמצעות ניצול APL בתור סוגה שוליינית, המורים יכולים לקדם את מודעות תלמידיהם לשפה של

הדיסציפלינה ובכך להקל על כניסתם של תלמידיהם אל קהילת השיח המדעית. מחקר זה מראה גם כי הוראה אפקטיבית של כתיבה מדעית של סטודנטים לביולוגיה בתיכון צריכה להתבסס על פדגוגיה המשלבת סוגה ותהליך. בנוסף לבניית ידע על הסוגה בקרב התלמידים, תהליך הוראת הכתיבה צריך לכלול גם הוראה של אסטרטגיות כתיבה ומיומנויות ויסות עצמי יחד עם משוב נרחב ויעיל ושיתוף פעולה בין התלמידים.

לסיכום, אני מציגה את מודל הוראה של מכ״ם לביוחקר, שבו אני טוענת כי ידע ומומחיות מפוזרים ומשותפים בין המורה, התלמידים והסביבה המתוקשבת מכ״ם לביוחקר. פיזור זה מאפשר את תהליך השוליינות ולבסוף את החיברות של התלמידים לתוך דרכי הידיעה וההבנה בדיסציפלינה.

2. Introduction and main research goal

The need to create a scientifically literate citizenry, which is capable of fully participating in the demands of the 21st century, is a widely accepted educational goal, and has been tied to the future of our society (National Research Council [NRC], 2012; Osborne, 2014; Snow & Dibner, 2016). Norris and Phillips (2003) argued that literacy is constitutive of science itself and that science as a discipline cannot function without reliance on the general literacy skills of speaking, listening, reading, and writing. Therefore, science cannot advance if scientists are unable to communicate their findings clearly and persuasively to their colleagues (National Research Council [NRC], 2012). Thus, literacy is considered to be an essential aspect of disciplinary practice (Moje, 2008). Accordingly, disciplinary literacy (Shanahan & Shanahan, 2008) emphasizes the unique tools that the experts in a discipline use to engage in the work of that discipline.

Due to its central role in a disciplinary practice, literacy is an essential part of enculturation and socialization into a specific discipline through its specialized discourse (Fang, 2012; Moje, 2008). Writing is one of the primary means of communicating in the scientific community and a crucial aspect of scientific literacy. Learning how to produce scientific texts is, therefore, essential to developing an understanding of science and to learning science. Thus, developing scientific writing skills has become a major educational goal in science education (Israeli Ministry of Education, 2011; National Research Council [NRC], 2012).

Indeed, high-school biology majors in Israel are required to conduct an inquiry-project ("Bio-Heker") and to summarize their investigation in a report. This report should be written in a scientific writing manner, similar to the Primary Scientific Literature (PSL) genre, which represents the main genre of communication in the scientific community (Bazerman, 1988). The writing stage was reported by teachers and students to be the most challenging stage of the inquiry project. This could be explained by the fact that despite knowing little about the discipline's discourse, the students must attempt to produce pieces of writing that imitate in a way those of scientists. As O'Neil (2001) claimed, this imitation is a necessary stage in entering a discourse community, however, we cannot expect to simply drop the scientific genre into the classroom and expect the students to understand its meaning or know how to write it themselves. We should provide the students with tasks and situations that will enable them to build the scientific genre knowledge themselves (Rijlaarsdam, Couzijn, Janssen, Braaksma, & Kieft, 2006).

It was previously argued that science educators must offer students the opportunity to experience and practice a broad range of discursive and literate activities and scaffold students in the specific forms of disciplinary literacy (Pearson, Moje, & Greenleaf, 2010; Shanahan & Shanahan, 2008). Yet, traditionally, science teachers do not pay much attention to texts, operating rather on the notion that there is nothing particularly distinctive about the genres in which science is communicated, and thus, teachers fail to mentor students in the necessary literate practices, which would help them read and write in science (Osborne, 2014). It was previously suggested that students should be exposed to PSL in order to learn how to write properly (Kuldell, 2003; Muench, 2000), however, students deal mostly with secondary literature type texts (i.e., textbooks, popular research articles from the media), and are usually not exposed to the primary scientific literature genre which is written for experts and is usually beyond their cognitive abilities (Wade & Moje, 2001; Yarden, Norris, & Phillips, 2015).

Adapted Primary Literature (APL) refers to an educational genre specifically designed to enable the use of research articles for learning biology in high-school (Yarden, 2009; Yarden, Brill, & Falk, 2001). APL retains the authentic characteristics of the PSL articles, while adapted to match students' knowledge, reading ability and cognitive skills. In the adaptation process, the practical reasoning involved in producing scientific knowledge is taken into account (Yarden, 2009; Yarden et al., 2001). The potential of APL as an educational genre which can facilitate the enculturation of students into the scientific discourse community was recently recognized (Baram-Tsabari & Yarden, 2005; Ford, 2009; National Research Council [NRC], 2012; Yarden, 2009). As was stated in the last K-12 framework for science education (NRC, 2012): "students need opportunities to read appropriate samples of adapted primary literature to begin seeing how science is communicated by science practitioners" (National Research Council [NRC], 2012).

The benefits of APL articles in science education were previously shown. It has been argued that reading APL articles can help students improve their understanding of inquiry, active learning and integration of knowledge (Yarden, 2009). Also, reading APL articles has been found to improve students' understanding of the nature of science, their ability to criticize scientific research (Baram-Tsabari & Yarden, 2005), and their level of inquiry thinking and uniqueness (Brill & Yarden, 2003). The possible potential of APL articles for learning and instruction of scientific writing has not been investigated so far.

In the past several decades scholars have systematically studied the effectiveness of practices for teaching and improving students' writing (Graham & Harris, 2003, 2006; Graham, Harris, & Chambers, 2016; Graham & Perin, 2007a, 2007b; Hillocks, 1986). However, many issues remain unclear regarding the learning goals and the suitable strategies to implementing writing practices in the science classroom. Although the relationships between writing and learning in science has been studied previously, most of these studies focused on the influences of short and limited writing tasks, while the process of learning scientific writing was less investigated (Carter, Ferzli, & Wiebe, 2007). Numerous tools and approaches have been developed for learning to write in science (Carter et al., 2007; Hand, Prain, Lawrence, & Yore, 1999; Keys, Hand, Prain, & Collins, 1999; Sampson, Grooms, & Walker, 2011), though, most of them focus on "school genres" such as argumentation and explanation (Klein & Rose, 2010), rather than on more authentic scientific genres (Jimenez-Aleixandre, Bugallo Rodriguez, & Duschl, 2000). Moreover, most of the studies on writing in the science classroom are not placed in an authentic classroom context and are not integrated to the formal curriculum. In addition, the writing tasks secondary science students are asked to write are usually not linked with opportunities to engage in other scientific practices, such as designing investigations or analyzing data (Carter et al., 2007; National Research Council [NRC], 2012; Sampson, Enderle, Grooms, & Witte, 2013; Yore, Bisanz, & Hand, 2003).

Lately, a call was made for design-based research that examines teachers' and students' enactment of new writing curricula from a sociocultural approach (Kwok, Ganding III, Hull, & Moje, 2016). Kwok et al. (2016) suggest that design-based research could examine issues such as how teachers apprentice students to the norms and practices of disciplinary communities and how a particular writing curriculum intervention works, for whom, why and under what conditions

In this design-based research I aimed to design and examine an instructional model that assists both the high-school teacher and the student in the writing process of an inquiry-project report. I examined the hypothesis that APL articles can provide a model for adequate scientific writing for secondary school science students for writing their inquiry-project report. Thus, I hypothesized that APL can serve as an apprenticeship genre (following Carter et al., 2007) for high-school biology students, and along with the teachers' mediation and coaching can promote the socialization of high school biology students into the scientific community.

Therefore, the main goal of this study is to design and examine an APL-based teaching and learning environment aimed at promoting scientific writing skills of high-school biology majors.

The overall research project addressed three broad concerns: (i) How should a teaching and learning environment be designed to promote scientific writing skills of high-school biology students? (ii) How can biology teachers be enabled to apprentice their students into the scientific discourse community using APL as an apprenticeship genre? (iii) In what ways does the learning environment develop students' scientific writing skills?

3. Literature review

This research stems from two perspectives: scientific writing as a fundamental component of disciplinary literacy and scientific writing in the context of writing in general. These two perspectives are grounded in theoretical frameworks such as: situated learning, cognitive and sociocultural models of writing and genre theory. In this chapter I first review the relevant theoretical frameworks from the perspective of disciplinary literacy; I then present the development of writing research and place scientific writing in that context; lastly I explore the current state of scientific writing instruction in high-school.

3.1. Scientific writing as a fundamental component of disciplinary literacy

3.1.1. Disciplinary literacy and scientific writing

The need to create a scientifically literate citizenry, which is capable of fully participating and in the demands of the 21st century, is a widely accepted educational goal, and has been tied to the future of society (National Research Council [NRC], 2012; Osborne, 2014; Snow & Dibner, 2016). While there is still no universally agreed definition of scientific literacy, recent literature has begun to emphasize the language aspects of the definition (Hand et al., 2003; Norris & Phillips, 2003; Pearson et al., 2010; Yore et al., 2003; Yore & Treagust, 2006). This understanding of scientific literacy makes explicit connections among the language of science and the resulting scientific knowledge (Pearson et al., 2010) and stresses that students must read, write, and communicate effectively in order to be able to make decisions as informed citizens and engage in the critical thinking that active science learning requires (Krajcik & Sutherland, 2010).

Shanahan and Shanahan (2008) termed the concept of 'disciplinary literacy'. By this term they refer to the specialized knowledge and abilities possessed by those who create, communicate, and use knowledge within each of the disciplines. They distinguish between content area literacy, which emphasizes the teaching of a generalizable set of study skills that can be used across content areas, and disciplinary literacy which emphasizes the unique tools that the experts in a discipline use to engage in the work of that discipline.

Literacy thus becomes an essential aspect of disciplinary practice, rather than a set of strategies or tools brought into the disciplines to improve reading and writing of subject-matter texts (Moje, 2008). Moje (2008) also argue that content learning is as much about learning to use the language of the disciplines effectively and fluently as it is about learning disciplinary concepts, therefore, literacy is an essential part of enculturation and socialization into a specific discipline through its specialized discourse (Fang, 2012; Moje, 2008). Learning science, for example, from a sociocultural learning perspective, is as much about learning to talk, read, and write science as is it about learning scientific concepts or facts (Lemke, 1990; Moje et al., 2004).

Norris and Phillips (2003) suggested two distinct meanings of scientific literacy: the fundamental sense, which is the ability to read, interpret and write a scientific text, and the derived sense, which is the knowledge of scientific ideas and the ability to use them in a scientific manner. These two meanings of scientific literacy support and complement each other. The emerging idea is that the fundamental sense is critical in supporting the derived sense, i.e. science as a discipline cannot function without reliance on the general literacy skills of speaking, listening, reading, and writing (Norris & Phillips, 2003).

This understanding of the important role of language in science learning has contributed to a search for pedagogical interventions to encourage the development of this type of scientific literacy for students (Keys et al., 1999; Krajcik & Sutherland, 2010; Pearson et al., 2010; Yore et al., 2004). For example, Krajcik and Sutherland (2010) suggested that for fostering literacy in the context of science inquiry, teachers should support students' engagement with the discourse of science, including the language of science and its practices.

Scientific writing is a fundamental component of scientific literacy and is, therefore, socially situated and context specific. As Halliday and Martin (1993) demonstrate, scientific writing has many features such as reliance on technical vocabulary, use of the passive voice, and nominalization. These features have evolved in science and other technical fields to serve certain communicative needs. Indeed, communicating in a written or spoken form is a fundamental practice of science; it requires scientists to describe observations precisely, clarify their thinking, and justify their arguments (National Research Council [NRC], 2012). Frequently, science is described as "a hands-on activity", however much of science is neither experimental nor field-based, but rather is more conceptual and theoretical and more concerned with ideas than with data. The hands-on activity is accompanied by the mental – reading, writing and speaking – "minds-on activities" of communication (Norris, Falk, et al., 2009) and in fact, science simply cannot advance if scientists are unable to communicate their findings clearly and persuasively to their colleagues.

One learns the content of a subject not merely by reading it but also by writing with it and about it in ways that are discipline specific; together with reading, writing is a literate behavior that underlies disciplinary “knowing” (Langer, 2011). Research suggests that learning to write effectively within a discipline is part of that discipline’s knowledge base. Thus, the skills and strategies that work well for writing in a certain subject class may not lead to effective writing in other subjects (Bazerman, 1988; Russell, 1991). Because writing is one of the primary means of communicating in the scientific community, learning how to produce scientific texts is essential to developing an understanding of science. Thus, developing scientific writing skills has become a major educational goal in science education (Israeli Ministry of Education, 2011; National Research Council [NRC], 2012).

3.1.2. Relations between reading and writing development

The relations between reading and writing were investigated extensively by researchers from different and diverse fields such as literature, linguistics, science education and more (Horning, 2013; Olson, 2007; Shanahan, 1997).

Three basic theoretical models have been used to guide research on reading-writing relationships (Shanahan, 2016). The first model explores the *shared knowledge* and cognitive processes that underlie reading and writing abilities. According to Fitzgerald and Shanahan (2000), readers and writers rely on four common knowledge bases. The first knowledge base is domain or content knowledge. The second knowledge base is meta-knowledge about written language, including knowing about the functions and purposes of reading and writing; knowing that readers and writers interact and monitoring one's own meaning making. A third common knowledge base for reading and writing deals with knowledge of text attributes (e.g. punctuation and text organization and formatting features). The fourth shared knowledge underlying reading and writing is procedural knowledge, including knowing how to access, use and generate information during reading and writing. A second theoretical model in the reading-writing research is *sociocognitive* in nature. According to this model, the reading-writing relations take place in the transactional space between readers and writers and all acts of literacy are fundamentally communicative. The third theoretical model treats reading and writing as *separate processes* that can be combined to accomplish a goal or to solve a problem. For example, reading are writing can be used together to facilitate student learning of content. Furthermore, writers, when trying to produce high quality texts – such as writing a report from sources – must alternate between reading and writing to accomplish the goal effectively (Shanahan, 2016).

Although the reading-writing relations were found to be strong, reading and writing are often considered as separate processes, mostly in school, where they are usually instructed as isolated skills (Shanahan, 2016). Recently, calls for reconnecting reading and writing instruction have emerged (Horning, 2013).

3.1.3. Reading scientific texts in science education

Scientific texts are used by scientists, the general public, science educators and students, however, reading is often neglected in the science classroom (Evagorou & Osborne, 2010).

While scientists are mainly reading and writing research articles (PSL), in order to communicate their findings to the scientific community, when students do read in science class, they read mostly texts obtained from textbooks, popular research articles from the media, or review articles from popular journals (Wade & Moje, 2001).

Textbooks for the K-12 levels are usually written by science educators and science writers, using an expository genre, which often includes facts with minimal evidence to support conclusions. Textbooks usually present statements as accredited facts with no hedging. They are frequently structured in a way that reflects the knowledge structure of the discipline and present the certain aspects of science (Yarden, 2009). Typical science textbooks are dense and disengaging to inexperienced science readers. Popular articles represent the genre of communication of scientific findings to the general public, in a form that can be interpreted by nonscientists (Norris & Phillips, 1994). Popular articles have a non-canonical structure; they present facts with minimum evidence, and are more expository and narrative in nature (Yarden, 2009).

Although students are expected to read scientific texts by the time they leave high-school, they usually have a great difficulty doing so. Norris and Phillips (2008) attributed this difficulty to a simple view of reading that prevails in science education. They suggest that conceiving reading as a form of inquiry could assist in bridging the gap between the language of school science and the language of science (Norris et al., 2009). In addition, science teachers have little access to well-designed texts that readers can understand given their developing knowledge base and varying reading skill levels (Pearson et al., 2010). APL articles could be useful in illustrating the nature of reading as inquiry and help bridge the gap to the language of science (Yarden, 2009; Yarden et al., 2015).

3.1.4. Adapted Primary Literature (APL)

Research articles represent the genre of communication among scientists. Scientific writing has unique characteristics. It uses mainly an argumentative genre, includes evidence to support conclusions, is constructed in a canonical manner (Introduction, Methods, Results and Discussion - IMRaD structure), and presents the uncertain aspects of science (Bazerman, 1988; Swales, 2001; Yarden, 2009). The canonical structure of the primary literature genre drives science writing toward the discipline's norms, values and ideology (Yore, Hand, & Prain, 2002). Another central communicative feature of scientific writing is the use of multiple representations, including graphical ones, to display the experimental results (Falk & Yarden, 2009). Each section in of the research article has its rhetoric and structural characteristics. For example, the Introduction section begins with a broad perspective on the research subject and narrow down to the specifics of the research, thus, the Introduction structure resembles a funnel (Swales, 2001)

APL 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; Yarden et al., 2015). The process of adaptation is maintaining the canonical structure and writing style of the article, while matching its content and complexity with students' prior knowledge and assumed cognitive capabilities (Yarden et al., 2001). Briefly, the Introduction is modified to give the novice reader basic background information that was either omitted from or simply quoted in the original paper; the main principles of the Methods are described, while details of amounts, solution compositions, and so on, are omitted; the Results are kept authentic, although offshoots of the main research question are omitted; the main figures are kept, with slight modifications; and, finally, the Discussion is expanded so that students can understand it more easily (Yarden et al., 2001). APL-based curricula are aimed to be authentic-context inquiry curricula, dealing with cutting edge biological research, and have been incorporated as elective topics (e.g., developmental biology, biotechnology, biodiversity) into the syllabus for high-school biology majors in Israel, in order to enhance students' inquiry skills and their understanding of the nature of science (Israeli Ministry of Education, 2011). They can be considered as second-hand inquiry interventions, as they present the students with data obtained through the hands-on inquiry of others (following Palinscar & Magnusson, 2001).

The use of APL in science education holds a great promise for enriching inquiry science instruction at the secondary level (Ford, 2009). Several investigations have been performed on the reading and enactment outcomes of the APL genre. Based on class observations in the context of APL-based curriculum enactment, it was observed that high-school students tend to pose questions that reveal a higher level of inquiry thinking and uniqueness (Brill & Yarden, 2003). It was also observed that high-school biology students who read an APL article understood better the nature of scientific inquiry and raised more scientific criticism on the researchers' work compared with students who read a popular scientific article on the same subject (Baram-Tsabari & Yarden, 2005). Falk and Yarden (2009) suggested that APL enables learning science as inquiry. Furthermore, Brill, Falk, and Yarden (2004) suggested that students reach deeper understanding by question-supported reading of APL. Norris at el. (2009) also reported on deeper understanding of mathematical biology using APL in high-school (Norris, Macnab, Wonham, & de Vries, 2009).

Recent findings from an analysis of APL using the Systemic Functional Linguistics (SFL) approach revealed that in the adaptation process, APL is different from primary scientific literature not only in content and length but also in grammatical features which lower the lexical complexity and increases the readability of the text, while at the same time maintains the grammatical features of the research articles and the language of science (Ariely & Yarden, Submitted). Up until now, the possible potential of APL for learning and instruction of scientific writing has not been investigated.

3.2. Scientific writing in the context of writing in general

3.2.1. Cognitive process models of writing

Until the 1980s writing was considered as a linear process consisted of the sub-processes of planning (Pre-writing), writing and revising (post-writing). Systematic research on the cognitive processes involved writing began in the 1980s, during which cognitive psychology replaced behaviorism as the dominant paradigm. The classical cognitive researches considered writing as a recursive and continuous problem-solving process occurring within the individual (Becker, 2006).

The first systematic program of cognitive research on writing was the seminal work of Hayes and Flower beginning in the late 1970s (Hayes & Flower, 1980). Hayes and Flower (1980) attempted to classify the various activities that occur during writing and their relationships to the task environment and to the internal knowledge state of the writer. Their model was based on "thinking aloud" protocols of college students solving a writing problem. The Hayes and Flower model includes three basic components: *task environment*, *writer's long-term memory* and *cognitive writing processes*. Hayes and Flower hypothesized that the writer’s long-term memory has various types of knowledge, including knowledge of the topic, knowledge of the audience, and stored writing plans (e.g., learned writing schemas). In the task environment, Hayes and Flower distinguished the writing assignment (including topic, audience, and motivational elements) from the text produced so far. Hayes and Flower identified four major writing processes: (1) Planning, which takes the writing assignment and long-term memory as input, which then produces a conceptual plan for the document as output. Planning includes setting goals, generating ideas, organizing ideas into a writing plan; (2) Translating, which takes the conceptual plan for the document and produces text expressing the planned content; (3) Reviewing, in which the text produced so far is read, with modifications to improve it (revise) or correct errors (proofread); and (4) Monitoring, which includes meta-cognitive processes that link and coordinate planning, translating, and reviewing.

The original Hayes and Flower 1980 model was revised over the years (Hayes, 1996, 2006, 2012; Kellogg, 1996). Yet, it has retained its cognitive character, as well as its influence on the field. Hayes's (1996) newer model included factors such as motivation and working memory and it provides a much more sophisticated and complicated view of skilled writing. However, one limitation of both models is that they do not provide substantial insight into how novice and competent writers differ (MacArthur & Graham, 2016).

Based on their study of children's writing, Breiter and Scardamalia (1987) proposed that beginning or novice writers use a greatly simplified version of the idea generation process included in the 1980 Hayes and Flower model. The Bereiter and Scardamalia model (1987) contrasts ‘‘knowledge-telling’’ writing with ‘‘knowledge-transforming’’ writing. According to this model, novice writers convert the writing task to simply telling what is known about the topic (i.e. writing-as-remembering or writing-by-pattern). On the other hand, a skilled writing is characterized by a dynamic process where information created in text cognitively reorganizes information previously known. The skilled writing involves planning text content in accordance with rhetorical, communicative, and pragmatic constrains. These two types of planning are carried out in separate spaces but operate in close interaction through a problem translation component. Reflective thought during writing involves an interaction between these two spaces. The writer develops a mental representation of the assignment and then engages in problem analysis and goal setting to determine what to say (content planning), as well as how to say it and who to say it to (rhetorical process planning).

Since the 1990s, cognitive writing researchers have included social processes in their research (see elaboration on the sociocultural perspective of writing in the next chapter, 3.2.2). Cognitive researchers understood that writing is situated in social contexts. Within those social contexts, writers apply their knowledge, skills, and strategic problem solving to the difficult task of making meaning.

In the turn of the millennium several models raised other aspects of cognitive processes in writing, such as self-regulation, strategies, knowledge and motivation. A model developed by Zimmerman and Risemberg (1997) specified mechanisms through which writers learn and grow. According to this model, self-regulation in writing occurs when writers use personal processes to strategically regulate their writing behavior or the environment. As they employ these strategies, writers monitor, evaluate, and react to their use of these strategies allowing learning from their actions. A writer's self-efficacy may be enhanced or diminished depending on the perceived success of the strategies, eventually influencing intrinsic motivation for writing, the use of self-regulatory processes during writing and literary achievement.

Research also expanded in the subject of attitudes towards writing and their influence on writing performance. Findings have consistently shown that positive attitudes towards writing are related to writing performances. Self-efficacy for writing was also found to be predictive to intrinsic motivation to write (Hidi & Boscolo, 2006; Pajares, 2003). In his framework for understanding cognition and affect in writing, Hayes (2000) integrated the elements of affect factors and motivation to the Hayes-Flower 1980 model of the writing process and described the role these factors play in the writing process. For example, students who believe both that they are poor writers and that writing is a gift are likely to experience writing anxiety (Hayes, 2000). Students' attitudes towards writing in science are often negative. It was shown that students consider writing in science to be irrelevant and unnecessary. They also don't recognize the value and importance of writing in science and lack confidence in scientific writing (Rivard, 1994). Prain and Hand (1999) showed that secondary school science students have negative attitudes toward passive writing tasks and that diversifying writing tasks has a positive influence on the students' attitudes to science in general. Also, students preferred writing styles that allowed them to be actively and creatively engaging in science (Prain & Hand, 1999).

The cognitive models of writing development are still being researched, reshaped and elaborated today. For example, van den Bergh, Rijlaarsdam, and van Steendam (2016) suggest a functional dynamic approach which attempts to explain individual variation in the quality of written products. They demonstrate that it is essential to model cognitive processes dynamically by considering not only which processes (e.g. generating ideas, rereading, and revising) occur but also when in the process they occur and in what order.

3.2.2. Sociocultural perspective

Writing is a complex socially-situated act in which the writer asserts meaning, goals, actions, connections and identities within a constantly changing social world, relying on shared texts and knowledge (Prior, 2006). Since the 1980s, scholars working from a sociocultural perspective have argued that rather than understanding learning to write as having only a textual dimension (e.g., from learning to write a report or analytical assay) or a cognitive dimension (e.g., shifting from knowledge telling to knowledge transforming), writing should be viewed as a social event involving construction of that event and relationships with others. In his critique of de-contextualized models of writing development, Applebee (2000) calls for a "social action" perspective – learning to write means providing students with social contexts constituted by particular demands requiring them to make rhetorical decisions related to purpose, audience, genre and situation.

Theories of situated cognition offer a model of learning as socialization, or enculturation, into a community of practice. Researches from a sociocultural perspective clearly established that learning is embedded in practice. That is, learning occurs as a function of participation in activities and practices (Lave & Wenger, 1991; Rogoff, 1990). As such, learning is domain-specific. The socialization into the community of practice occurs through apprenticeship: By participating in the ways of doing that define a community, a newcomer learn its ways of knowing (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). Based on the notion that knowledge is situated, being in part a product of the activity, context and culture in which it is developed and used, Brown et al. (1989) suggested that authentic activities are the 'ordinary practices of the culture'. They argued that authentic activity is important for learners ‘because it is the only way they gain access to the standpoint that enables practitioners to act meaningfully and purposefully’.

In their review, Englert, Mariage, and Dunsmore (2006) identify three tenets of sociocultural theory in writing research: (1) Sociocognitive apprenticeship in writing; (2) Procedural facilitators and tools; and (3) Participation in communities of practices. Learning to write depends on a range of explicit teaching practices, and is facilitated by having those who are more proficient explain their decisions about language or form to those who are new to the community. Vygotsky's work (1978) demonstrates that effective teachers make tacit knowledge perceptible through think-aloud that make the discourse, thoughts, actions, decisions, struggles and deliberations that are part of the writing process, visible. Scardamalia, Bereiter, and Steinbach (1984) considered writing as a situated act and developed an approach to the teaching of writing that relies on elements of cognitive apprenticeship. Their approach is designed to give students a grasp of the complex activities involved in expertise by explicit modeling of expert processes, gradually reduced support or scaffolding for students attempting to engage in the processes, and provide opportunities for reflection on their own and others' efforts.

Writing takes place within a particular activity through which students acquire the use of language, genres, discourse and tools unique to that activity, pointing to the importance of analysis of how students and teachers are constructing the meaning of activity in different ways in different contexts mediated by different uses of certain social practices (Beach, Newell, & VanDerHeide, 2016).

Gee (2004) argued that the scientific language is situated in a science discourse community that is facilitated by a more proficient member of that community. The term "discourse communities" was defined by Swales (2001) as: "socio-rhetorical networks that form in order to work towards sets of common goals". Writing development occurs while students acquire increased knowledge of norms and genre expectations constituting certain kinds of writing through participation in particular discourse community or disciplinary culture (Hyland, 2000). Gee (2004) also claimed that "no effective science education program would be complete if it did not support students in acquiring the facility of oral science language and the ability to access, produce, and comprehend the full range of science text and representations".

3.3. Writing instruction

3.3.1. Brief history and recent practices of writing instruction

For over 100 years, scholars have systematically studied the effectiveness of practices for teaching and improving students' writing. Writing instruction was developed, changed and shaped in parallel and in accordance with the research in the field (Graham et al., 2016).

Until the 1970s the *product-focused* instructional models were prevalent. These models engaged students in detailed analysis of sample texts in books with chapters entitled "Writing a cause-and-effect paper", for instance, and then sent students off (typically alone) to mimic the genre (De La Paz & McCutchen, 2011).

During the 1980-1990s the improvement in writing instruction has emphasized teaching students the skills and strategies needed to write effectively in a variety of contexts and disciplines. Such instruction has typically been called *process approach* and has emphasized teaching students to engage in extensive prewriting activities, sharing work with partners or small groups, sometimes writing more than one draft, and careful revision of the drafts (Applebee & Langer, 2013). The process approach is typically characterized by an emphasis on personally-meaningful writing contexts and development of students' identities as writers. Other instructional models that have been developed and practiced during this period were various forms of novice-expert apprenticeship and procedural facilitation (Bereiter, 1987).

The last two decades are characterized by a shift towards *socially-oriented* writing instruction. Genre pedagogy, which sees writing as purposeful, socially situated responses to particular contexts and communities, was formed and introduced to schools (Hyland, 2003). Currently, genre pedagogy is still prevalent (Rose, 2016). In addition, instructional models emphasizing the importance of self-regulation and strategy instruction (e.g. the Self-Regulation Strategy Development – SRSD) have emerged (Graham & Harris, 2003; Harris & Graham, 1992).

Several meta-analyses conducted in recent years have synthesized research on effective writing instruction in order to better foster "evidence-based" practice (Graham & Harris, 2003, 2006; Graham et al., 2016; Graham & Perin, 2007a, 2007b; Hillocks, 1986). In their meta-analytic review of research on writing instruction, Graham et al. (2016) provide a general roadmap for teaching writing in grades 1-12, embedding identified evidence-based practices. Their analysis resulted in six recommendations: (1) Write – Increasing the amount of time students spend writing enhance the quality of their texts; (2) Create supportive writing environment – Including elements from the process approach, such as: teachers setting clear goals, collaborative writing, engaging students in prewriting inquiry activities designed to help them gather, organize and think about their writing, teachers providing nuanced support to meet the needs of individual students; (3) Teach writing skills, strategies, knowledge and motivation – Effective writing instruction included teaching students specific strategies and skills (e.g. drafting, planning, revising and editing) using modeling, explanation and guided practice. In addition, teaching students self-regulation procedures, increasing students' knowledge about the characteristics of good writing (i.e., using model text) and enhancing their motivational disposition resulted in better writing; (4) Provide feedback – Students' writing improve when they receive feedback from their teachers, evaluate their own writing, give and receive feedback from peers and from a computer program; (5) Use 21st-century writing tools – students become better writers when they compose with word processing programs that include additional software that facilitates different aspects of writing, like planning; (6) Use writing as a tool to support student learning – teachers asking their students to write for a variety of purposes enhanced their learning and comprehension (Graham et al., 2016).

The meta-analyses and reports published would seem to imply that the teachers are using effective approaches to writing instruction, but achievement levels would suggest otherwise (Applebee & Langer, 2013). An important challenge is to understand how and whether research-based practices are being implemented or should be implemented.

3.3.2. Writing across the curriculum (WAC) vs. Writing in the disciplines (WID)

Two opposing viewpoints have developed in relation to the broad question of what types of writing that encourage learning should be used in science classrooms – "Writing across the curriculum" (WAC) and "Writing in the disciplines" (WID) (Bazerman et al., 2005). WAC is a pedagogical movement that began in the 1980s. Generally, writing across the curriculum programs share the philosophy that writing instruction should happen across the academic community by applying and teaching general writing skills and strategies. Writing across the curriculum programs also value writing as a method of learning. WID approach recognizes that each discipline has its own unique language conventions, format, and structure. In other words, the style, organization, and format that are acceptable in one discipline may not be acceptable in another. WID believes that to participate successfully in the academic discourse of their community, students must be taught discipline-specific conventions and should practice using these conventions. Some common WID assignments are reports, literature reviews, project proposals, and lab reports.

WAC usually supports the use of "nontraditional" and "informal" writing tasks and is represented in the "Writing-To-Learn" (WTL) movement. WID, on the other hand, promotes the use of "traditional" or "formal" genres in science, and also referred to as "Writing to communicate" or "Learning to write" (LTW) movement (Keys et al., 1999). Each position supports the general idea that writing should be implemented as a tool in the science classroom to both communicate and to develop knowledge, but they offer contrasting plans about how to attain this. The dichotomy between WAC and WID is often characterized as "writing to learn" (WTL) – i.e., writing as a means of acquiring information, understanding concepts, and appreciating significance in any discipline versus "learning to write" (LTW) – i.e., acquiring the socially-mediated communication skills and genre knowledge appropriate to a specific discipline. Carter et al. (2007) elaborated on this dichotomy and suggested that WAC and WID are founded on different concepts of learning: "for WID, learning is largely social; learning is the act of being socialized into disciplines. Thus, WID may be better understood as writing to learn by learning to write in the disciplines".

Supporters of the use of traditional writing genres (i.e. the WID movement) generally hold that writing in the accepted scientific genres can provide opportunities for understanding the relationships between evidence and knowledge claims, and the tentative nature of the scientific enterprise. Supporters of this view contend that everyday language is not technical or precise enough to accurately describe scientific phenomenon (Gee, 2004). Coupled with opportunities for authentic investigation, writing to communicate science can provide the opportunity for in-depth scientific thinking and promote crystallization of new understandings through verbal modes of discourse (Keys, 1999). Halliday and Martin (1993) argued that scientific writing genres should be explicitly taught, so that all children might have access to the discursive power of scientific texts. Keys (1999) claimed that writing in scientific genres promotes the production of new knowledge by creating a unique reflective environment for learners engaged in scientific investigations. She proposed that learners involved in authentic scientific inquiry will take personal ownership of their own scientific ideas and should learn to write in scientific genres to express those ideas. Learning to write in traditional scientific genres is a natural outgrowth of the inquiry process, fostering a profound understanding of the connections between inquiry problems, procedures, data, and knowledge claims (McDermott & Hand, 2010; Pearson et al., 2010).

The LTW approach, designed to improve student scientific writing, has gained considerable attention lately as a strategy to move students from thinking about science as a collection of facts to be memorized towards a deeper understanding of concepts and scientific ways of thinking. At the same time the WTL movement had started to migrate from general approaches to discipline-specific studies of the relations between writing and learning and there has been a relative neglect of the generic WTL strategy (Moskovitz & Kellogg, 2011; Reynolds, Thaiss, Katkin, & Thompson, 2012).

3.3.3. Genre-based pedagogy

Genre refers to abstract, socially recognized ways of using language. It is based on the assumptions that the features of a similar group of texts depend on the social context of their creation and use, and that those features can be described in a way that relates a text to others like it and to the choices and constraints acting on text producers (Swales, 2001).

Over the past three decades the Genre-based pedagogy was developed mainly by Australian researchers and educators and received increasing attention as an effective writing instruction pedagogy, also known as the "Sydney school" (Rose, 2016). Based on the SFL theories of Halliday and Martin (1993), genre-based pedagogies offer students explicit and systematic explanations of the ways language functions in social contexts (Hyland, 2003). These perspectives pose a challenge to the earlier emphasis on writing as a generic skill, taught primarily in language or composition classes, and transferred directly to other disciplinary contexts. They suggest that what counts as effective writing (e.g., argument and persuasive evidence) varies greatly in moving from one context (or discipline) to another, therefore what counts as “good writing” is itself socially constructed and context specific (Applebee & Langer, 2013).

According to the genre-based pedagogy, explicit instruction in different genres is needed to promote students' writing skills. A typical instructional cycle begins with analysis (deconstruction) of a genre, followed by joint construction, with the teacher guiding the class, and then independent writing (Rose, 2016). The genre-based pedagogy was found as an effective writing instruction strategy in numerous studies, including the recent meta-analyses of writing instruction (Graham et al., 2016; Graham & Perin, 2007a), which identified the study of model texts as an effective instructional strategy. Graham and Perin (2007a) recommended providing adolescents with good models for each type of writing that is the focus of instruction. These examples should be analyzed, and students should be encouraged to imitate the critical elements embodied in the models (Graham & Perin, 2007a).

3.3.4. Sociocultural instructional approaches

There is a general acceptance of the inherently social nature of writing (Englert et al., 2006). Numerous instructional models have been developed and researched, relying on the sociocultural nature of writing.

According to the cognitive apprenticeship pedagogical approach (Collins, Brown, & Newman, 1989) learning occurs in a socio-cultural context by observation, imitation and mediation with other learners. Written language learning, in particular, 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. One of the first and most influential instructional models of writing was the cognitive apprenticeship framework, conceptualized by Scardamalia and Berieter (Scardamalia & Bereiter, 1985; Scardamalia et al., 1984) for teaching writing. This framework proceeds through a combination of the following steps: *modeling*, *coaching*, *scaffolding* and *fading*. By modeling, the expert makes his/her tacit knowledge visible to the novices, usually by think aloud. Then, by coaching, the expert scaffolds students' activity using various procedural facilitators and tools. Eventually, in gradually fading away, the expert encourages novices to develop independence. In the classical cognitive apprenticeship model what begins with a teacher-centered discourse in an authentic writing activity is succeeded by an interactive and collaborative discourse in which mental activity is distributed and shared between the teacher and students (Englert et al., 2006).

Carter et al. (2007) investigated the role of writing in the socialization into a discipline using the term 'apprenticeship genres'. They argue that apprenticeship genres have the potential of being perceived as legitimate genres that may socialize students into a particular discipline. It is argued that the genre socializes students into ways of knowing and understanding within that particular discipline, and that apprenticeship genres tend to familiarize students with particular behaviors and routines in certain contexts, such as the lab.

Another social practice often enacted in writing instruction involves the ability to engage in collaborative learning (Applebee & Langer, 2013). While writing collaboratively, students are working with each other on writing tasks with shared sense of roles and responsibilities. Collaborative writing is often mediated through digital tools such as wikis, class blogs or Google Docs. By engaging in collaborative writing mediated by the use of digital tools, students are exposed to alternative perspectives leading them to generate insights and deeper understanding beyond what they may have generated on their own. In addition, through peer-feedback activities, students are more likely to employ more revisions than if they are self-editing. Through participation in theses collaborative activities, students develop an increased awareness of the complexity of texts, awareness that itself is a marker of writing development (Beach et al., 2016).

3.3.5. Self-regulation and strategy instruction

There is an extensive evidence for the efficacy of writing interventions that teach students to regulate their problem solving. The Self-Regulated Strategy Development (SRSD) model is a well-established, thoroughly validated instructional model used to teach a variety of writing strategies to elementary, middle, and high-school students. SRSD is a flexible instructional model that complies with that mandate by helping students explicitly learn the same kinds of planning, drafting, and revising strategies that are used by highly skilled writers. Over 30 researches and meta-analyses documented that SRSD leads to significant and meaningful improvements in writing knowledge, writing quality, writing approach, self-regulation skills, and motivation (Graham & Harris, 2003, 2006; Graham & Perin, 2007a).

The major goals of SRSD are threefold (Harris, Schmidt, & Graham, 1998): (1) Assist students in developing knowledge about writing and powerful skills and strategies involved in the writing process, including planning, writing, revising, and editing; (2) Support students in the ongoing development of the abilities needed to monitor and manage their own writing; (3) Promote children's development of positive attitudes towards writing and themselves as writers.

In the SRSD instructional model the teacher first provides explicit support for learning the strategy. Over time, the teacher transfer control to the student, who assumes greater responsibility for monitoring the strategy's application. In addition, students receive from the teacher explicit instruction about a writing strategy's purposes and potential benefits, as well as experiences designed to ensure the strategy's internalization, maintenance and generalization (Graham & Harris, 2005; Graham & Harris, 1996).

In addition to the SRSD model, researches also examined the relations between the student's writing strategy and the writing instruction provided (Kieft, Rijlaarsdam, & Van den Bergh, 2006). For example, Kieft, Rijlaarsdam, Galbraith, and Van den Bergh (2007), found that adapting the writing instruction (i.e., planning or revising) to students' level of writing strategy (i.e., planner or reviser) is an effective approach for learning to write.

3.3.6. Computer-based writing instruction

For at least the past two decades, the growing prevalence of digital media in homes and in the workplace and community has led to calls for schools to embrace the possibilities that such media can create in supporting the writing process, building community, encouraging collaboration, and providing near-instant access to information from sources around the world and across time. However, technology adoption by teachers has been relatively slow, and has primarily been used to reinforce a presentational mode of teaching (Applebee & Langer, 2013). Various studies have highlighted ways in which a variety of evolving technologies may interact with writing and learning to write. Research over the past three decades consistently finds that instructional uses of computers for writing are having a positive impact on students' writing, both in terms of quantity and quality. In their meta-analysis, Goldberg, Russell, and Cook (2003) found that in general, when students write using computers, writing becomes a more social process in which students share their work with each other. When students write with computers, they engage in revising their work throughout the writing process, more frequently share and receive feedback from their peers, and benefit from the teacher's input earlier in the writing process. In most cases, students also tend to produce longer passages when writing using computers.

There has been an increased effort to develop computer-based systems for writing assessment and instruction. These systems vary widely in their primary purpose, from the automated scoring of student essays to the provision of formative feedback or the explicit instruction of writing knowledge and strategies (Allen, Jacovina, & McNamara, 2016). The majority of research conducted on this topic has focused on the development of computer-based systems that can provide reliable and valid scores to students' essays. However, more recently, researchers have placed a stronger emphasis on the development of computer-based systems that incorporate more instructional materials, such as formative feedback and explicit instruction on writing process (McNamara, Crossley, & Roscoe, 2013).

The advantages of a web-based writing environment have been presented previously (Applebee & Langer, 2013; DeVoss, Eidman-Aadahl, & Hicks, 2010; Yancey, 2009). It was shown that learning to write in a web-based environment can improve students' writing skills over the conventional writing environment. For example, students can easily review and learn from each other's work. The anonymity of the Internet may help motivate students to review other students' work (Yang, 2005). Additionally, various Internet features, such as interactive discussions, enable students to interact with each other and with the teacher. Teachers can constructively criticize students' work. The advantages of a web-based writing environment can be summarized as enabling students: (i) to inspect and learn from each other; (ii) to give and receive feedback; (iii) to publish their work; and (iv) to provide a good editing environment for students (Yancey, 2009).

It is clear that middle and high-school students are comfortable with a wide range of technologies that can support writing and interaction, however, they are often more comfortable with technology than their teachers are. Only a relatively small minority of the teachers utilize complex technological platforms (e.g. Moodle) to engage students in intellectually challenging ways to think about and with the concepts they are studying, as well as to interact conceptually with their teachers and peers (Applebee & Langer, 2013).

3.3.7. Instruction of writing in secondary school science

Writing entails important advantages in science learning. The role of writing as a learning tool was extensively investigated in the past (Galbraith, 1999; Klein, 1999; Rivard, 1994) and was also reviewed in recent meta-analyses (Bangert-Drowns, Hurley, & Wilkinson, 2004; Gillespie, Graham, Kiuhara, & Hebert, 2014; Gunel, Hand, & Prain, 2007; Klein & Boscolo, 2016). When students write about new concepts and ideas, they learn them better. In this way writing becomes in effect a comprehension strategy that can be used instructionally to activate what students know, consolidate new learning, or extend what they have learned (Applebee & Langer, 2013).

Although the ability to convey thoughts, ideas and findings through writing is essential for students in developing science literacy, and despite its important role as a learning tool, implementing scientific writing among high-school students can be problematic and poses difficulties for students and teachers. Zion, Cohen, and Amir (2007) reported that students exhibit difficulties in scientific writing of an inquiry report. Some of these difficulties are: to form a logical sentence using correct language, to discriminate between what is important and what is not and to write continuously with a clear and relevant link between segments of the text. Other research studies point out difficulties with organizing data and analyzing it (Porter et al., 2010); a lack of reference to conclusions, and when conclusions are present, they are often missing evidence – in the form of data – to support their claims (Keys et al., 1999; Rutherford, 2007). It was also previously shown that students struggle to communicate their ideas, coordinate evidence and theory or provide an adequate challenge to an alternative claim when they are asked to craft an argumentative text in the context of science (Kelly & Bazerman, 2003; Kelly, Regev, & Prothero, 2008; Kelly & Takao, 2002).

Students' difficulties in scientific writing are not surprising giving the fact that they are usually not required writing substantially in the course of their studies (Sampson et al., 2011). Writing assignments at the school level are usually mechanical and trivial and aimed to demonstrate knowledge transfer and to document information. Only a minor part of writing tasks given to students facilitate processes of knowledge organization, inquiry learning, meaningful learning and deep understanding of scientific ideas (Moore, 1992; Rivard, 1994). To complicate matters further, many science teachers are reluctant to teach students how to write science-specific argumentative texts because they claim that the amount of instructional time that is required to help students learn to write will only decrease the amount of time available to address the content they need to "cover" in an already overcrowded curriculum, or they feel unqualified to teach students how to write in science (Galbraith, 1999; Holliday, Yore, & Alvermann, 1994).

Despite the complexity of teaching and learning of scientific writing in high-school, there are numerous successful examples. One of the most researched approaches is an inquiry-based approach called the Scientific Writing Heuristics (SWH) (Hohenshell & Hand, 2006; Keys et al., 1999). The SWH is a tool intended to help students construct understanding during practical work. Students are required to produce written explanations of the processes involved in the activity through completion of a template, with particular emphasis placed on claims, evidence and reflection. Another example is the Argumentative Driven Inquiry (ADI) model (Sampson et al., 2011). The ADI model, consisted of 8 stages, provides students with opportunities to engage in the authentic practices of science while participating in laboratory activities. In the ADI model, students design their own investigations, engage in scientific argumentation as they develop and critique arguments, write a report about their investigation for a critical and knowledgeable audience, participate in the peer review process, and revise the report based on the critiques offered by the reviewers. Other examples are: Writing for different audiences. For instance, Gunel, Hand, and McDermott (2009) showed that students' writing for peers or younger students performed significantly better on conceptual questions than students writing for the teacher or the parents; and Klein and rose's model (2010) for teaching argument and explanation genres.

Several solutions and pedagogical approaches have been developed for writing instruction of undergraduate students, among them are: (i) the use of tutorials, such as LabWrite (Ferzli, Carter, & Wiebe, 2005). LabWrite is a process-oriented tutorial, focusing on the process of science as it happens in the science laboratory. It provides a framework to help students develop scientific thinking skills as they write before, during, and after lab; (ii) Peer review and Calibrated Peer Review designed to reflect the writing process in the academic world (Reynolds & Thompson, 2011). Calibrated Peer ReviewTM (CPR) is an online application designed to increase student reading and writing in science. The application is modeled on the peer review process of scientific research proposals and manuscripts; (iii) other studies incorporate primary literature to promote undergraduate students' scientific writing skills. These studies suggest that students should be exposed to examples of adequate scientific writing in order to learn how to write properly and that exposure to the similarity between the inquiry process and scientific writing can assist in understanding each of them (Kuldell, 2003; Muench, 2000).

Despite the recognition of the importance of writing in the high-school science classes, many issues remain unclear regarding the learning goals and the suitable strategies to implementing writing practices in the science classroom and addressing the students' and the teachers' challenges.

4. Research goal and questions

The main goal of this study was to design and examine an APL-based teaching and learning environment aimed at promoting scientific writing skills of high-school biology majors.

The overall research project addressed three broad concerns:

(i) How should a teaching and learning environment be designed to promote scientific writing skills of high-school biology students?

(ii) How can biology teachers be enabled to apprentice their students into the scientific discourse community using APL as an apprenticeship genre?

(iii) In what ways does the learning environment develop students' scientific writing skills?

Several overarching research questions were derived from these concerns, among them are:

(i) What design principles and instructional practices the learning environment should be based on to enhance students' scientific writing skills? (See research questions 1-4, 13 in Table 1)

(ii) How was the teaching and learning environment adopted and implemented?(See research questions 5, 7, 9,12 in Table 1)

(iii) What are the outcomes of the enactment of the teaching and learning environment? (See research questions 6, 8, 9, 10, 11in Table 1)

This research is consisted of four phases. Each phase entailed different and specific research questions. These questions are summarized in Table 1.

Table 1. Research questions according to the research phases

Phase	Research questions addressed
I	1. Which components of scientific writing do high-school biology majors struggle with while writing an inquiry report? 2. What are the instructional strategies that teachers implement for teaching scientific writing in high-school and what are the challenges that the teachers are facing in this process? 3. How does learning with APL influence the process of inquiry-based writing and the scientific writing skills of high-school biology majors?
II	4. What design principles and instructional practices the learning environment should be based on to enhance students' scientific writing skills?
III – Iteration 1	5. How was the SWIM environment adopted and implemented? 6. How does enactment of the SWIM environment influence students' scientific writing skills?
III – Iteration 2	7. How was the SWIM 2.0 environment adopted and implemented? 8. How does enactment of the SWIM 2.0 environment influence students' scientific writing skills? 9. How does the teachers' orientation for writing instruction reflected in the apprenticeship model and how does it influence the writing process? 10. How does the writing process using SWIM 2.0 environment influence the attitudes of high-school biology majors towards writing in science? 11. How does the writing process using SWIM 2.0 environment influence the understanding and learning process of high-school biology majors?
III – Iteration 3	12. How was the SWIM 3.0 environment adopted and implemented in a large-scale?
IV	13. As the design experiment evolved, what design principles and instructional practices were generated or changed and how were they changed, to enhance students' scientific writing skills?

5. Methods and tools

5.1. Description of research context

This research was carried out in 12th grade biology classes conducting an inquiry-project. The inquiry-project is a mandatory 1 credit unit for Biology majors in Israel (Israeli Ministry of Education, 2011). The inquiry-project, entitled "Bio-Heker" is conducted collaboratively in groups of 2-3 students. Students are required to summarize their work in a report, written according to customary scientific writing rules (See the guidelines of the Ministry of Education in Appendix 9. The Ministry of Education's guidelines for writing the inquiry-project report). In the course of the inquiry project, the students conduct an inquiry on a biological issue while implementing biological knowledge and reasoning strategies acquired during the theoretical study of the issues, in the lab, reading scientific papers and other activities, and applying methods and laboratory skills acquired during laboratory activities. During the inquiry, the students go through a process by which they experience authentic practices of scientific research. They design an experiment based on a research question, carry out the experiment and collect data, analyze the collected data and report their investigation in a summarizing report. The reports should incorporate relevant biological knowledge integrated from various sources with the students' experimental results and eventually link their conclusions to core ideas in biology. This process is demanding overall, but the writing stage was reported by teachers and students to be the most challenging stage of the inquiry project.

"Gene Tamers – Studying Biotechnology through Research (Falk, Piontkevitz, Brill, Baram, & Yarden, 2003) is an elective APL-based curriculum for 11th-12th grade biology majors. The curriculum is aimed at enhancing students' inquiry-thinking skills and their understanding of the nature of research practices in biological sciences, and is expected to represent contemporary research in biology, which is only seldom used for science learning in secondary schools (Israeli Ministry of Education, 2003). The "Gene tamers" is one of three topics in the 1 credit elective unit – "The Research Topic" – for biology majors that was designed for 11th and 12th grade students. The curriculum materials include three adapted research articles. The three adapted research articles, all from leading peer-reviewed professional literature, present cutting-edge research and deal with three different topics in biotechnology. The "Gene tamers" curriculum is accompanied by a web site (http://stwww.weizmann.ac.il/g-bio/biotech//) that includes background material, questions and answers for each article, various activities, links and a closed section for teachers.

5.2. Design-based research approach

The methodological approach chosen for this research was Design-Based Research (DBR). Educational DBR can be defined as a genre of research in which the iterative development of solutions to practical and complex educational problems provides the context for empirical investigation, which yields theoretical understanding that can inform the work of others, and potentially impact learning and teaching in naturalistic settings (Barab & Squire, 2004; The Design-Based Research Collective, 2003; McKenney & Reeves, 2013; Plomp, 2009; Van den Akker, 1999). Cobb, Confrey, Lehrer, and Schauble (2003) suggested that DBR has a number of common features, including the fact that it results in the production of theories on learning and teaching, is interventionist (involving some sort of design), takes place in naturalistic contexts and is iterative. The last decade has witnessed a growing trend towards DBR in education and, in particular, on the use of technology in education (Anderson & Shattuck, 2012; Reeves, 2006; Wang & Hannafin, 2005).

DBR is an appropriate approach for this study, because it is focused on the process of developing innovative tools and activities as a means of understanding learning and advancing educational practice (Klein & Rose, 2010). Furthermore, lately a call for DBR in the field of writing instruction in high-school science was made, as examples of design research are well represented across the fields of literacy, mathematics, science and technology, but are less widely used in the study of secondary writing instruction (Kwok et al., 2016). As Kwok et al. (2016) suggested, "design-based studies can examine important sociocultural dimensions of writing instruction, such as how teachers apprentice students to norms and practices of disciplinary communities".

Some of the primary characteristics of DBR are that it requires practitioners and researchers to collaborate in the identification of real teaching and learning problems, the creation of prototype solutions based on existing design principles, and the testing and refinement of both the prototype solutions and the design principles until satisfactory outcomes have been reached by all concerned (Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006). In this study I attempted to design a solution to the problem of learning and teaching scientific writing in high-school biology. To this aim, this study was conducted in a close collaboration with biology teachers and instructors. From the beginning of the study, I collaborated with practitioners to identify and define the problem, to design and develop the prototype of the environment, to implement it in classes and to revise the various versions in order to obtain the most effective solution.

As mentioned above, DBR is iterative and cyclical in character: analysis, design, evaluation and revision are iterated until a satisfying balance between ideals and realization has been achieved. In this study I followed the four phases model of DBR described by Reeves (2006). This process was illustrated by Plomp (2009) in the following diagram (Figure 1):

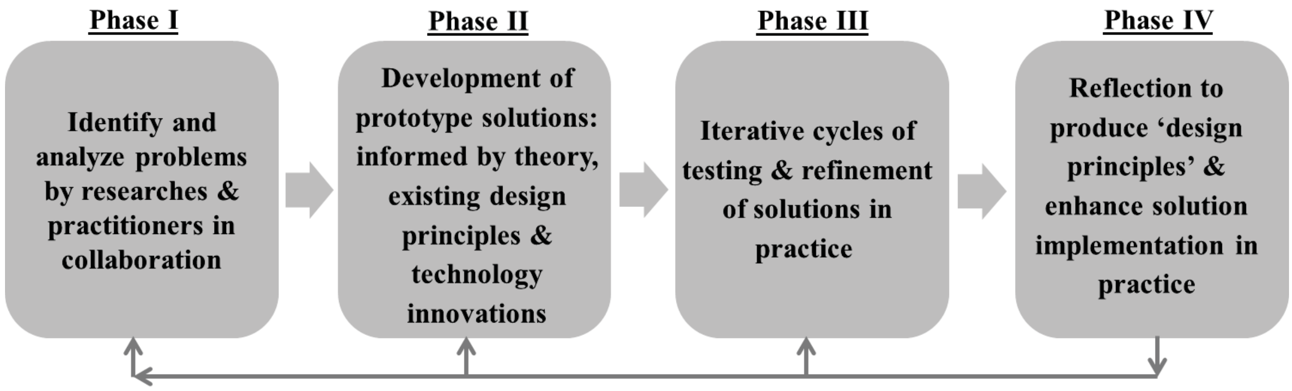

Figure 1. The DBR process: Refinement of Problems, Solutions, Methods, and Design Principles (following Plomp, 2007).

The four phases of this study are presented in Table 2. Educational design research starts with identification of significant educational problems in need of innovative solution. In the first phase of the study, the educational problems in the process of inquiry-based writing in high-school biology classes were identified and characterized by several means: (i) literature review was conducted to identify previously described problems and possible solutions; (ii) interviews with teachers, and (iii) text analyses of inquiry-project reports. These means were used to identify current scientific writing difficulties of biology majors, common instructional strategies and challenges in the process of writing the inquiry-project report. In the first phase I also wished to examine whether learning with APL can facilitate scientific writing skills of high-school biology students.

In the second phase, an in initial definition of the design principles was made. Based on these design principles, the prototype of the learning and teaching environment was designed and developed. The environment was named "*SWIM*" which stands for – "*Scientific Writing Interactive Model*". The prototype is referred to as SWIM 1.0.

Table 2. The four phases of the study.

Phase	Goal and description
I	**Identify an educational problem**
	- Literature review
	- Research tools development
	- Characterization of scientific writing difficulties, instructional strategies and challenges
	- Examination of possible influence of learning with APL on scientific writing skills
II	**Prototype design and development**
	- Definition of initial design principles
	- Development of SWIM 1.0
III	**Iterative cycles of implementation-evaluation-revision**
	Iteration 1: - Implementation of SWIM 1.0
	- Evaluation of SWIM 1.0, feedback, findings and challenges
	- Revise to create SWIM 2.0
	- Development of additional required research tools
	Iteration 2: - Implementation of SWIM 2.0
	- Evaluation of SWIM 2.0, feedback, findings and challenges
	- Revise to create SWIM 3.0
	- Development of additional required research tools
	Iteration 3: - Implementation of SWIM 3.0
IV	**Reflection**
	- Evaluation of SWIM 3.0, feedback, findings and challenges
	- Revise to create SWIM 4.0
	- Production of final design principles
	- Recommendations for future research

In the third phase of the study, three consecutive iterations were performed during the years 2013-2015. In each iteration the SWIM environment was implemented, evaluated and revised to create the subsequent version. The implementations included teachers' training workshops and enactment in 12th grade biology classes. In the fourth phase of the study, the SWIM 3.0 environment was evaluated and revised to create the final learning and teaching environment (SWIM 4.0). In addition, this phase included a deep reflection of the design process to produce the final design principles and to outline recommendations for future research.

5.3. Methods and tools

A summary of the research questions, tools and population according to the phases of the study is presented in Table 6.

5.3.1. Research population

The main goal of this study is to design and examine an APL-based teaching and learning environment (The SWIM environment) aimed at promoting scientific writing skills of high-school biology majors. Four types of populations were examined in this study (Table 3): SWIM-APL classes, SWIM-Non APL classes, Non SWIM-APL classes and Non SWIM-Non-APL classes.

Table 3. The four population types of the study

Population type	Name of population	SWIM	APL
Experimental	SWIM-APL	+	+
	SWIM- Non APL	+	-
Comparison	Non SWIM- APL	-	+
	Non SWIM- Non APL	-	-

SWIM classes – classes which implemented the SWIM environment,
APL classes – classes which study an elective APL-based unit called "Gene tamers" (Falk et al., 2003).

Teachers and students

Twenty one Biology teachers participated in this research in its four phases. The details of the participating teachers are presented in Table 4. Overall, 171 students participated in this research (in the second iteration, in the third phase of the research). The number of students in each class is presented in Table 4.

In addition to the four types of classes listed above, this study's population also consisted of the teachers who participated in training workshops about the SWIM environment (approximately 200 teachers participated during the years 2013-2015). The training workshops are described in section 6.3.1.1.

Table 4. Research population

Teacher	Experience in years	Academic background	Phase	Research population type	Data sources	School characteristics (No. of students participating in the study)
1	14	BSc (RW)	II		Development team	
2	12	BSc (RW)	II			
3	18	BSc (RW)	II			
4	13	BSc (RW)	II			
5	10	BSc (RW)	II, III			
6	26	MSc (RW)	I, II, III	APL – Non SWIM		
7	19	BSc (RW)	I, III	Non APL-Non SWIM	Reports (n=5), Interview	Rural, medium-high socioeconomic status
8	17	BSc (RW)	I, III	Non APL-Non SWIM	Reports (n=4), Interview	Urban, medium-high socioeconomic status
9	22	MSc	I	Non APL-Non SWIM	Reports (n=7) , Interview	Rural, medium-high socioeconomic status
10	19	MSc	I, III	Non APL-Non SWIM	Reports (n=7)	Urban, medium-high socioeconomic status
11	16	BSc	I, III	Non APL-Non SWIM	Reports (n=3)	Urban, medium socioeconomic status
12	29	MSc	I	APL – Non SWIM	Reports (n= 7), Class observations, Interview	Urban, medium-high socioeconomic status
13 (Control)	23	MSc	I, III	Phase I: APL – Non SWIM Phase III: Non APL-Non SWIM	Phase I: Reports (n=7), Class observations, Interview Phase III: Pre / Post SWS test (n=13)	Urban, medium-high socioeconomic status (n=24 students)
14	26	MSc	I	APL – Non SWIM	Class observations, Interview	Urban, high socioeconomic status
15 (Ann)	15	BSc (RW)	III	Non APL-SWIM	Reports (n=7), Class observations, Interviews	Urban, medium-high socioeconomic status
16 (Bella)	29	BSc	III	Non APL-SWIM	Reports (n=7), Class observations, Interviews	Rural, medium-high socioeconomic status
17 (Carol)	25	MSc	III	Non APL-SWIM	Class observations, Interviews, Pre / Post SWS test (n=12), Attitudes questionnaire, feedback analysis	Rural, medium-high socioeconomic status (n=35 students)
18 (Dana)	10	MSc	III	Non APL-SWIM	Class observations, Interview, Pre / Post SWS test (n=22), Attitudes questionnaire	Urban, medium-high socioeconomic status (n=25 students)
19 (Eleanor)	23	MSc	I, III	APL-SWIM	Phase I - Class observations, Interview Phase III - Pre / Post SWS test (n=23), Attitudes questionnaire	Urban, medium-high socioeconomic status (n=29 students)
20 (Frida)	20	BSc (RW)	I, III	APL-SWIM	Phase I - Class observations, Interview Phase III - Pre / Post SWS test (n=17), Attitudes questionnaire	Urban, medium-high socioeconomic status (n=32 students)
21 (Control)	16	MSc	I, III	APL – Non SWIM	Phase I - Class observations, Interview Phase III - Pre / Post SWS test (n=20)	Urban, medium-high socioeconomic status (n=26 students)

RW – participant in the Rothschild-Weizmann Program for Excellence in Science Education

5.3.2. Research tools

DBR interventions are assessed on a wide variety of indices using multiple methodologies and typically involves mixed methods using a variety of research tools and techniques (Anderson & Shattuck, 2012). Following is a description of the main research tools used in the research. These tools were adjusted and modified as the research progressed and new tools were adopted or developed as needed. For each tool, the phase of implementation is indicated.

Interviews with teachers and students

Semi-structured interviews were conducted with biology teachers in all phases of the study. In the first phase, interviews were carried out with 9 Biology teachers, two national supervisors and the Chief Inspector of Biology Education in Israel. In the third phase, I interviewed the teachers who enacted the SWIM environment in their classes. In the 45-60 minutes interviews the teachers were asked to express their knowledge and views on the following issues:

- Their academic background and teaching experience,
- Their knowledge and experience about instructional strategies for teaching scientific writing,
- Difficulties they and their students are facing during the writing process of inquiry reports,
- Feedback on specific exercises from the SWIM environment implemented in their classes,
- Feedback on the SWIM environment in general (design, technology, structure, etc.).

In addition, several groups of students from the four research populations were randomly chosen for 30 minutes semi-structured interviews. In these interviews, I examined the students' perceptions of scientific writing, their difficulties in the writing process of their inquiry reports and their motivation to write them. The interviews were performed in focus groups of two-three students.

Scientific Writing Assessment Rubric (SWAR)

This tool is aimed to assist in evaluating the abilities of high-school biology students to scientifically write their inquiry-project reports, thus it enables to reveal difficulties in specific components of their scientific writing. This tool was used in the first phase and in the first iteration of the third phase. The criteria of SWAR (see Table 5 for criteria definitions) were developed following Timmerman et al. (2011), along with the guidelines of the Ministry of Education for the inquiry-project report (See Appendix 9. The Ministry of Education's guidelines for writing the inquiry-project report), and specific writing difficulties extracted from interviews with teachers and supervisors 6.1.2, Table 7). Each criterion is assessed according to 4 levels and scores (not addressed=0, novice=1, intermediate=2 and proficient=3). The complete rubric is presented in Appendix 1. The SWAR was used as follows: Drafts of the inquiry-project reports were assed according to the criteria in the rubric.

Each criterion was given a score (0-3) and an average score was calculated. Five experts scored 15% of all drafts to validate the results. Observed agreement was 87.3%.

Table 5. List of criteria and definitions in the SWAR

Section	Criteria	Definition (at the proficient level)
Introduction	Justification of inquiry	Demonstrate a clear understanding of the importance of the inquiry question.
	Inquiry question	Inquiry question is clear and well written.
	Background	Content knowledge is accurate, relevant and provides appropriate background including defining critical terms.
	Hypothesis	Hypothesis is relevant, testable and clearly stated.
	Hypothesis – scientific merit	Hypothesis has scientific merit and foundation.
Methods	Experimental design	Experimental design is likely to produce salient and fruitful results. Include description of dependent and independent variables.
	Replications	Appropriate replications are present and explained.
	Controls	Appropriate controls are present and explained.
Results	Data selection	Data chosen are comprehensive, accurate and relevant.
	Data presentation	Data are summarized in a logical format. Table/graph types are appropriate, including proper labels, units, scales and statistical data.
	Results description	Description is clear and accurate.
Discussion	Conclusions based on results	Conclusions are logically drawn from data provided.
	Results explanation and alternative explanation	Explanation of results is clear and logical. Alternative explanations are considered.
	Criticism	Conclusion expressed cautiously. Limitations of the data and/or experimental design are discussed.
General writing	Structure	Report is constructed properly and presents clear understanding of the role of each section.
	References	Several reliable and relevant resources are properly and accurately cited.
	Language and grammar	Grammar, word usage and organization facilitate the reader's understanding of the paper.

Class observations

Class observations were held in all the phases of the research. Forty lessons of 8 classes were observed and recorded during the academic years 2013-2015. The observations focused on the instruction of writing of the inquiry-project report, APL-based learning and the implementation of various exercises from the SWIM environment. Overall, the main goals of the observations were to characterize different strategies of writing instruction, to examine whether the students and the teachers make connections between the APL and the writing of the inquiry report, and to evaluate the implementation of the SWIM environment.

Teachers' questionnaires

In order to corroborate the qualitative data obtained from teachers' interviews, a quantitative questionnaire was developed (See Appendix 2) and distributed during the first phase of the research. The questionnaires were administered prior and following the SWIM training workshops. The questionnaires examine four main aspects:

- Students' scientific writing difficulties
- Teachers' challenges in instruction of scientific writing
- Teachers' strategies for instruction of scientific writing
- Feedback on the workshop: quantitative and qualitative (open questions about specific exercises and general feedback).

The different items in each aspect were derived from the interviews. The teachers were asked to rate the items in the students' scientific writing difficulties and teachers' instructional challenges aspects such as: *'Major difficulty'*, *'Minor difficulty'* or *'Not a difficulty'*, and the items in the teachers' instructional strategies aspect as: *'Main strategy'*, *'Secondary strategy'* or *'Not implemented'*.

Pre/Post Scientific Writing Skills test (SWS)

Students' scientific writing skills and genre knowledge were evaluated pre- and post-intervention (i.e., implementation of the SWIM environment) using a *Scientific Writing Skills Test* (See Appendix 3). This instrument was used in the second iteration during the third phase of the research. The test is composed of a short (one-page) adapted research article and open-ended questions. The article contains a short introduction, methods and a graphic representation of the results, without a description. The discussion is omitted. The questions section is divided to four parts; each part examines different scientific writing skill:

1. Give a title to each paragraph
2. Identify the research component (i.e. research question, hypothesis, variables, and controls).
3. Describe the results
4. Write a discussion

Researcher diary and E-mails correspondence

The researcher diary and E-mails correspondence were used to document the design process in this study from several angles. All the meetings of the development team were documented in the researcher's diary and relevant E-mails were categorized and analyzed. These two tools enabled the close examination and reflection of the design progression, revealing the decision-making progress that was conducted.

Students' attitudes towards writing questionnaire

This instrument was applied in the second iteration during the third phase of the research, and refers to three main aspects:

1. Attitudes about writing
2. Attitudes about scientific writing
3. Attitudes about writing with computers

The instrument is based on the following questionnaires:

- Students' Perceptions of Writing with Computers (SPWC) (Hertz-Lazarowitz & Bar-Natan, 2002).
- Attitudes Toward Using Computers Survey (Warschauer, 1996).
- Student Writing Attitudes Survey (Dietz, 2012)

The attitudes questionnaire can be found in Appendix 4.

The questionnaire is a Likert 1-5 scale and consists of 26 items divided to 6 constructs. Confirmatory factor analysis yielded six sub-scales:

Writing self-efficacy – This scale consisted of four items, 2 positive and one negative. For example: "I think I am a good writer". Cronbach's Alpha was: 0.63.

Importance of writing – This scale consisted of four items, all positive. For example: "Writing is an important skill". Cronbach's Alph was 0.73.

Importance of writing in science – This scale consisted of three items, two positive and one negative. For example: "Writing skills that are taught in biology can be helpful to me in my everyday life". Alpha was Cronbach's 0.53.

Learning to write in science – this scale consisted of three items, two positive and one negative. For example: "When the teacher shows us a successful lab report or paper I try to figure out what makes it successful on my own". Cronbach's Alpha was 0.62.

Writing to learn with computers – This scale consisted of six items, four positive and two negative. For example: Using a computer gives me more control over my learning". Cronbach's Alpha was 0.84.

Writing with computers – affective factors – This scale consisted of six items, four positive and two negative. For example: "Learning to use a computer gives me a feeling of accomplishment ". Cronbach's Alpha was 0.81

Students' SWIM artifacts and log files

Students' artifacts of SWIM exercises were collected and analyzed. This analysis enabled us to examine the process the students experienced and to monitor the way the SWIM environment was implemented. The log files of the students' work in the computerized environment were collected and analyzed to identify technological problems, to evaluate students' self-regulation and genre knowledge and to monitor the writing process.

Feedback analysis

This instrument was used in the second iteration during the third phase of the research. By analyzing the teachers' feedback on their students' writing, I wished to explore any differences in the feedback strategies of teachers who implemented the SWIM environment, to examine the students' reactions to different kinds of feedback and to reveal the most successful feedback strategies for the writing process of the inquiry-project report using the SWIM environment.

The feedback analysis was carried out as follows: four inquiry–project reports (3-4 drafts for each report) were selected from two intervention classes ("SWIM classes") in the second iteration. From each class, one of the reports was defined as novice level and the other as proficient level, by the teachers. All of the teacher's comments were coded according to several criteria: Draft number, section in the report, type of comment (Genre / Content), Nature of comment (Solution / No solution provided), explanation (Provided / Not provided) and implementation of the comment by the students (Implementation / Partial implementation / No implementation). Fifteen percent of the comments were coded by two researchers, and the agreement reached was 87%. The coding scheme and analysis examples are presented in Appendix 5.

5.3.3. Data analysis

Qualitative data

The qualitative data sources of this study were: interviews, class observations, researcher's diary and e-mails correspondence. Interviews with the students, teachers and supervisors and the recordings of classroom observations were transcribed and analyzed according to Shkedi's (2003) qualitative analysis approach. Transcripts were read several times, primary categories were chosen from the collected data, general domains were established and data were mapped according to the chosen domains and categories. These data were used in the first phase of the study to characterize different strategies biology teachers apply for teaching scientific writing of inquiry reports, to reveal students' writing difficulties and teachers' instructional challenges. In the third phase, the qualitative analysis was used to evaluate the implementation process of the SWIM environment, mostly in regard to the apprenticeship process, to characterize the teachers' pedagogical approach to scientific writing instruction and to explore the students' and teachers' perceptions of the limitations and successes of SWIM environment.

Quantitative approach

The quantitative data sources in this research were: texts analysis using SWAR (Appendix 1. Scientific writing rubric (SWAR) (Final version), Pre / post SWS test (Appendix 3. Scientific Writing Skills (SWS) test, Attitudes towards writing questionnaire (Appendix 4. Attitudes questionnaire and feedback analysis (Appendix 5. Feedback analysis The teachers' comments on the drafts of the inquiry-project report were qualitatively coded followed by a quantitative analysis. All quantitative data were statistically analyzed using Statistical Package for the Social Sciences (SPSS) program while applying the following statistic tests: Mann-Whitney *U* test was used to examine significant differences in the text analysis scores using SWAR; One-way ANOVA with post-hoc Tukey HSD test was used to compare the pre- and post-SWS test's scores of SWIN and control classes; Wilcoxon signed-ranked test was used to determine if the SWS post-test's scores were significantly different from the pre-test's scores. χ^2 test was used for feedback analysis; and paired t-test was used to determine significant differences in the attitudes towards writing questionnaire.

Table 6. Summary of the research questions, tools and population

Phase	Research questions addressed	Research tools	Population and data sources
I	1. Which components of scientific writing do high-school biology majors struggle with while writing an inquiry report? 2. What are the instructional strategies that teachers implement for teaching scientific writing in high-school and what are the challenges that the teachers are facing in this process? 3. How does learning with APL influence the process of inquiry-based writing and the scientific writing skills of high-school biology majors?	• Scientific Writing Assessment Rubric (SWAR) • Teachers' Interviews (n=12 – questions 1&2; n=6 – question 3) • Class observations (n= ~20 lessons) • Teachers' questionnaires (n=65)	• Nine biology teachers (teachers no. 1-9) • Two national instructors • The chief inspector of biology education in Israel • Inquiry-project reports from APL and Non-APL classes (Non SWIM classes) (n= 40 reports) • Six Non SWIM-APL classes and their teachers (teachers no. 6, 12, 14, 19 20, 21)
II	1. What design principles and instructional practices the learning environment should be based on to enhance students' scientific writing skills?	• Researcher diary	In collaboration with 6 biology teachers (no. 1-6) and an educational technology expert (i.e. The development team)
III – Iteration 1	1. How was the SWIM environment adopted and implemented? 2. How does enactment of the SWIM environment influence students' scientific writing skills?	• SWAR • Interviews with teachers (n=4 interviews) • Class observations (n=4) • Researcher diary	• Three classes and their teachers: - Two experimental classes (Ann's and Bella's) • Inquiry-project reports from SWIM (n=14 reports, Ann and Bella) and Non-SWIM (n=9 reports, teacher 7 & 8) classes
III – Iteration 2	1. How was the SWIM 2.0 environment adopted and implemented? 2. How does enactment of the SWIM 2.0 environment influence students' scientific writing skills? 3. How does the teachers' orientation for writing instruction reflected in the apprenticeship model and how does it influence the writing process? 4. How does the writing process using SWIM 2.0 environment influence the attitudes of high-school biology majors towards writing in science? 5. How does the writing process using SWIM 2.0 environment influence the understanding and learning process of high-school biology majors?	• Interviews with teachers (n=6) and students (n=14 group interviews, 2-3 students in a group) • Class observations (n=6) • Pre/Post scientific writing skills test (n=107) • Researcher diary • Feedback analysis (n=4 reports, 12 drafts, 593 comments) • Students' attitudes towards writing questionnaire (n=70)	• Six teachers and their classes: - 4 experimental classes: 2 SWIM-Non APL classes - Carol's (n=35) and Dana's (n=25) and 2 SWIM-APL classes - Eleanor's (n=29) and Frida's (n=32) classes. - 2 comparison classes: 1 Non SWIM-Non APL class - Control class, teacher no. 13(n=24) and 1 Non SWIM-APL class - Control class 2, teacher no. 21 (n=26)
III – Iteration 3	1. How was the SWIM 3.0 environment adopted and implemented in a large-scale?	• Students' SWIM artifacts • Log files from the SWIM environment	• Forty three SWIM classes • Online national SWIM training workshop
IV	1. As the design experiment evolved, what design principles and instructional practices were generated or changed and how were they changed, to enhance students' scientific writing skills?		

6. Findings

6.1. Phase I – The educational problem

6.1.1. Overview of phase I and research questions

In the first phase of this study I wished to characterize and refine the complex problem of inquiry-based writing in high-school biology classes. The characterization of this problem was established by several means: I reviewed the literature to identify previously described problems and possible solutions; interviews with teachers and text analyses of inquiry-project reports. These means were used to identify current scientific writing difficulties of biology majors and common instructional strategies and challenges teachers are facing in the process of writing the inquiry-project report. By refining the problem at stake from several perspectives I wished to set the grounds and establish the need for the development of a new instructional framework for learning to write in high-school biology. My initial hypothesis as described in the introduction was that APL can serve as an apprenticeship genre for high-school science students.

Thus, **the goals of the first phase** of this research were to characterize the difficulties and challenges in the process of writing an inquiry-project report and to examine whether learning with APL (without any other intervention) can mitigate those difficulties. For achieving those goals I asked the following questions in the first phase of the study:

1. Which components of scientific writing do high-school biology majors struggle with while writing an inquiry report?

2. What are the instructional strategies that teachers implement for teaching scientific writing in high-school and what are the challenges that the teachers are facing in this process?

3. How does learning with APL influence the process of inquiry-based writing and the scientific writing skills of high-school biology majors?

6.1.2. Students' scientific writing difficulties

Three methods were applied in order to investigate which components of scientific writing that high-school biology majors struggle with while writing an inquiry report: interviews with teachers and supervisors, teachers' questionnaires and text analysis of drafts of inquiry-project reports using the SWAR. The interviews were recorded, transcribed and analyzed (n=9 teachers, no.1-9, 2 national supervisors and the chief inspector of Biology Education in Israel). The interviewees were asked to describe the process of writing the inquiry-project reports as they experience it in their classes, including the instructional strategies they apply, the parts students find more difficult and the ways they (the teachers and the students) dealt with those problems. The components of scientific writing students struggle with were extracted from the transcribed interviews and divided according to the sections of the inquiry report (Table 7).

Table 7. Students' difficulties while writing an inquiry report – extracted from teachers' interviews.

Section of inquiry-project report	Difficulties
Introduction	• Introduction includes irrelevant information. • Introduction is too detailed or too concise. • Introduction is repetitive. • Justification of inquiry is irrelevant, trivial or too general. • Lack of proper organization. • No merging of sources.
Methods	• No distinction between methods and results – methods section includes results. • Methods description includes irrelevant details. • No distinction between biological and technical replications. • Difficulty distinguishing between controls.
Results	• No distinction between the description and the explanation of the results. • The data presentation format is not appropriate for the inquiry question.
Discussion	• No reference to the role of the controls and the limits of the controls. • Overgeneralization, Conclusions are overly broad and excessive. • Discussion is too shallow and trivial. • No transfer to additional biological levels of organization.
General	• Language is inappropriate and contains errors.

The qualitative data obtained from the interviews, regarding the scientific writing difficulties and instructional strategies, were used as a basis for the teachers' questionnaires. The questionnaires were administered prior and following the SWIM training workshops. Sixty five high-school biology teachers completed the questionnaire (out of the 200 teachers who participated in the workshops). Figure 2 presents the scientific writing difficulties students' are facing while writing an inquiry-project report, according to their teachers, in a descending order (from minor to major difficulties). The most difficult component according to the teachers was 'Language and Grammar', as 72% of the teachers considered it to be a major difficulty. The least difficult component was 'Experimental design', as only 9% of the teachers considered it to be a major difficulty. Other major difficulties (i.e., the majority of the teachers considered them as major difficulties) were: 'Resource and citations' (67%), 'Logical organization' (67%), 'Criticism' (67%), 'Justification of the inquiry' (63%), 'Conclusions based on results' (61%), 'Scientific merit of the hypothesis (59%) and 'Relevant information' (56%). In general, the teachers reported that the components belonging to the introduction and the discussion sections of the report are more difficult for the students than the components belonging to the methods and results sections.

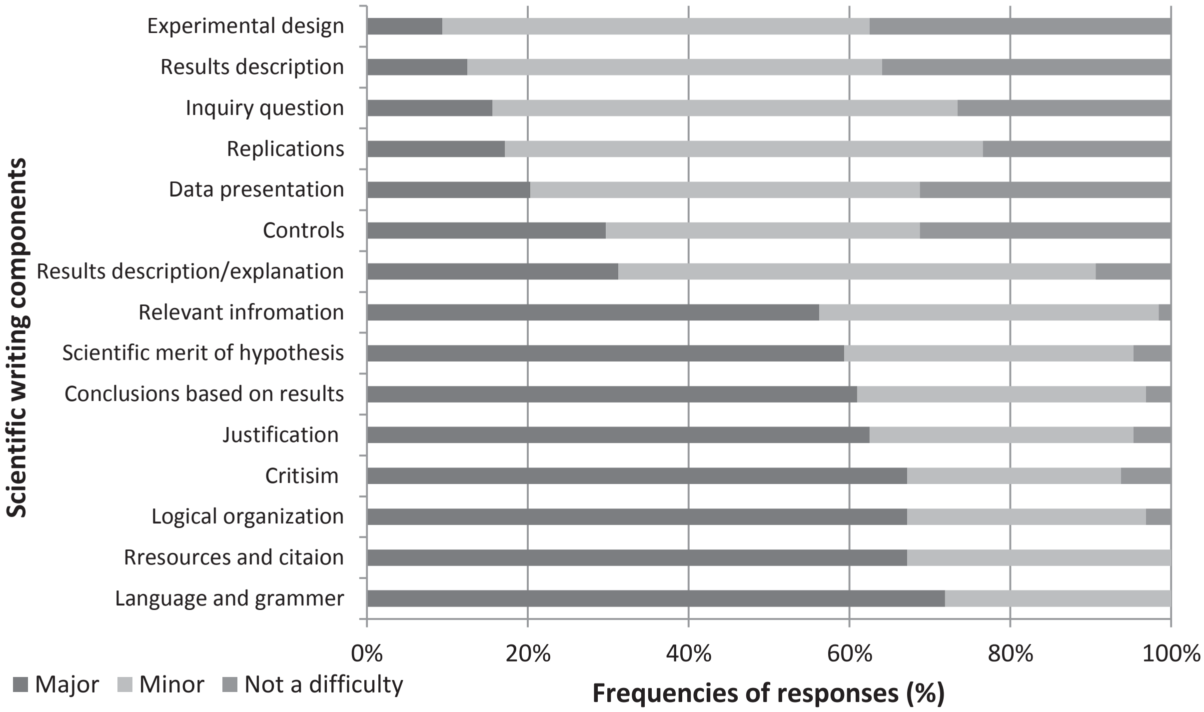

Figure 2. Students' difficulties while writing an inquiry-project report, as reported in teachers' questionnaires. Teachers (N=65) were asked to rate each scientific writing component as: 'Major difficulty', 'Minor difficulty' or 'Not a difficulty' for their students while writing the inquiry report.

To verify the results obtained from the interviews and questionnaires, and possibly reveal additional difficulties, 52 drafts (initial and final draft) of 26 inquiry-project reports were analyzed and assessed using the SWAR (See section 5.3.2 and Appendix 1). The inquiry-project reports were obtained from 5 Non-APL Non-SWIM classes (teachers no. 7-11, see Table 4. Research population).

The analysis of the drafts of inquiry-project reports reveals that in the initial drafts the weaker sections of the inquiry-project report were the Introduction and the Discussion with an average score of approximately 1 (novice level) (Figure 3). The Methods and the Results sections had an average score of 1.4 (between novice and intermediate levels) and the average score of the General scientific writing components was 1.25. In the final drafts an improvement was observed in all the sections of the report, with an average score of 2-2.5 (intermediate – proficient level). The Discussion section appeared to be the weakest, with an average score of 1.9. These findings correlate with the findings from the interviews with the teachers, who stated that students struggle mostly with the Introduction and the Discussion sections.

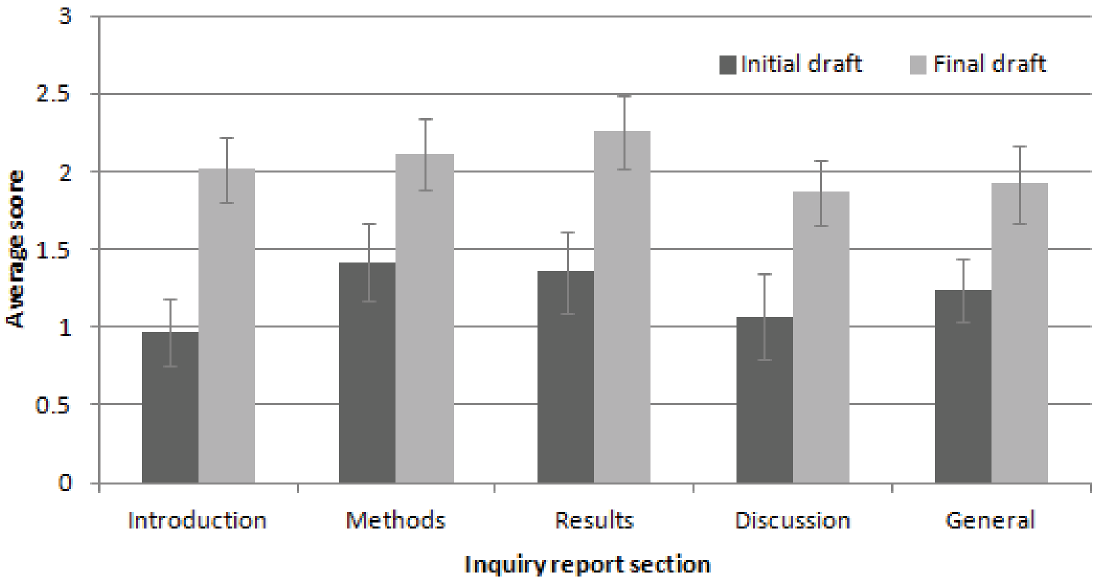

Figure 3. Average Score of the different sections of the inquiry-project reports using SWAR. N=26 reports, 52 drafts. Bars represent standard errors.

The analysis of the reports according to the different criteria in the SWAR shows that in the initial drafts the weakest components of scientific writing were: Resources and citations, the Scientific merit of the hypothesis, Criticism, Results description and Justification of the inquiry (Figure 4). The components that received the highest scores were: Data selection and Language and grammar. Interestingly, formulating the Inquiry question also appeared to be easy for the students, suggesting that question-asking may have been the focus of their teachers' instruction. All of the criteria improved in the final drafts. In the final drafts the weakest components (Resources and citations, the Scientific merit of the hypothesis, Criticism and Justification of the inquiry), although improved, remained weaker than others, along with providing alternative explanations and the structure and organization of the report. The scores of the other scientific writing components' were above 2 (Intermediate level).

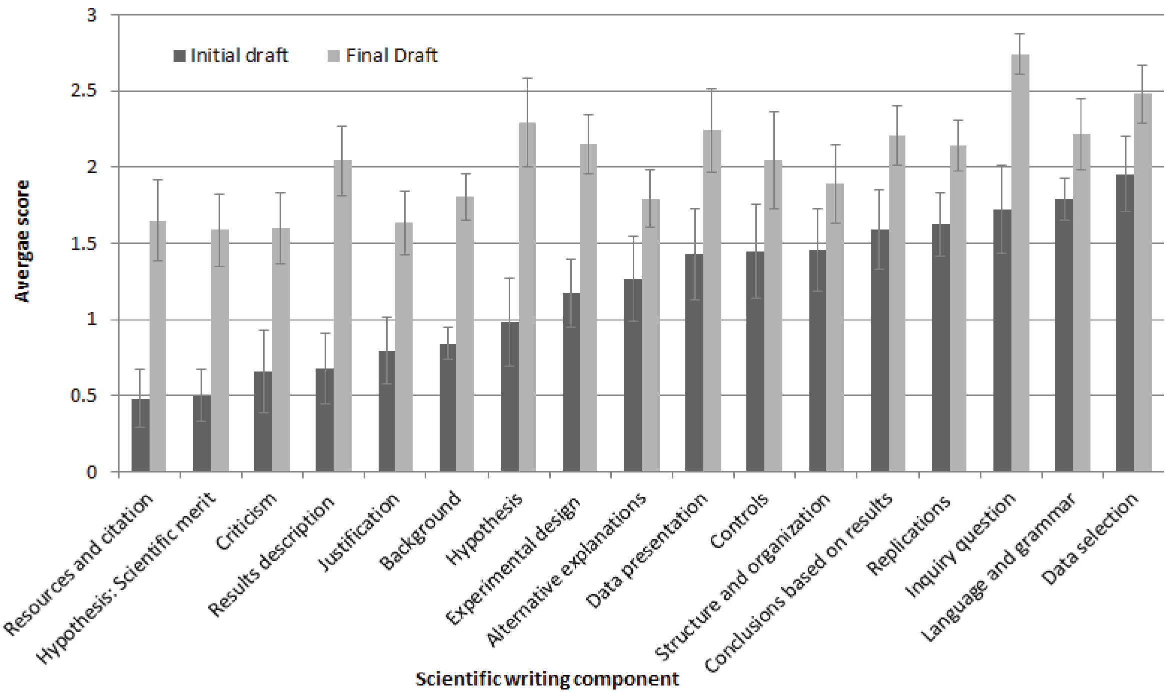

Figure 4. Analysis of initial and final drafts of inquiry-project reports using SWAR. N=26 reports, 52 drafts. Bars represent standard errors.

Comparison of the results from the teachers' questionnaire (Figure 3) and the text analysis (Figure 4) suggests that there is a relatively good alignment between what teachers perceive of their students' scientific writing difficulties and the difficulties emerged from the text analysis. For example, the component Resources and citation received the lowest score in the text analysis (0.48) and most of the teachers (67%) considered it to be a major difficulty. However, in some of the components there was a discrepancy between the results from the teachers' questionnaires and the text analysis: most of the teachers reported Language and grammar as a major difficulty (72%), yet it received relatively high score in the text analysis (1.8). On the other hand, only 13% of the teachers reported Results description as a major difficulty, while its score in the text analysis was relatively low (0.68). These results suggest that the teachers' perception of the students writing difficulties is not always accurate.

6.1.3. Teachers' challenges in teaching scientific writing and the instructional strategies they implement

For the characterization of existing instructional strategies that teachers apply for teaching writing of inquiry-project reports, two instruments were used: Interviews with teachers and teachers' questionnaires.

From the semi-structured interviews with biology teachers (n=9 teachers) five main instructional strategies were identified. The strategies biology teachers apply for teaching writing of inquiry-project reports are: (i) Individual instruction: the teacher works with each student / group of 2-3 students separately, explain the instructions and give feedback to what they write. Usually the feedback is given electronically, where the teacher writes notes / corrections on the report. This individual instruction strategy is characterized by numerous back-and-forth cycles of note / corrections and is time-consuming and exhausting process for the teacher and the students; (ii) Distribution of the Ministry of Education's guidelines and instructions to the students (see Appendix 9. The Ministry of Education's guidelines for writing the inquiry-project report; (iii) Distribution of an outline of the report to the students; (iv) Distribution of the Ministry of Educations' rubric to the students; and (v) Distribution of example reports.

In the questionnaires, teachers (n=65) were asked to rate the five instructional strategies identified in the interviews as: *'Main strategy'*, *'Secondary strategy'* or *'Not implemented'*. The teachers' primary instructional strategy is individual instruction (5. **Teachers' strategies for instruction of writing an inquiry report.** Teachers (N=65) were asked to rate different instructional strategies as: 'Main strategy', 'Secondary strategy' or 'Not implemented'.). All the teachers reported the use of individual instruction and 97% of them reported this as their main strategy for instruction of writing an inquiry-project report. Almost all the teachers (76% main strategy, 23% secondary strategy) also distribute the Ministry of Education's guidelines and instructions to their students. Most of the teachers give their students an outline of the report (65% main strategy, 24% secondary strategy) and a rubric (published by the Ministry of Education, 58% main strategy, 34% secondary strategy). The distribution of examples of reports was least implemented by the teachers (27% main strategy, 47% secondary strategy and 26% not implemented). Additional strategies that teachers reported to have used are: (i) Peer review: *"Class feedback – everyone presents their report to the class, and different dyads evaluate each other and give feedback. New things rise* [in this process] *and they also learn from this"*; (ii) A template: *"I give my students a template in which I incorporate the instruction to each chapter and instruct them to write according to the instructions and erase each time what they have already written"*; and (iii) Writing in steps: *"We write the report in steps according to the report progress"*.

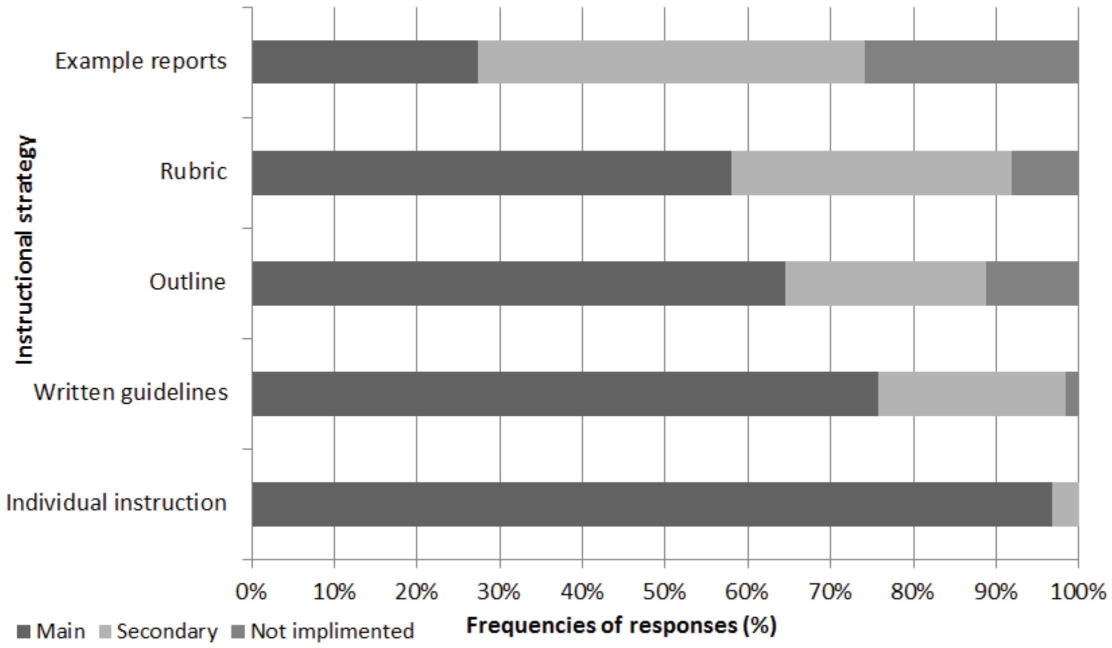

Figure 5. Teachers' strategies for instruction of writing an inquiry report. Teachers (N=65) were asked to rate different instructional strategies as: 'Main strategy', 'Secondary strategy' or 'Not implemented'.

In the questionnaires, teachers were also asked to report on the difficulties they are facing while instructing their students how to write their inquiry-project reports. The teachers were asked to rate several instructional difficulties and had the option to raise additional difficulties. Most of the teachers feel that Lack of time is the major obstacle for them in the instruction of the writing process, 69% consider this to be a major difficulty and 23% a minor difficulty (Figure 6. **Teachers' difficulties in instruction of writing an inquiry report.** Teachers (N=65) were asked to rate different instructional difficulties a: 'Major difficulty', 'Minor difficulty' or 'Not a difficulty'.). Work load for the teacher is also considered as a main problem, as 43% believe this is a major difficulty and 51% believe it to be a minor difficulty. Another main barrier for the teachers in instruction of writing inquiry reports is Lack of appropriate scientific writing examples, such as scientific articles. Thirty five percent of the teachers think this is a major difficulty for them and 45% think this is a minor difficulty. The other three difficulties – Insufficient training of teachers, Vague instructions from the Ministry of Education and Scientific writing skills of the teacher are inadequate – were considered less influential for them, as 9%-17% of the teachers think these difficulties are 'Major difficulty', 34%-46% a 'Minor difficulty' and 37%-54% 'Not a difficulty' (Figure 6. **Teachers' difficulties in instruction of writing an inquiry report.** Teachers (N=65) were asked to rate different instructional difficulties a: 'Major difficulty', 'Minor difficulty' or 'Not a difficulty'.).

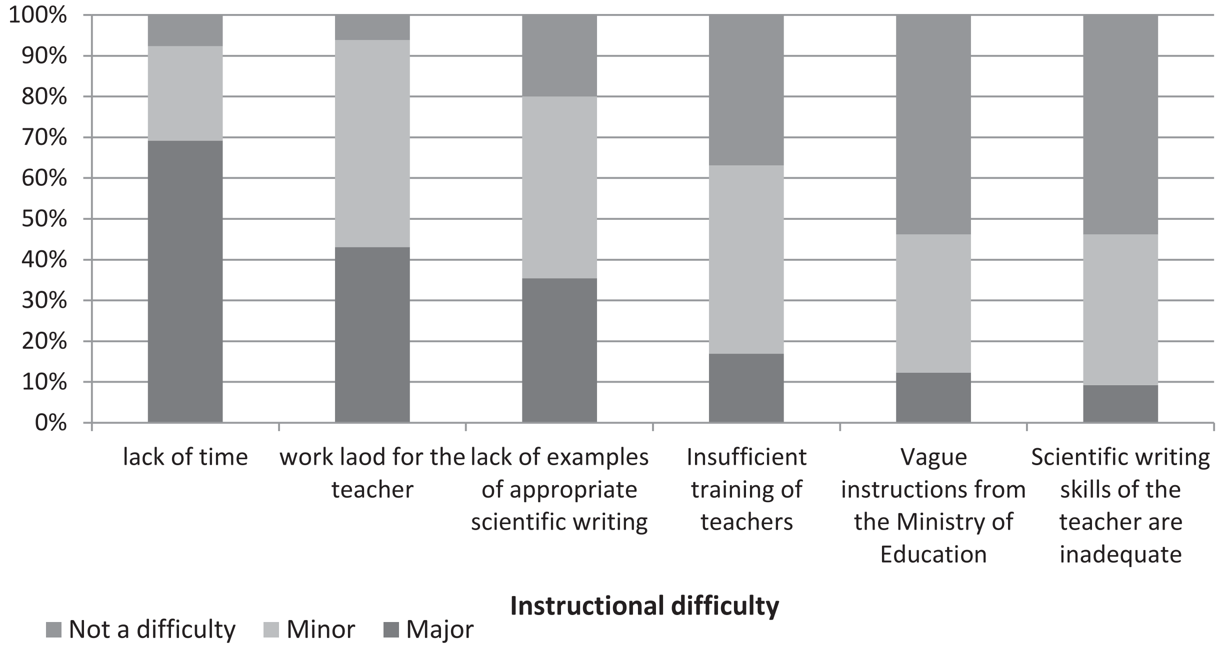

Figure 6. Teachers' difficulties in instruction of writing an inquiry report. Teachers (N=65) were asked to rate different instructional difficulties a: 'Major difficulty', 'Minor difficulty' or 'Not a difficulty'.

Other obstacles teachers mentioned were: "*Lack of cooperation from the students";" The demands are too high for the students"; "Laboratory exam, inquiry project and matriculation exam in one year is too much", "Difficulty in time management and meeting deadlines* [both for the teacher and the students]".

6.1.4. The influence of learning with APL on the process of inquiry-based writing and the scientific writing skills of high-school biology majors

My initial hypothesis was that APL can be used as a model for scientific writing in high-school, and that learning with APL may assist students develop their scientific writing skills (see the Introduction and main research goal section, for elaboration). In order to examine this hypothesis the following three tools were used: Text analysis of drafts of inquiry-project reports of students who learned the elective APL-based curriculum "Gene tamers" ("APL classes") (Falk et al., 2003) and students who did not learn this unit ("Non-APL classes"); Interviews with the teachers of the APL classes and Class observations. The process of writing the inquiry-project report was similar in both populations and did not include any intervention.

I wished to characterize possible differences in the instructional strategies teachers apply for teaching writing of an inquiry-project report in the APL classes versus the characterized strategies in the Non-APL classes (See the previous section). For this purpose, I interviewed 6 biology teachers who taught the elective APL-based curriculum unit – "Gene tamers" (teachers no. 12, 13, 14, 19, 20, 21 see Table 4), and observed lessons (approximately 20 lessons) in their classes, while they were teaching this unit. In the interviews, all 6 teachers mentioned they try to use the APL article as a model for scientific writing and present the students the similarities between the APL article and the inquiry-project report. Some of the teachers said they "have a feeling" that learning with APL assist the students write their own reports.

Class observations corroborated these findings and revealed that the teachers of the APL classes did use various methods to indicate the analogy between the APL article and the inquiry report to their students. This strategy was used by the teachers in almost all of the observed lessons as can be seen in the following representative quotes extracted from transcripts of observations in APL classes:

> Teacher 12: We are moving to the methods section, which is also just like in your reports… what do you think will be written in this section? ... In your reports you should make an outline, like here...
>
> Teacher 13: What is the purpose of the Introduction? You are also writing your reports now and have some difficulties with this… think of your reports, what should be included in the introduction?
>
> Teacher 14: Look at the references of the article, who knows how references should be written? Student: We collect all the sources we use.
> Teacher: Right, when you write your report you should write a reference to the source you used (writing an example on the board) and make a list of the sources in the end of the report.
>
> Teacher 19: Your report should look eventually like this, like the article".
>
> Teacher 20: What can we learn from the title of the article? Why do we need a title for an article?... What is the purpose of the title?… what will follow the title in a scientific article?
>
> Teacher 21: In the Discussion section – just like in our Bio-Heker [inquiry project] – you go back [and describe] what we did, what we should have done differently… Also, when you write your Bio-Heker you have to justify your research.

After observing the use of the APL article for teaching scientific writing in the APL classes, I wished to examine whether this use facilitated the scientific writing of the inquiry-project reports in the APL classes. For this aim, initial and final drafts of 14 inquiry-project reports of students from two APL classes (teachers no. 12 and 13), and 14 inquiry-project reports of students from a Non-APL class (teachers no. 9 and 10) were analyzed using SWAR (total of 28 reports, 56 drafts). The 14 reports from the Non-APL class were selected from the 26 reports analyzed and described in section 6.1.2. The reports were chosen from these two classes as a control because they had similar characteristics as the APL classes (i.e. same region, similar socio-economic status, similar background and experience of the teacher, see Table 4). A Mann-Whitney *U* test for non-parametric analysis showed no significant differences between the average scores of inquiry-project reports of APL and Non-APL classes. The average score of each section in the report (i.e. Introduction, Methods, Results, Discussion and General) was similar in both populations (i.e APL and Non-APL) in the initial drafts (Figure 7. **Average Scores of the different sections in the initial (a) and final (b) drafts of the inquiry-project reports of APL and Non-APL classes.** N= 28 reports, 56 drafts**.** Bars represent standard errors. A Mann-Whitney *U* test found no significant differences between APL and Non-APL classes.a) and in the final drafts (Figure 7. **Average Scores of the different sections in the initial (a) and final (b) drafts of the inquiry-project reports of APL and Non-APL classes.** N= 28 reports, 56 drafts**.** Bars represent standard errors. A Mann-Whitney *U* test found no significant differences between APL and Non-APL classes.b).

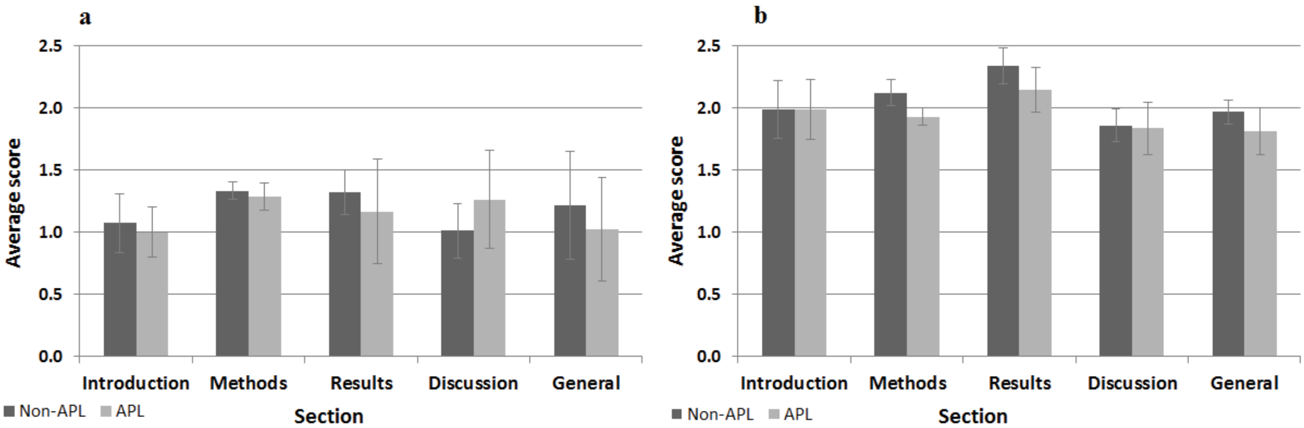

Figure 7. Average Scores of the different sections in the initial (a) and final (b) drafts of the inquiry-project reports of APL and Non-APL classes. N= 28 reports, 56 drafts**.** Bars represent standard errors. A Mann-Whitney *U* test found no significant differences between APL and Non-APL classes.

Analysis of the different scientific writing components (Figure 8. **Average scores of initial (a) and final (b) drafts of inquiry-project reports of APL and Non-APL classes.** N= 28 reports, 56 drafts. Bars represent standard errors. A Mann-Whitney *U* test found no significant differences between APL and Non-APL classes.) revealed that all the components were scored similarly in the reports of APL and Non-APL classes in the initial drafts of the inquiry-project reports, and no significant differences were detected (Figure 8a). Also, no significant differences were measured between APL and Non-APL classes in the final drafts of the reports (Figure 8b).

These findings indicate that although the teachers use the APL article to teach their students how to write their inquiry-project reports, mostly by indicating the similarities between the two, the students' scientific writing skills do not appear to be better than those of students who have not learned with APL, and they encounter similar difficulties as the Non-APL students. The results also suggest that reading an APL article (and pointing out the similarities to the inquiry-project report) is not sufficient for teaching how to write an inquiry-project report, and that, additional instructional tools are required. These findings guided me in developing the SWIM environment.

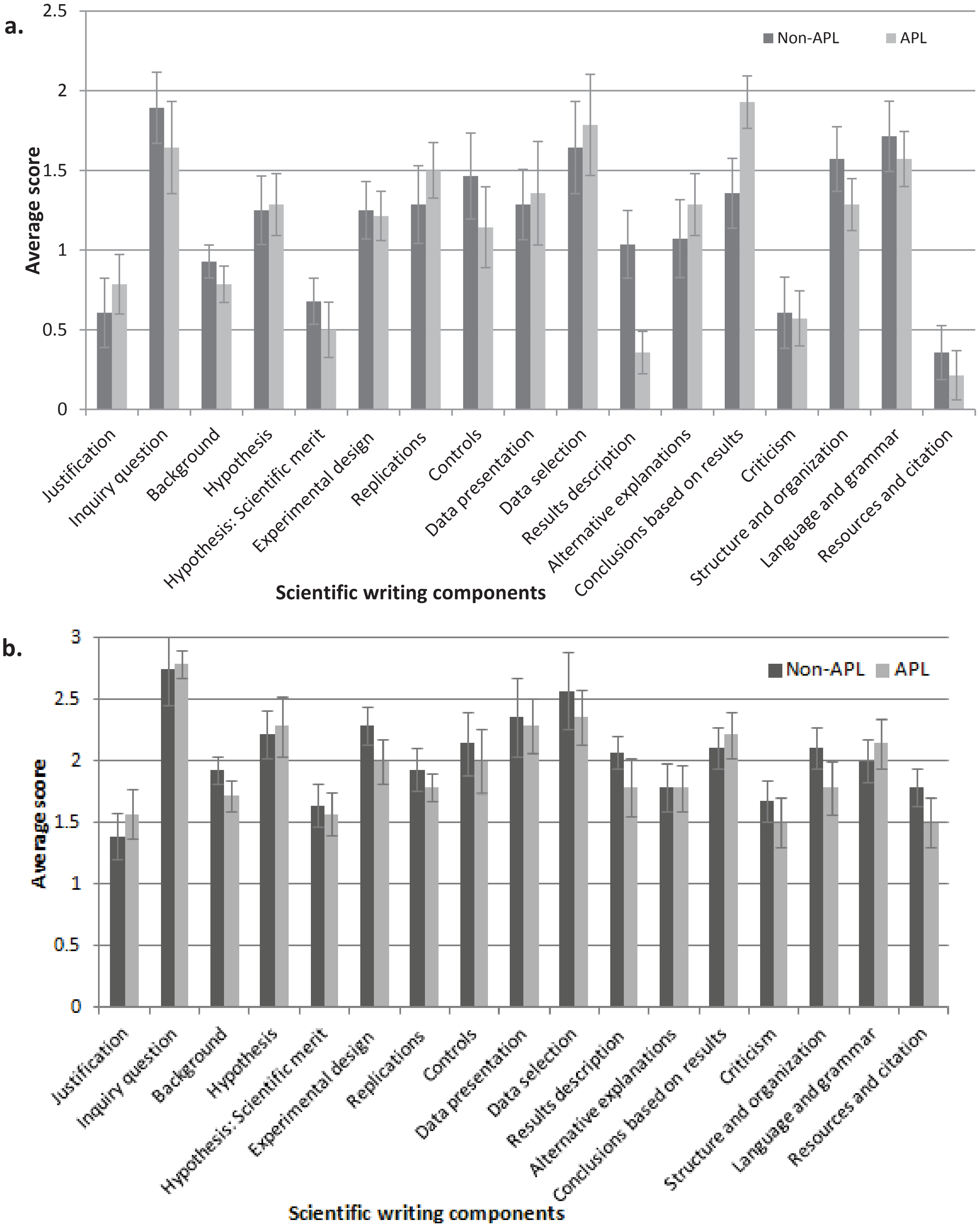

Figure 8. Average scores of initial (a) and final (b) drafts of inquiry-project reports of APL and Non-APL classes. N= 28 reports, 56 drafts. Bars represent standard errors. A Mann-Whitney *U* test found no significant differences between APL and Non-APL classes.

Summary of Phase I

Findings:

- High-school biology majors are lacking the genre knowledge required for writing of an inquiry-project report. This is reflected in specific scientific writing components students are struggling with, such as: raising criticism, justification of the inquiry, resources and citation, scientific merit of the hypothesis.
- Teachers experience difficulties instructing writing of an inquiry-project report and usually implement an inefficient individual instruction.
- Although the teachers use the APL article to teach their students how to write their inquiry-project reports, mostly by indicating the similarities between the two, the students encounter similar difficulties as students who do not learn with APL. The results also suggest that reading an APL article (and pointing out the similarities to the inquiry-project report) is not sufficient for advancing scientific writing skills of high-school biology majors, probably due to focusing on content rather than on genre.

Conclusion:

- There is a need for an instructional framework that will exploit the APL as an apprenticeship genre to assist the teachers in instructing the writing process of an inquiry-project report and to address specific scientific writing difficulties the students experiencing during this writing process.

6.2. Phase II – Prototype design and development of the SWIM environment

6.2.1. Overview of Phase II and research questions

In the second phase of this study we designed and developed the prototype of the instructional framework for learning and teaching scientific writing based on the findings and insights of the first phase. This phase was conducted In collaboration with 6 biology teachers and an educational technology expert (i.e. The development team). The details of the teachers from the development team are presented in the Methods chapter, Table 4).

In the following section I will present and discuss the prototyping process of the SWIM 1.0 environment including: the initial design principles defined based on the literature and the findings from the first phase; the prototype of the SWIM environment; and the tentative learning process with the SWIM environment.

In the second phase of the research I asked:

1. What design principles and instructional practices the learning environment should be based on to enhance students' scientific writing skills?

6.2.2. Initial design principles of the SWIM environment

Design experiments incorporate theoretically motivated design elements (often referred to as design principles). Typically, several such elements are implemented in a given study, in order to address multiple aspects of teaching and learning and they reflect the conditions in which they operate (Anderson & Shattuck, 2012; Klein & Rose, 2010). An important aspect of design experiments is to identify the critical elements of the design and how they fit together to accomplish the goals of the design. The critical elements of a design may be the materials, the activities, a set of principles, or some combination of all these (Collins, Joseph, & Bielaczyc, 2004). As design experiments evolve, the design principles undergo changes and modifications. Therefore, a description of the initial design principles (DP) is given here.

At the beginning of this project, I defined that the SWIM learning environment should be based on the following principles:

DP1. Construction of genre knowledge by analyzing APL as a model.

DP2. Interactive, inquiry-based learning for learning to write an inquiry-project report.

DP3. Exercises address specific skills, processes and knowledge of scientific writing.

DP4. Strategy Instruction for scientific writing.

DP5. Flexibility in use to maximize implementation possibilities.

DP6. Technology enhanced learning.

DP1: Construction of genre knowledge by analyzing APL as a model

The genre-based pedagogy was found as an effective writing instruction strategy in numerous studies, including the recent meta-analyses of writing instruction (Graham, Harris, & Chambers, 2015; Graham & Perin, 2007a), which identified the study of model texts as an effective instructional strategy. Graham and Perin (2007a) recommended providing adolescents with good models for each type of writing that is the focus of instruction. These examples should be analyzed, and students should be encouraged to imitate the critical elements embodied in the models (Graham & Perin, 2007a).

An example for this design principle can be found in the framework Klein and Rose (2010) developed for teaching argument and explanation genres. Their approach to teaching these genres is based on problem solving: students read, compare, analyze, and evaluate sample texts to generate guidelines for their own writing.

Regarding scientific writing, it was previously suggested that students should be exposed to examples of adequate scientific writing in order to learn how to write properly and that exposure to the similarity between the inquiry process and scientific writing can assist in understanding each of them (Kuldell, 2003; Muench, 2000). Therefore, I hypothesized in this study that APL can be used as a model of adequate scientific writing for high-school biology students and along with the teachers' mediation could promote the construction of the genre knowledge by the students.

DP2: Interactive, inquiry-based learning for learning to write an inquiry-project report

Studies on effective instruction of writing have revealed that the interactive approach – inductive format, is more effective than the presentational approach – deductive format (Hillocks, 1986). In the interactive approach the students and teachers share roles and activities and it includes tools such as scales (comparing various texts of different quality), inquiry (active involvement with content), and peer feedback with clear goals (Rijlaarsdam, Van den Bergh, & Couzijn, 2004). According to Rijlaarsdam et al. (2006), genres are not acquired in a deductive way, from knowledge about rules to application of rules, but via active participation in well-chosen communicative activities. Students must construct the genre themselves and develop awareness of text qualities in certain communicative circumstances, through guided trial and error. Inquiry-based writing involves engaging students in activities that can help them develop ideas and content for a particular writing task by analyzing immediate and concrete (Graham & Perin, 2007a).

In this study, I applied an inductive instructional strategy for teaching scientific writing of an inquiry-project report, based on inquiry activities in which the students construct the genre knowledge themselves.

DP3: Exercises address specific skills, processes and knowledge of scientific writing

Explicit teaching of writing skills, processes and knowledge was shown to be an effective writing instruction in previous studies and meta-analyses (Graham & Perin, 2007a; Hillocks, 1986). Englert et al. (2006) stressed that effective writing instructors make tacit knowledge perceptible through explicit teaching and think-aloud that make visible the discourse, thoughts, actions, decisions, struggles and deliberations that are part of the writing process. This process is accomplished by sociocognitive apprenticeship that supports novices in the participation and performance of a discipline, including the acquisition of discourses and writing skills (Englert et al., 2006). The sociocognitive apprenticeship is based on the Scardamalia and Bereiter's (1984) model for writing instruction. They considered writing as a situated act and developed an approach to the teaching of writing that relies on elements of cognitive apprenticeship. Their approach is designed to give students a grasp of the complex activities involved in expertise by explicit modeling of expert processes, gradually reduced support or scaffolding for students attempting to engage in the processes, and provide opportunities for reflection on their own and others' efforts.

According to the literature and the characterization of specific scientific writing difficulties, we decided that the SWIM learning environment should address specific difficulties and skills and provide the tools to enable the teachers to apprentice their students in each individual scientific writing skill using APL as an apprenticeship genre. According to this design principle all the exercises in the environment were designed to address specific scientific writing difficulties which were characterized in the first phase of the study. For example, exercises in the environment deal with skills such as using appropriate and scientific language, logical organization, distinguish between relevant and irrelevant information, merging sources and summarizing.

DP4: Strategy instruction of scientific writing

In general, the two most well-defined strategies that have been found in writing research are a planning strategy, in which writers ‘concentrate on working out what they want to say before setting pen to paper, and only start to produce full text once they have worked out what they want to say’, and a revising strategy, in which ‘writers work out what they want to say in the course of writing and content evolves over a series of drafts’ (Kieft et al., 2007; Kieft et al., 2006). The strategy-focused instruction involves explicitly teaching students strategies for planning, revising and/or editing text (Graham & Harris, 2006). In this study, I wished to provide the students some idea of the two main writing strategies. To this purpose I incorporated the strategy-focused instruction into some of the exercises in the environment. For example, in one of the exercises the students are instructed (by scaffolding questions) to revise a "bad" introduction. In another exercise the students recognize the characteristic structure of the discussion section, which helps them plan their own discussion section (See Table 9 for a description of the exercises in the SWIM environment).

DP5: Flexibility in use to maximize implementation possibilities

This is a universal design principle which states that all designs should be flexible in use and accommodate a wide range of individual preferences and abilities (Mcguire, Scott, & Shaw, 2006). The flexibility of the design presented in this study can be seen in the following elements: (i) Modular exercises – every exercise in the environment can stand on its own; (ii) Content integration to the curriculum – the content of the exercises in the environment matches the curriculum for 12th grade biology majors which enables an easy integration of the environment to the routine learning sequence; (iii) Different types of exercises: the environment includes exercises of various types such as exercises with automated feedback, open exercises led by the teacher, collaborative exercises etc. The goal of these elements of flexibility in the learning environment is to enable the teacher to create the most appropriate and suitable learning sequence for them and their classes. We believe each class has different requirements and faces different difficulties; therefore, teachers have different instructional preferences and considerations.

DP6: Technology enhanced learning

As described in the Literature review, technology has numerous advantages to writing instruction, such as: engaging students in revising their writing; students give and receive feedback more frequently; students tend to produce longer texts; and it increases interactions and collaborations between students. In this study, relying on these advantages, we designed and developed a Technology-Enhanced Learning Environment (TELE) which is a web-based environment integrated with automated feedback options and other technologies, such as Smart Board video lessons.

6.2.3. Prototype of the SWIM environment

As mentioned above, the learning environment was named "***SWIM***" which stands for – "***Scientific Writing Interactive Model***". The prototype is referred to as SWIM 1.0. The prototype of the SWIM learning environment was developed during the year 2012 by a group of 5 biology teachers participating in the initiatives truck of the Rothschild-Weizmann Program for Excellence in Science Education, under my instruction. The framework was designed to address specific difficulties of students in scientific writing and of teachers in instructing scientific writing, as characterized in the first phase of the project. We developed ten inquiry-based, interactive exercises. These exercises were divided according to the sections of a scientific report. In addition, the site includes short videos showing an analysis of an APL text that can serve as a model for scientific writing. SWIM 1.0 environment can be accessed in the following link (Hebrew version): SWIM 1.0 (https://goo.gl/pq4vVU). A summary of the exercises in SWIM 1.0, their learning goals, writing difficulties addressed by each exercise and the design principles reflected in the exercises appear in Table 9 and Table 10.

The learning process with the SWIM environment - Genre-oriented pedagogy and sociocognitive apprenticeship

We developed and designed the SWIM environment to support the process of writing an inquiry-project report in high-school biology. Due to its' modular and flexible nature, teachers can integrate the SWIM environment in various means and timing. However, we did have a learning sequence in mind when designing the environment. This sequence is grounded in genre-based pedagogy and built according to the socio-cognitive apprenticeship framework. The suggested learning sequence and its rational were presented to the teachers in training workshops. The steps of the learning sequence, incorporated in the whole inquiry process are presented in Table 8.

Table 8. The proposed learning sequence of the SWIM environment

Step of the inquiry-project	SWIM exercises / components
Opening of the inquiry-project process	• *Introduction to scientific communication* • *Components of the scientific article* • *Analyze a research article – short videos*
Planning of inquiry experiment	• *Components of inquiry 1* • *Components of inquiry 2*
Conducting a controlled experiment	• *Analyze an experiment*
Collect data	• *Raw vs. processed data*
Analyze data and draw conclusions	• *Data presentation*
Writing inquiry-report – results, methods, introduction, discussion	• *Getting to know the Introduction* • *Good Intro-Bad Intro* • *Learning to write a Discussion*

Table 9. The exercises in SWIM 1.0 learning environment

Name of exercise	Description	Goals	Writing difficulties addressed	DP addressed
1. *Introduction to scientific communication*	Comparison between popular and scientific article	The students will identify the main characteristics of scientific writing	Inappropriate language	DP1, DP3 DP5
2. *Components of scientific article*	Interactive exercise to introduce the components of a scientific article	The students will identify and recognize the components of a scientific article and their location in the article	Lack of logical organization, No distinction between methods and results, No distinction between results description and explanation	DP1, DP2 DP3, DP5
3. *Analyze a research article – short videos*	Short videos presenting an analysis of an APL	The students will be familiarized with the features of a scientific article		DP1, DP2 DP3, DP5 DP6
4. *Getting to know the Introduction*	Interactive exercise with automatic feedback	The students will know the structure and components of the introduction	Lack of proper organization of the introduction	DP1, DP2 DP3, DP4 DP5, DP6
5. *Good Intro – Bad Intro*	Comparison between "good" and "bad" introductions using guiding questions	The students will learn the proper structure, language and content of an introduction. The students will learn the characteristics of the introduction by reading critically a "bad" introduction	Introduction includes irrelevant information, Introduction is too detailed or too concise, Introduction is repetitive, Lack of proper organization of the introduction	DP1, DP2 DP3, DP4 DP5
6. *Components of inquiry 1*	Interactive exercise with automatic feedback	The students will identify the inquiry components in an experiment	No distinction between biological and technical replications, Difficulty distinguishing between controls	DP2, DP3 DP5, DP6
7. *Components of inquiry 2*	Interactive exercise with automatic feedback	The students will identify the inquiry components in an experiment	No distinction between biological and technical replications, Difficulty distinguishing between controls	DP2, DP3 DP5, DP6
8. *Analyze an experiment*	Interactive exercise with automatic feedback following a filmed experiment	The students will identify the inquiry components in an experiment	No distinction between biological and technical replications, Difficulty distinguishing between controls	DP2, DP3 DP5, DP6
9. *Raw vs. processed data*	Guiding questions to help students to process raw data.	The students will distinguish between raw and processed data and experience data processing	No distinction between raw and processed data	DP2, DP3 DP5
10. *Data presentation*	Comparing two ways to present the same data	The students will choose the appropriate format for presenting the data. The students will learn to write the title of a graph / table	The data presentation format is not appropriate for the inquiry question	DP2, DP3 DP5, DP6
11. *Learning to write a Discussion*	Arranging the paragraphs of an APL discussion and examine its characteristics	The students will recognize the typical structure of the discussion and become aware of its logical organization, its language and other characteristics	No critical reference to the experiment, Overgeneralization, Conclusions are overly broad and excessive, Discussion is too shallow and trivial, Conclusions are not based on results	DP1, DP2 DP3, DP4 DP5
12. *Merging resources*[1]	Writing a paragraph on sprouting, by merging from three sources	The students will rewrite information in their own words; logically organize their paragraph; quote the sources according to citation rules	No merging of sources, Introduction includes irrelevant information, Lack of logical organization, Incorrect citation	DP2, DP3 DP5

[1] The *Merging resources* exercise was added in the SWIM 2.0 version and was not included in the prototype.

Table 10. Embodiment of the design principles in SWIM 1.0

Initial design principles	SWIM 1.0 (Prototype)
DP1- Construction of genre knowledge by analyzing APL as a model	Six APL–based exercises (exercises no. 1, 2, 3, 4, 5, 11)
DP2 - Interactive, inquiry-based learning	All exercises are inquiry-based Five interactive exercises (exercises no. 2, 4, 6, 7, 8)
DP3 - Exercises address specific skills, processes and knowledge	Each exercise was designed to address specific difficulties and skills (see Table 9)
DP4 - Strategy instruction of scientific writing	One revision exercise (exercise no.5) Two planning exercises (exercises no. 4, 11)
DP5 - Flexibility in use	Modular exercises: each exercise stands on its own Integration to the curriculum (e.g., content is suitable for the syllabus: Cell, Ecology and Human biology)
DP6 - Technology enhanced learning	Web-based platform (Clickit3 ©, Ort). Five automated feedback exercises (exercises no. 2, 4, 6, 7, 8) Four short video lessons *(*exercise no. 3)

As I described above, one of the premises in designing the SWIM environment was that APL can serve as an apprenticeship genre for high-school biology students to gain genre knowledge of scientific writing in a cognitive apprenticeship process.

According to the cognitive apprenticeship pedagogical approach (Collins, Brown, & Newman, 1989) learning occurs in a socio-cultural context by observation, imitation and mediation with other learners. The cognitive apprenticeship framework, conceptualized by Scardamalia and Berieter (1984) for teaching writing, proceeds through a combination of modeling, coaching, scaffolding and fading. By modeling, the expert makes his / her tacit knowledge visible to the novices. Then, by coaching, the expert scaffolds students' activity. Eventually, in gradually fading away, the expert encourages novices to develop independence.

In the SWIM environment students' engage in interactive dialogue with the teacher and peers in four phases: teacher modeling of writing processes, text analysis, scaffolded and collaborative students' practice and independent writing.

To demonstrate the integration of the cognitive apprenticeship process in the implementation of the SWIM environment, a tentative apprenticeship cycle for writing the Introduction section of the inquiry-project report is presented in Table 11.

Table 11. The apprenticeship process for writing the introduction section of the inquiry report using SWIM

Active party	Component of the SWIM environment	Apprenticeship step
Instructor	• Teacher presents an APL section using the short video. • Analyzing an introduction of an APL as a model • Instructor demonstrates planning an introduction of the inquiry-project report	Modeling
Students and instructor	• Students analyze an introduction of an APL in a structured exercise and receive automated and instructor's feedback • Students review an introduction of an inquiry-project report, revise it and discuss it in class	Coaching and Scaffolding
students	• Students plan the introduction for their inquiry-project report • Students write their inquiry-project report	Fading

Conjectures mapping

Generally, learning environment design begins with some *high-level conjecture(s)* about how to support the kind of learning we are interested in supporting in that context. That conjecture is embodied in the specific design. That *embodiment* is expected to generate certain *mediating processes* that can produce the desired *outcomes.* Conjectures about the relations between embodied elements and the resulting mediating processes are referred as *design conjectures.* Conjectures about the relations between the mediating processes and the desired outcomes are referred as *theoretical conjectures.* These conjectures are visualized in a conjectures map, which enables mapping the way high-level conjectures are translated into design features, and how “design conjectures” and “theoretical conjectures” can be articulated and studied (Sandoval, 2014).

As I stated above, the high level conjecture in this research was that inquiry-based writing in high-school biology requires genre knowledge that can be gained using APL as an apprenticeship genre. This conjecture was embodied into our design, through genre elements integrated in the environment in the form of interactive exercises for analyzing APL article as a model text, and technological support (including the website and automated feedback). Our design conjecture was that these features would support instructors to gradually fade away their guidance and enable students to become more and more active and independent in writing. Our theoretical conjecture was that due to the apprenticeship processes supported by the technology, students' inquiry-based writing skills will improve. Figure 9 illustrates the mapping of these conjectures.

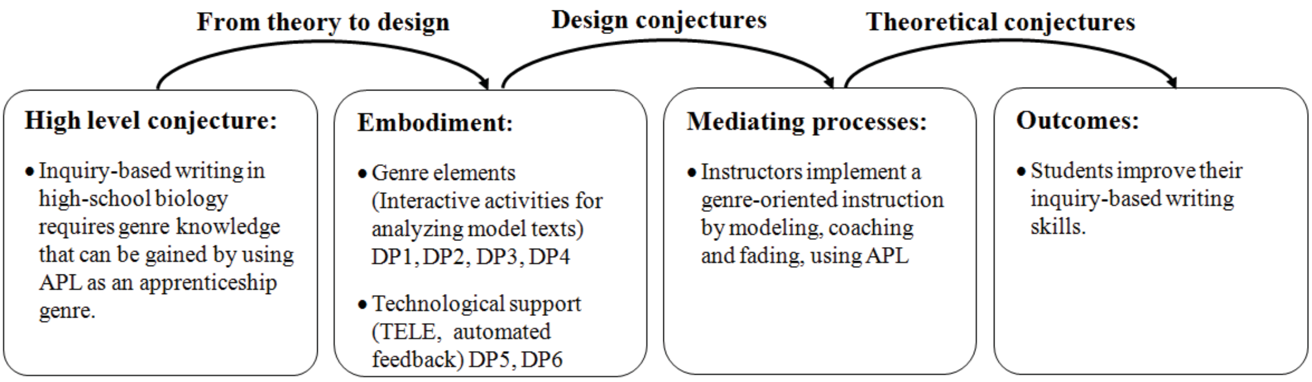

Figure 9. Conjecture mapping of SWIM 1.0 (Based on Sandoval, 2014).

Summary of Phase II

- In the second phase of this DBR, the initial design principles (DP) of the SWIM learning environment were defined.
- These DP were founded on the basis of genre-oriented pedagogy and enable the implementation of the SWIM environment according to the sociocognitive apprenticeship framework.
- My high-level conjecture about the SWIM environment is that inquiry-based writing in high-school biology requires genre knowledge that can be gained by using APL as an apprenticeship genre. This conjecture is embedded in the environment in different elements. These elements enable mediating apprenticeship processes that may result in the improvement of students' scientific writing skills. My conjectures about the SWIM environment can be visualized in a conjectures map (Figure 9).

6.3. Phase III – Three iterations of implementation of the SWIM environment

Three iterations of implementation of the SWIM environment in schools took place during the academics years 2013-2016 (three school-years). In the following chapters I will present the implementation process in each iteration, its impact on the students' scientific writing skills and strategies, and I will discuss the revisions made after evaluation of each iteration.

6.3.1. Iteration 1 – SWIM 1.0

6.3.1.1. Overview of iteration 1 and research questions

The prototype of the SWIM environment (SWIM 1.0) was implemented in 12th grade biology classes in the 2013-2014 school-year. The implementation process began with a four hours training workshop for teachers. Two teachers and a researcher from the developing team conducted the workshop. This workshop was given 7 times and approximately 180 teachers participated in it over this year. Following the workshop, support for teachers implementing SWIM was given in several means including on-line forum, e-mail and telephone support and personal guidance from a member of the developing team, if requested.

Because teaching material of the SWIM environment was available at that time in an on-line open-access website, I do not have exact data of the number of teachers who implemented SWIM (or parts of it) in their classes in the 2013-2014 school-year. The website statistics showed that 2,698 people visited the homepage of the website and 12,242 entries to the inner pages of the website were counted. These statistical data suggest that teachers were interested in the SWIM environment and probably implemented it (or parts of it) in their classes. During the 2013-2014 school-year, I examined the implementation of SWIM in two of the participating classes (Ann's class and Bella's class). The implementation was carried out approximately for 3 months, from December 2013 until March 2014.

The questions I asked in the first iteration of enacting the SWIM environment were:

1. How was the SWIM environment adopted and implemented?

2. How does enactment of the SWIM environment influence students' scientific writing skills?

To answer these questions, I conducted two case-studies. In these case-studies, I examined the processes and experiences of implementing SWIM using two main methods: (1) Class observations – I observed four lessons in which the SWIM environment was implemented. (2) Semi-structured interviews – I conducted interviews with the two teachers in the beginning and the end of the implementation of the SWIM environment. The lessons and the interviews were recorded and transcribed. The transcripts were coded and analyzed from the following aspects: sequence of instruction, adoption of the genre pedagogy, apprenticeship process and general design feedback. In addition, I examined the influence of the SWIM environment on the students' scientific writing skills by analyzing drafts of inquiry-project reports of students from SWIM and Non-SWIM classes, using SWAR (n=23 reports: 7 reports from Ann's class, 7 reports from Bella's class, 5 reports from teacher no. 7's class and 4 reports from teacher no. 8's class).

6.3.1.2. Adoption and implementation of the SWIM environment

The case of the teacher Ann

Ann is an experienced biology teacher (15 years teaching experience) teaching high-school biology classes in an urban school of medium-high socioeconomic status. At the time of the intervention Ann was a student towards a Masters' degree in the Rothschild-Weizmann Program for Excellence in Science Teaching. That year Ann was instructing the inquiry-project for the second time.

The learning sequence Ann implemented in her class, as well as the apprenticeship steps applied in this sequence, are summarized in Table 12.

Table 12. The learning sequence and apprenticeship steps of the teacher Ann

SWIM exercise / component	Timing of exercise / component in the inquiry-project process	Apprenticeship steps
Introduction to scientific communication & *Components of scientific article*	At the beginning of the inquiry-project process	Modeling Scaffolding
Components of inquiry 1 & *Components of inquiry2*	Before students planned their inquiry project	Scaffolding
Raw vs. processes data	After data collection, before writing the Results section	Scaffolding
Getting to know the Introduction – video + demonstration of planning an introduction of an inquiry-project report.	Before writing the Introduction section	Modeling
Good Intro-Bad Intro	Before writing the Introduction section	Scaffolding
Students write their inquiry-project reports	Final step in the inquiry-project process	Fading

Adoption of the genre-oriented pedagogy

Ann chose to begin the inquiry-project process with introducing her students to scientific communication, its purposes and characteristics. By doing so she wished to demonstrate her students the link between their inquiry-project and the way research is conducted and reported in the scientific community.

To this aim, her students first carried out the *Introduction to scientific communication* exercise. Ann gave her students a hard copy of the exercise and the students worked in groups of 3-4. After independent work, Ann conducted a whole-class discussion in which they summarized the characteristics and purposes of the two genres presented in the exercise popular scientific article and APL article) and discussed which of these genres is more similar to the inquiry-project report they are required to write. Afterwards Ann's students did the *Components of scientific article* exercise in groups.

> Ann: I did with them the exercise with the article that you need to find the components of the article and match [to the right location].
> Researcher: How was it?
> Ann: It was great. I gave them the exercise in class. I told them: "you won't like me, but you have to read all of this". It wasn't easy for them, but they did it, and they were thinking, and asking me questions, and deliberated with each other, like, they had a discussion during this exercise, and it was really nice… sometimes there was something [unclear] so I stopped their work and said [to the whole class]: what do you think? How should we classify this? and discussed it together.
> Researcher: What do you think the students gained from this exercise?
> Ann: This exercise gives them the structure [of an article], what goes to the Introduction, where is the Introduction, the Materials and methods? What is [the purpose of] each section? And then goes to a smaller resolution. What can we find in each section? How each section is written? I wish we would have done this exercise closer to writing their reports, it would have been more efficient.

Before Ann's students planned their experiments for the inquiry-project, she gave them the *components of inquiry 1* exercise as a homework assignment. Ann already taught her class the main components of inquiry (i.e. variables, controls and replications) therefore she used this exercise for practice and reminder. Ann indicated that her students found the interactivity and automated feedback of this exercise very enjoyable. She believed this interactivity facilitated the learning from this exercise. Next, the students conducted their group experiments and collected data. Afterwards they began writing the first draft of the inquiry-project report, starting with the results section as Ann instructed them to do. To guide her students how to write the Results section, Ann asked them to complete the *Raw vs. processed data* exercise. She wanted to accomplish two goals with this exercise: teach her students how to use Excel and present them with different types of graphs and discuss each type's purpose.

> Ann: I projected the exercise on the board and we discussed it together. We talked about each graph and what does it represent and what's important. Why did I do it in class? Because when I asked them to do it at home, wow, what horrible graphs I got, they didn't know how to do it. So I showed them and then they did it themselves. And then it was much better.

Next, they moved to the Introduction section. Ann showed her class the short video deconstructing the Introduction of an APL. Throughout the video she emphasized the concept of the "funnel" structure of the introduction. After this, the students completed the *Good Intro-Bad Intro* exercise. Ann was happy to see that her students assimilated the concept of the "funnel" presented in the video, and used it in the exercise. She also indicated that the students enjoyed the scoring process and learned a lot by revising the 'bad' introduction.

Due to time limitations, Ann did not ask her students to do any other SWIM exercises and from this point on the students took increasing responsibility of their writing, while Ann continued to coach and guide them by giving written feedback to three successive drafts her students had submitted. Ann summarized her impression of the implementation of the SWIM environment in her class this way:

> Ann: The possibility to talk with them about everything, this is what contributed the most. Until now, I didn't stop and showed my students, I only gave them instructions, where should everything be, what should be [written], but without the opportunity for them to do something active to learn, and then discuss it together. This [The SWIM environment] made them pay attention to details of language and structure and other things [in scientific writing].

Sociocognitive apprenticeship steps in the implementation of SWIM

While enacting the SWIM environment in her class, Ann applied the sociocognitive apprenticeship steps in several stages of the inquiry-project process. From class observations and the interviews, all major steps of the apprenticeship process could be located and identified. I also recognized mini-cycles of apprenticeship as Ann and her students moved through the sections of the report. The learning sequence of most sections began by Ann modeling (or using a SWIM component to model and demonstrate) a certain strategy in writing the particular section. Following the modeling the students engaged in interactive scaffolded exercises, while receiving coaching and feedback and finally, the students wrote the section themselves with a gradual release of Ann's responsibility. In the following section I will demonstrate the three main steps of sociocognitive apprenticeship, namely modeling, scaffolding and fading, as they were applied by Ann. I bring these examples only to illustrate the presence of the apprenticeship process as a means to implement the SWIM environment, and not present the whole apprenticeship process performed.

Modeling: To begin teaching how to write an Introduction, Ann wanted to teach her students how to **plan** an Introduction of an inquiry-project report. To do so, she did two modeling steps: First she showed her students the short video analyzing the structure and language of an APL introduction. Based on this demonstration, Ann modeled the planning strategy of an Introduction section of an inquiry-project report. For this, she took the inquiry topic of one group in the class ("The influence of Streptomycin on the reproduction of *E. coli"*) and demonstrated the actions and decisions she makes while planning the Introduction section for this topic:

> Ann: OK, let's take Streptomycin and let's take *E. coli*, and see what is the connection between them. So, I have two concepts here. And now I should do an educated search [for more information]. What are we looking for? Which words should I write on Google?
> Student: Streptomycin
> Ann: So, good, what else can help me? So we are talking about antibiotics in general and bacteria in general. And the connection between them could be reproduction, or inhibition of reproduction, so I need to look for [information about] reproduction in *E. coli*. And now, if I wanted to write a summary of the information I could write it from the macro to the micro, for example: bacteria in general, reproduction in general and then specifically in *E. coli*, and then the influence of antibiotics on reproduction and specifically how Streptomycin inhibits reproduction.

Scaffolding and Coaching: After observing her actions in planning an Introduction, Ann's students worked independently on the *Good Intro- bad Intro* exercise. In this exercise, the students apply the knowledge they gained so far regarding the Introduction to review and revise an authentic Introduction of an inquiry-project report. The exercise is embedded with scaffolds in the form of scoring criteria and guiding questions by which the students come to realize what information is irrelevant, what is missing and what should be improved in this introduction.

> Ann: After I showed them the video we did the *Good Intro - Bad Intro* which was great. In the video they learned the concept of "funnel" and then they used it. It was… I was surprised. I gave them the exercise, printed, and they caught all the things… the copying from Wikipedia, the language, all the things that were missing, and wrote there all kinds of things [to improve].

Fading: The fading step was consisted mostly of the students writing their inquiry-project reports independently. According to Ann, as reflected in the following quote, she felt that the fading step was incomplete and that the students did not fully implemented the genre knowledge they have gained through her modeling and the scaffolds in the SWIM exercises. Ann believed that the cause for this was a long gap between the time her students completed the SWIM exercises and the time they started to write their reports.

> Ann: We did the third exercise and we talked about things and what the logic behind them, like how do we organize it [the discussion] and why it's important that this part would be here and not there? Or why does it seem like we're repeating everything we said in the

> beginning but we're actually not? and how does it make the connection to the beginning… so, it's not there… yes, writing is something we must practice. I wish I have done the practice exercises closer to the writing. The long time gap between the exercises and the actual writing impaired the overall process.

To summarize, this description along with Ann's previous reflections suggest that Ann adopted the genre-oriented pedagogy and that she followed (at least partially) the steps of sociocognitive apprenticeship to teach her students how to write an inquiry-project report. Other aspects that emerged from Ann's reflection on the implementation of the SWIM environment in her class were the importance of active learning and interactivity which, in Ann's opinion, facilitated the learning process and increased her students' motivation to learn to write. The second aspect was timing. From her experience, Ann gave several recommendations for the timing of implementing the SWIM environment: mainly, she proposed to precede the writing of each section of the report with the appropriate exercise and avoid long periods between a SWIM exercise and the students' writing.

The case of the teacher Bella

Bella is a very experienced biology teacher. She has a Bachelor's degree in biology and 30 years of teaching experience. Bella also served as a regional instructor for the last several years. During the year of the intervention, Bella was instructing the inquiry-project for the fifth time. The learning sequence Bella implemented in her class, as well as the apprenticeship steps she applied in this sequence, are summarized in Table 13.

Table 13. The learning sequence and apprenticeship steps of the teacher Bella

SWIM exercise / component	Timing	Apprenticeship step
Getting to know the Introduction	Before writing the Introduction section	Modeling, Scaffolding
Good Intro - Bad Intro	Before writing the Introduction section	Scaffolding and fading
Learning to write a Discussion	Before writing the Discussion section	Modeling, Scaffolding
Students write their inquiry-project reports	Final step in the inquiry-project process	Fading

Adoption of the Genre-oriented pedagogy

Bella started working with the SWIM environment after her students planned and conducted their experiments, before they began writing the inquiry-project report. Bella indicated that she felt her students already have good knowledge about the Methods and the Results sections of the report, because they practiced these concepts during lab lessons. Therefore, Bella planned to use the SWIM environment to focus on the Introduction and Discussion sections, which she believed are the most difficult to write.

> Bella: In my opinion the introduction and the discussion, these are the two main mines. The methods section is technical. Results - they deal with that enough in the lab lessons. Writing a text is like crossing the sea, do you know what poor language they have?

In general, I identified some aspects of genre-oriented pedagogy in Bella's approach to teaching writing during the implementation of the SWIM environment in her class. In the summarizing interview Bella referred to SOME genre features, such as the importance of logical organization of the Introduction and the Discussion, which reflects the scientific process and the logical way of thinking in science, as well as the use of appropriate conjunctions to construct this sequence. Bella also emphasized the significance of scientific accuracy and indicated that using accurate and correct scientific terms can greatly improve the quality of an inquiry-project report.

Although I could identify some genre pedagogy elements in Bella's enactment of the SWIM environment, her overall approach to scientific writing instruction in her class emphasized the writing process components and tended to a process-oriented approach. Bella emphasized the importance of a process-oriented pedagogy such as explicit teaching of writing strategies like planning and revision and the importance of feedback. Bella's process-oriented approach can be best seen in her concluding remark on the whole enactment process:

> Bella: There can be 20 exercises, 800 exercises of analyzing [an APL], but still, there has to be the component of the process in which the team of students working with the teacher, of planning together the structure of the report, correct, comment and improve… It [the learning environment] has to be linked to the writing of their own reports.

Sociocognitive apprenticeship steps in the implementation of SWIM

Similarly to Ann, Bella also followed apprenticeship steps while instructing her students to write their inquiry-project reports using the SWIM environment. I will demonstrate each step with examples obtained mainly from the interviews with Bella.

Modeling: In the course of the intervention, Bella modeled her students mostly the planning strategy. She modeled the planning of the introduction and the discussion section. The modeling of planning an introduction section was similar to that of Ann's, where Bella took one topic of an inquiry-project ("The effect of salt concentration on osmosis in algae") and gradually built the outline for the introduction to that topic, while verbalizing her choices and her way of thinking. For the discussion section, Bella also demonstrated the planning process in a whole-class discussion. She deconstructed the discussion while explaining and illustrating each component.

> Researcher: How was the process of writing the discussion?
> Bella: It was much harder than the introduction, the introduction was more structured. So, in the discussion I also deconstructed. I told them: "what do we need to write in the discussion? Start with the question, the results and then confirm or refute the hypothesis". And then I told them: "now we need to discuss the results". This was the difficult part. They don't understand what it means. So I broke it down to questions, such as: Why did I get more when I put more? for example – the influence of alcohol on yeast, or the inhibition of a substance on germination. What's happening there? What is the mechanism?
> I guided them, when you write I want you to think what's happening in the molecule, in the cell, in the organelle, to give a more complete picture. So when I show them how to [incorporate] different levels of organization [to the discussion], suddenly they seem to understand what is the meaning of "discuss the results".

Scaffolding and Coaching: After observing Bella modeling how to plan an introduction, her students completed the two exercises for the introduction section in groups. First, in the *Getting to know the introduction* exercise, the students implemented what they have learned on the structure of the introduction to answer scaffolding questions and instructions. These scaffolds were designed to lead the students to actively reveal the special feature of the Introduction of an APL and by this building their genre knowledge. Bella's students next learned how to revise a text by engaging in the *Good intro - bad intro* exercise.

> Bella: In the introduction, in the exercise where they have to score a text. They 'slaughtered' it…
> Researcher: good
> Bella: so I told them, guys, you'll be evaluated the same way, some of the things here are good, why are you so negative?
> Researcher: They liked this thing of criticizing others…?
> Bella: Yes! It was excellent, they enjoyed it very much. Now, it gave them some sense of what they will go through, so they were much more aware to how they should write after this [exercise].

Other than the scaffolded exercises, Bella also coached her students how to write their reports. She coached them mainly by guiding each group separately, where she planned with them parts of the reports and gave them feedback on their drafts.

Fading: The release of Bella's responsibility and the students' independent work could be seen in the phase in which the students wrote the drafts for their inquiry-project reports. Bella indicated that compared to previous years, she felt this year was much more efficient and less time-consuming and she believe that the work she did with her students in class facilitated this process.

> Bella: Since we practiced in class and talked generally about [writing] the reports, I set with each group, and we didn’t need a lot, the product was good, almost final, it saved a lot of time.

Bella also recognized the impact of the exercises on her students self-monitoring abilities. She indicated the exercises made the students more aware of their own writing and caused them to reflect and revise their work more than before.

> Bella: after the introduction exercise, at the end of the lesson, a girl came to me and said: I wanted to submit the introduction section today, but I see there are some things I have to correct, so I will bring it tomorrow. It was so, you know, for this moment it was worth it, all the effort… that I did this thing

6.3.1.3. The influence of using the SWIM environment on students' scientific writing skills

In the first iteration I wished to examine whether engaging in the SWIM environment for learning to write in science impacts the students' scientific writing skills. To this aim, I analyzed initial and final drafts of inquiry-project reports from the two experimental classes (Ann's and Bella's classes) (N=28 drafts, 14 reports). To provide a comparison, I also analyzed drafts of inquiry-project reports of a nonintervention control class (N=18 drafts, 9 reports) from similar background and abilities as the intervention classes, who also conducted an inquiry-project, but received traditional instruction regarding the writing of the inquiry-project reports. This instruction included the teacher giving and explaining the guidelines for writing the report and individual guidance the teacher provided for each group. I assessed the drafts using SWAR.

Non-parametric analysis was used. Mean scores and standard errors are shown in Figure 10 (for U-values see Appendix 6). As can be seen in Figure 10, the scores of the initial drafts of students from the experimental classes (SWIM), were significantly higher than the scores of students from the control class (Non-SWIM), in all the sections of the report. The average scores of students from the intervention classes ranged from 1.6-2.25 (out of 3) and in the control class the scores ranged from 0.85-1.2.

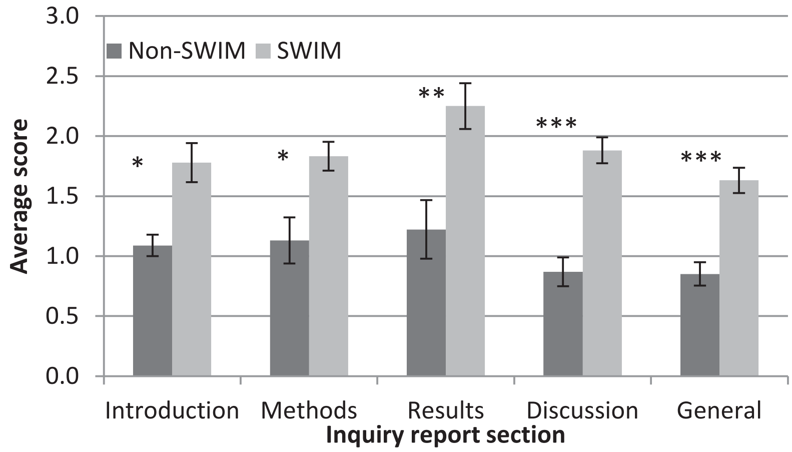

Figure 10. Average scores of the different sections in the initial drafts of the inquiry-project reports of students from SWIM (n=14 reports) and Non-SWIM (n=9 reports) classes using SWAR. Bars represent standard errors. * $p< 0.05$, ** $p<0.01$, ***$p<0.001$ in A Mann-Whitney *U* test.

A comparison between the reports from the two intervention classes showed that there are no significant differences between them, which allowed us to combine the scores of the two classes.

Assessment of the average scores of the different scientific writing components of each section revealed that the average score of all the components was higher in the initial drafts of the intervention classes than in the control class (Figure 11). All the scores, excluding three, were significantly higher (results of the Mann-Whitney test can be found in Appendix 6). The average scores of the intervention classes' reports ranged from 0.7-2.5 (out of 3) and in the control class from 0-1.8 for the different components.

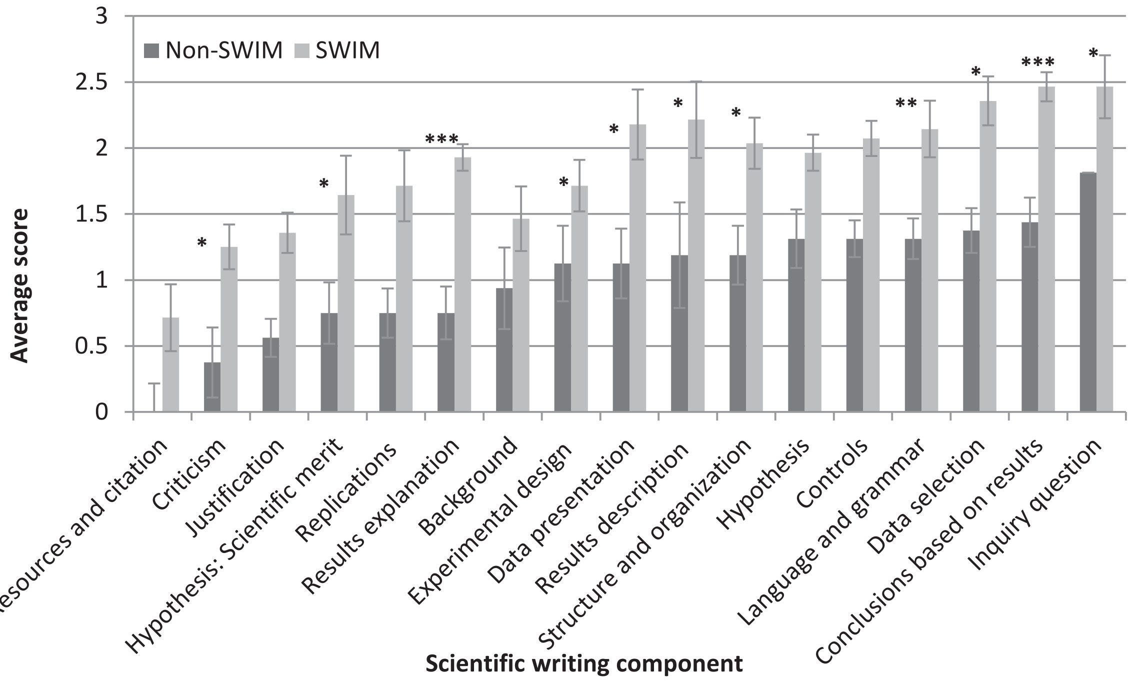

Figure 11. Average scores of the initial drafts of inquiry-project reports of SWIM (n=14 reports) and Non-SWIM (n=9 reports) classes using SWAR. Bars represent standard errors. * p< 0.05, ** p<0.01, ***p<0.001 in A Mann-Whitney *U* test.

In the final drafts (Figure 12) the average scores of the sections of the report were higher in the intervention classes, however only in the Introduction, the Methods and the General sections the differences were significant (U = 0, p< 0.01; U=4, p<0.05 and U=0, p<0.01, respectively).

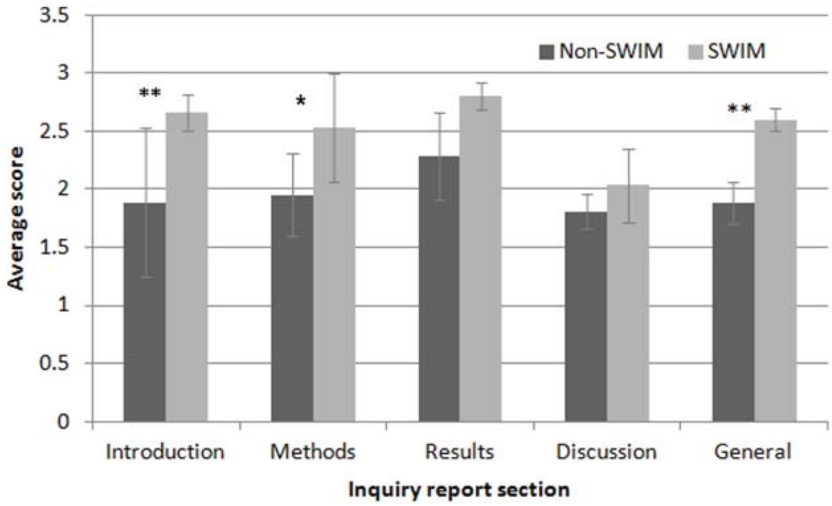

Figure 12. Average scores of the different sections in the final drafts of the inquiry-project reports of SWIM (n=14 reports) and Non-SWIM (n=9 reports) classes using SWAR. Bars represent standard errors. * p< 0.05, ** p<0.01, in A Mann-Whitney *U* test.

A comparison of each scientific writing component indicates that the average scores of all components were higher in the reports of the intervention classes (Figure 13). In four of the components the scores' difference was statistically significant: Justification of the inquiry (U=3, p<0.05), Scientific merit of the hypothesis (U=0, p<0.01), Controls (U=0, P<0.01) and Experimental design (U=5, P<0.05).

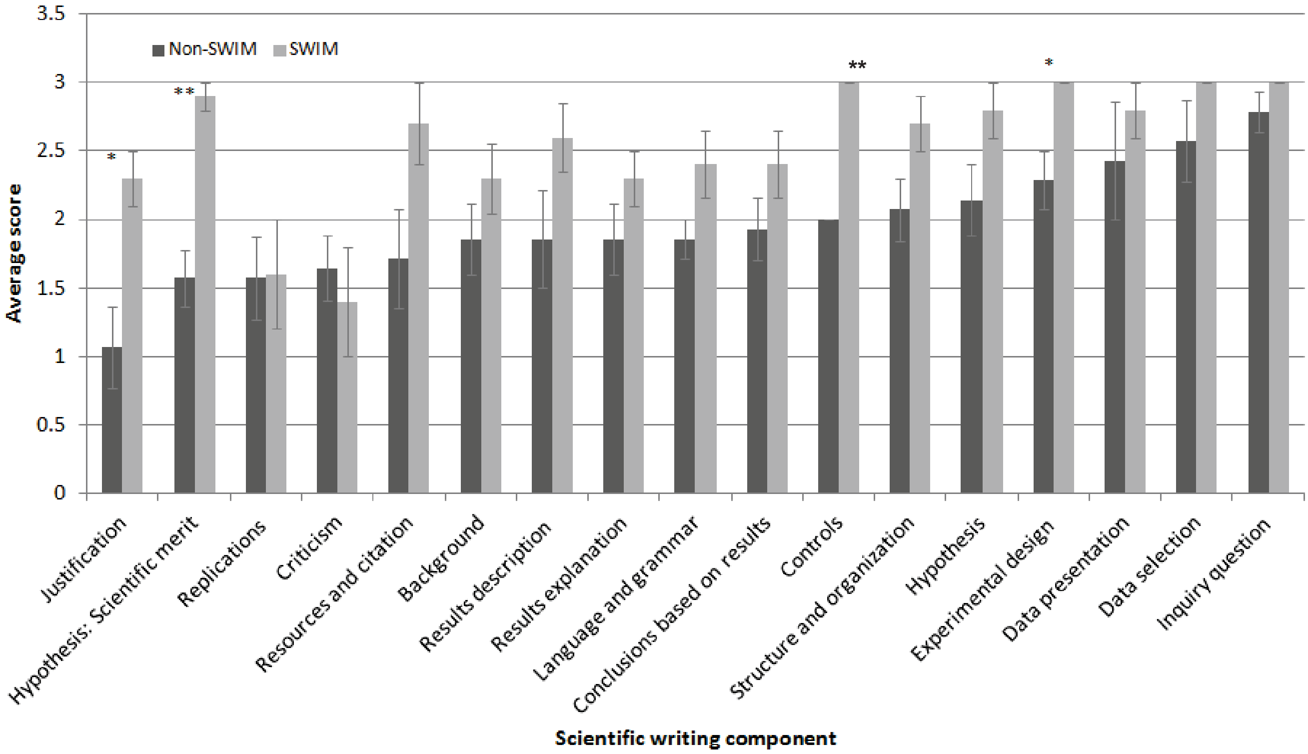

Figure 13. Average scores of the final drafts of inquiry-project reports of SWIM (n=14 reports) and Non-SWIM (n=9 reports) classes using SWAR. Bars represent standard errors. * p< 0.05, ** p<0.01, in A Mann-Whitney *U* test.

Summary of Iteration I

Findings:

- The SWIM environment had a positive impact on the students' scientific writing skills.
- Both teachers adopted (to some extent) the genre-oriented pedagogy of the SWIM environment and implemented it by a cognitive apprenticeship process.
- Interactivity (in the form of automated feedback) can increase students' motivation to learn to write.
- Timing is crucial for effective fading, the SWIM learning exercises should be in proximity to the writing of each section of the inquiry-project report.
- There is a need for integrating process strategies and elements to the SWIM environment, which will enable the teacher to coach the students more efficiently and to increase the students' self-monitoring capabilities.

Conclusion:

- The findings from the first iteration showed that our conjectures were partially corroborated. The apprenticeship process was not as effective as could be due to possible disconnection between the genre knowledge gained and the students' writing process of their own inquiry-project report
- The positive impact of the SWIM environment, which is based on genre-oriented pedagogy, could be increased by: (1) integrating a process-oriented pedagogy that would better link the genre knowledge gained to the writing of the students' inquiry-project reports; (2) adding more interactive exercises into the environment that could increase the students' motivation and learning.

6.3.2. Iteration 2 – SWIM 2.0

6.3.2.1. Overview of Iteration 2 and research questions

In the second iteration, the second version of the SWIM environment (SWIM 2.0) was implemented. The SWIM 2.0 can be accessed in the following link, with the user name: **macam2016**, and the password: **macam2016**:
https://st-moodle.weizmann.ac.il/course/view.php?id=42.

I revised and redesigned the SWIM 1.0 environment based on the conclusions and insights from the first iteration. Two major changes were introduced to the SWIM 2.0 environment – a technological change and a pedagogical change. The technological change was the transformation of the SWIM environment to a Learning Management System (LMS). For this purpose I redesigned the SWIM 2.0 environment on a Moodle platform. The Moodle environment is hosted in the server of the Department of Science Teaching at the Weizmann Institute of Science. The pedagogical change I introduced to the second version of the SWIM environment was the integration of a process-oriented pedagogy, resulting in **genre-process pedagogy**. The modifications made in the first version to create the second version are elaborated in the next section and summarized in Table 14.

In the second iteration, which took place in the 2014-2015 school-year, I examined the implementation process of the SWIM 2.0 environment in four classes, of the following teachers: Carol, Dana, Eleanor and Frida. The implementation process and its influence was examined in depth by qualitative and quantitative means in Carol's and Dana's classes, while in Eleanor and Frida's classes I only tested the impact of the SWIM environment using quantitative tools.

In this iteration I asked the following questions:

1. **How was the SWIM 2.0 environment adopted and implemented?**
2. **How does enactment of the SWIM 2.0 environment influence students' scientific writing skills?**
3. **How does the teachers' orientation for writing instruction reflected in the apprenticeship model and how does it influence the writing process?**
4. **How does the SWIM 2.0 environment influence the attitudes of high-school biology majors towards writing in science?**
5. **How does the writing process using SWIM 2.0 environment influence the understanding and learning process of high-school biology majors?**

To answer these questions, two case-studies were conducted. In these case-studies, I examined the processes and experiences of implementing SWIM 2.0 using two main methods: (1) Class observations – I observed six lessons in which the SWIM 2.0 environment was implemented in Carol's and Dana's classes. (2) Semi-structured interviews – I conducted interviews with the two teachers in the beginning and the end of the implementation of the SWIM 2.0 environment, as well as group students interviews (2-3 students in each group, n = 12 interviews). The lessons and the interviews were recorded and transcribed. The transcripts were coded and analyzed from the following aspects: sequence of instruction, adoption of the genre-process pedagogy, adoption of the technology, apprenticeship process, and general design feedback. In addition, I examined the influence of the SWIM environment on the students' scientific writing skills by pre / post SWS test, that was given to 107 students from 4 SWIM classes – two Non-APL SWIM classes (Carol's and Dana's classes) and two APL-SWIM classes (Eleanor's and Frida's classes), compared to two control classes (the classes of teachers no. 13 and 21, see Table 4). To answer the third question, I analyzed the feedback given on 12 drafts of 4 reports of students from Dana's class. In this iteration I also examined the attitudes towards writing of students from SWIM classes (n=70), using the Attitudes towards writing questionnaire.

6.3.2.2. Revision of SWIM 1.0 and conjectures mapping for SWIM 2.0

Following the first enactment of the SWIM 1.0 environment I introduced some changes and modifications to the environment, some more substantial than others. All the revisions are summarized in Table 14 (see Table 9 and Table 10 for the SWIM 1.0 description). The design principles remained the same, except for **DP4 – "Strategy instruction of scientific writing**" which was elaborated to the design principle "**Process-oriented instruction of scientific writing".**

Table 14. Revisions in the SWIM environment following the first iteration

Initial design principles	**Modified design principles**	**SWIM 1.0 (Prototype)**	**SWIM 2.0 (Revisions from SWIM 1.0)**
DP1- Construction of genre knowledge by analyzing APL as a model	Same	Six APL–based exercises: *1. Introduction to scientific communication* *2. Components of the scientific article* *3. Analyze a research article – short videos* *4. Getting to know the Introduction* *5. Good Intro – Bad Intro* *6. Learning to write a Discussion*	Six APL-based exercises. • *Getting to know the introduction* exercise was revised • *Good intro – Bad intro* exercise was revised
DP2 - Interactive, inquiry-based learning	Same	• All exercises are inquiry-based • Five interactive exercises	• All exercises are inquiry-based • All exercises are interactive
DP3 - Exercises address specific skills, processes and knowledge	Same	• All the exercises were designed to address specific difficulties and skills	• *Merging resources* exercise was added • *Data presentation* exercise revised • Collaborative writing option was added
DP4 - Strategy instruction of scientific writing	Process-oriented instruction of scientific writing	• One revision exercise (*Good intro-Bad intro*) • Two planning exercises (*Getting to know the introduction, Learning to write a discussion*")	• The learning unit: *My inquiry-project report* was added, including: - Scaffolds for planning - Checklists for revising - On-line feedback from the teacher - Writing strategy -personality quiz - Collaborative writing
DP5 - Flexibility in use	Same	• Modular exercises: each exercise stands on its own • Integration to the curriculum: - Content is suitable for the syllabus: Cell, Ecology and Human biology	• No revisions
DP6 - Technology enhanced learning	Same	• Web-based platform (Clickit3 ©, Ort). • Five automated feedback exercises • Four short video lessons *(Analyze a research article – short videos*)	• Web-based LMS platform (Moodle) • All exercises with automated feedback

The main pedagogical change was increasing and emphasizing the writing process in addition to the genre elements to create integrated genre-process pedagogy. By process-oriented pedagogy I refer to a broad sense of writing process rather than a narrow sense, in which students plan, draft, revise and edit their work (Applebee & Langer, 2013). My definition of process-oriented pedagogy includes strategy instruction (explicit teaching of specific strategies for planning and revising), teaching of self-regulation procedures, encourage collaboration and give extensive feedback to multiple drafts to facilitate writing. Integrating the process-oriented pedagogy to the environment, creating genre-process pedagogy, also intended to strengthen the connection between the genre knowledge, the students are constructing by engaging in the inquiry-APL based exercises, and the writing process of their own inquiry-project reports. This can provide the opportunity for the students to transfer what they have learned and apply it in proximity to the learning process.

The process-oriented approach was incorporated mainly in a new learning unit in the environment called "My inquiry-project report" (Figure 14). This unit includes scaffolds for planning each section of the report, in the form of procedural facilitators such as outlines and guiding questions. Each scaffolded exercise is submitted to the teacher, who can provide immediate feedback on the students' plans of the different section. This unit also includes a tool for submitting multiple drafts of the different sections of the report, as well as the final combined draft. In this tool the teacher can monitor the progress of each group, provide feedback using several means (including on-line feedback, in-file remarks and a grade). After planning and drafting a certain section, the students are encouraged to self-asses their writing and revise it, before submitting it to the teacher. For this, the students can use interactive checklists that provide visual indication of their progress.

All the exercises in "My inquiry-project report" are designed for collaborative work. The teacher defines the inquiry-project groups at the beginning of the writing process in the SWIM environment and from this point each group is working together (i.e., all the members of the group see the files uploaded, the teacher's feedback and the checklists). The students can also chat or send messages to each other through the platform.

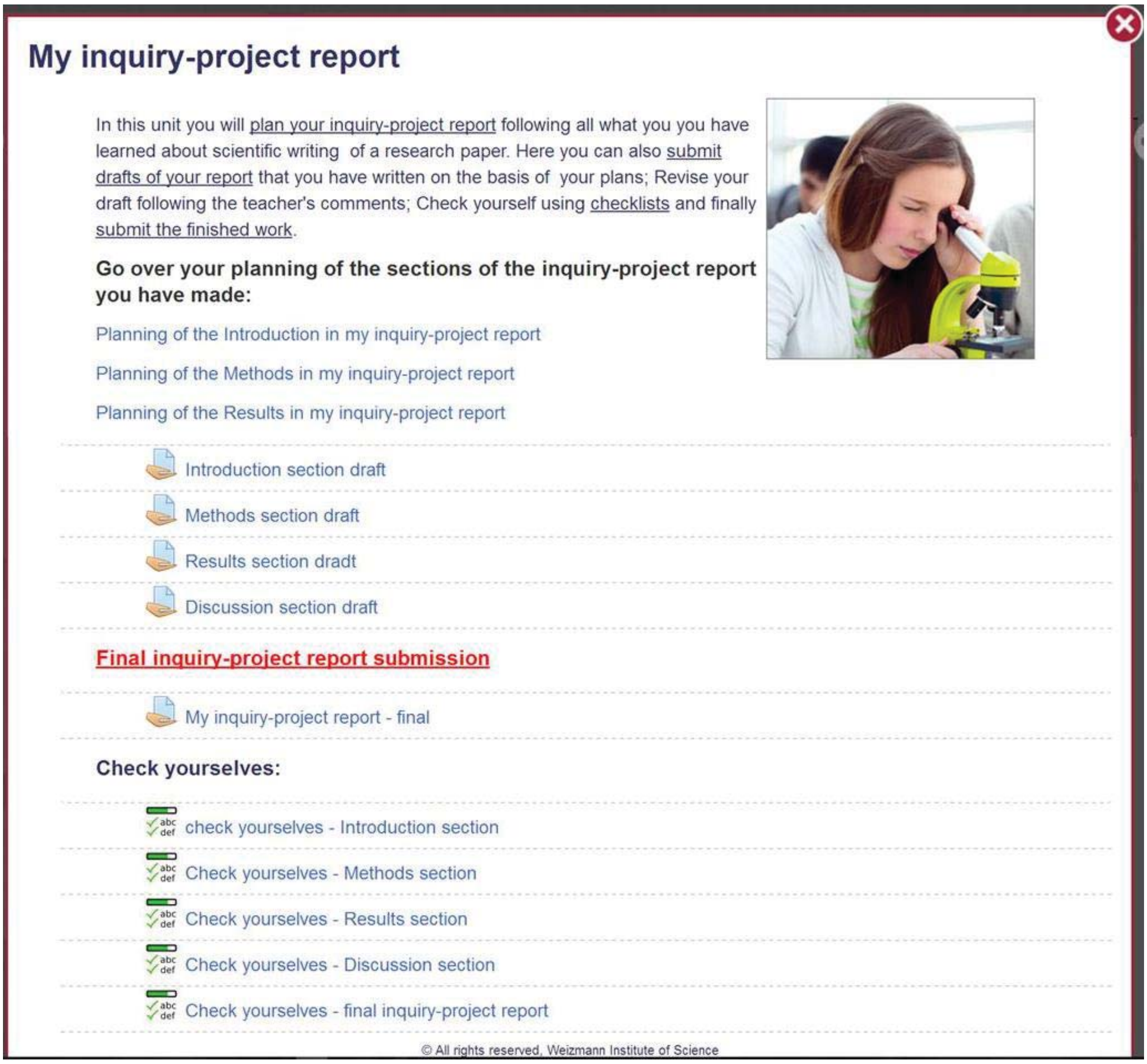

Figure 14. "My inquiry report" unit from SWIM 2.0 environment

The main technological change that was incorporated into the SWIM 2.0 was the transformation of the SWIM environment to a Learning Management System (LMS). The chosen LMS for this purpose was Moodle. I chose to use a Moodle platform for several reasons: First, this platform provides numerous technological possibilities for integrating the genre-process pedagogy, including automated feedback on exercises, collaborative work, built-in self-assessment checklists, integrated progress reports enabling the teacher to effectively monitor the students' progress, grading tools and more. The Moodle-based SWIM environment was programmed with the assistance of an educational technology expert.

Additional revisions made to create SWIM 2.0 were: A new exercise designed to teach the skill of merging resources was added (DP3). I also revised three of the exercises (*Good intro – Bad intro*, *Getting to know the introduction* and *Data presentation*) to better fit the genre-pedagogy, emphasizing the APL characteristics compared to the inquiry-project report.

Figure 15 presents the homepage of SWIM 2.0. The APL-based exercises are divided to learning units according to the sections of the inquiry-project report in addition to two general scientific communication units.

Figure 15. SWIM 2.0 homepage

6.3.2.3. Conjectures map

According to the revisions made in the SWIM environment, I also amended my conjectures, integrating the process approach and the technological upgrade to my conjectures map (Figure 16). The genre-process pedagogy is reflected in the revised high level conjecture. In addition, the process elements embodied in the SWIM 2.0 environment were added, along with the upgraded technological support tools. See Figure 9 for the conjecture map of SWIM 1.0.

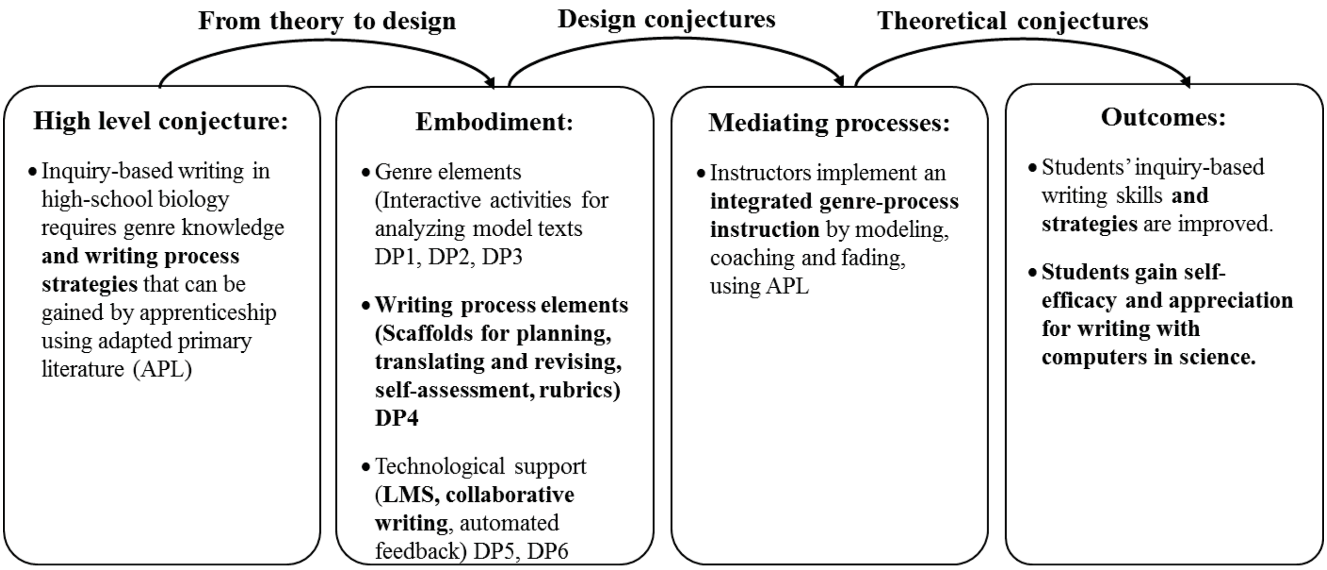

Figure 16. Conjectures mapping for SWIM 2.0. (see for comparison the conjectures mapping for SWIM 1.0 in Figure 9). The revisions of the conjectures mapping for SWIM 1.0 are marked in **bold**.

6.3.2.4. Implementation and adoption of SWIM 2.0

The case of the teacher Carol

Carol is an experienced biology teacher. She has a Master's degree in biology and 20 years teaching experience. In the year of the intervention, Carol was instructing the inquiry-project for the third time.

The learning sequence Carol implemented in her class, as well as the apprenticeship steps she applied in this sequence, are summarized in Table 15. Carol's students completed the exercises in a digital format in the SWIM environment while working in a computers room. Each student worked independently or in pairs. Carol accompanied the exercises with class discussions usually before and after each exercise.

Table 15. The learning sequence and Apprenticeship steps of the teacher Carol

SWIM exercise / component	Timing	Apprenticeship step
Raw vs. processed data	After conducting the experiments of the inquiry-project	Scaffolding
Data presentation	Before writing the results section	Scaffolding
Getting to know the Introduction	Before writing the Introduction section	Modeling, Scaffolding
Good Intro - Bad Intro	Before writing the Introduction section	Scaffolding and fading
Learning to write a Discussion	Before writing the Discussion section	Modeling, Scaffolding

Adoption of the genre-process pedagogy by the teacher

From the interviews with Carol and from the class observations it was evident that Carol adopted both the genre elements and the process elements of the pedagogy underlying the SWIM environment.

Although Carol did not choose to teach the introductory to scientific communication exercises due to time limitations, she did highlight genre features of each section of the report in the exercises she chose to teach her class. Carol's genre approach to writing instruction can be reflected in the following quote from the concluding interview:

> Carol: This is, in my opinion, what was excellent in all the exercises they did. Because they saw also what is good and what's not good, and they had to discover it on their own… A lot of times in the past years, I pointed them directly to what they should write and actually did the work for them. Here, because they had to identify what's good and the wrong places, so they did it themselves, and I think this is the best way to learn. Not me telling them what's good and what's not good. Therefore, in all those places in which they had to identify characteristics, extract the right sentences, put paragraphs in order, identify what's not appropriate for a scientific article, these were the places, that for me, as a teacher, are really really effective. This is what they should learn.

In addition to the benefits the genre-pedagogy in general, and using APL as an apprenticeship genre in particular, have for learning to write in high-school science, Carol also saw its potential for the whole inquiry process as a way of enculturating the students to the scientific community.

> Carol: When they read an article, they are in fact reading… the article is written like a research, so they understand the meaning of research, OK? They see… they try a little bit to get into the head of the researcher. I don't know how many of them are doing that, but they're trying. And when they get into the researcher's head, I believe this is the pick of their biology high-school studies. Therefore, I think learning with articles, and not

> textbooks, is a way of learning that elevates the student's thinking to higher places. It challenge's them. It's also not obvious; it requires a lot of thinking.

Carol's process approach to writing instruction was clearly evident as well, while she enacted the SWIM environment. Carol indicated the advantages the SWIM environment possesses with regards to the writing process.

> Carol: This ability to upload the materials this way, that each team sees what everyone uploaded, and I can see everything and they see my feedback… All of this was one of the great things in the environment.

An important aspect of the process approach is seeing the writing process as a system involving a set of cognitive activities that interact with the task environment (i.e., task elements, coauthors, sources, technology, and the emerging text) and that are bound by internal constraints involving a writer's resources (i.e., working memory, genre knowledge, topic knowledge, and linguistic proficiency; van den Bergh et al., 2016). Carol recognized this variation among her students writing abilities and understood the importance of relating to it. She also indicated that the SWIM environment can provide the teacher the support and tools for matching the teaching to the students' capabilities.

> Carol: maybe for the weaker students, these exercises are good. Because the strong students, they get it pretty quickly, but the weaker ones need more… so, it [The SWIM environment] gave the weaker students an opportunity to practice more, and it was great. So, this practice really opened their eyes, and… because in the past, I think that from my explanations to the whole class about writing the [inquiry-project] report, the weaker students didn't understand enough how the actual writing is done… and now, the practice helped them focus on the important things.

Adoption of the genre-process pedagogy by the students

From the group interviews with students from Carol's class (n=14 interviews, 2-3 students in a group), computer log files and recorded observations of class interactions, there is evidence that Carol's students adopted certain aspects of the genre-process pedagogy of the SWIM environment. I identified several issues raised by the students regarding the genre perspective of the pedagogy. These issues are: logical organization of the scientific article in general and the introduction section in particular and proper scientific language. Most of the students mentioned in the interviews the aspect of logical organization in scientific writing and indicated that the SWIM environment assisted them in developing and establishing this organization in their inquiry-project reports. The students also stated that the SWIM environment helped them understand what elements belong to each section of the report and prevented confusion between the sections. Examples of these genre-related issues can be seen in the following segment extracted from a group interview:

> S1: I wanted to say that the site actually really helped us. Because it puts emphasis on each section separately and also on how to do it, then it really divides it for you, like, when you think of the report as a whole you can mix the sections. This [the SWIM environment] really organized things for us.
> S2: And another thing. Now we write the Introduction at the end, using Carol's instructions.
> Researcher: What do you think of that? Is it right to write the introduction last?
> S2: Yes, I think it is.
> S1: I think so as well, because all the information is already written in the report and the introduction is sort of a summary of that, so we just have to write what's relevant.

In another interview the students referred to the benefits of the two introduction exercises, one that uses a model text that the students can learn to emulate and the other that focuses on criticizing and revising a "bad" text, aimed at advancing the students' revision skills.

> S3: The introduction exercise really helped me understand better how it is supposed to be… how the final product actually should look like and what I should do to write it like this.
> S4: I also liked the introduction exercise where we checked it and graded it. Then it got to my head better, what should and shouldn't be in the introduction.

Issues related to the process perspective of the pedagogy could also be identified while the students engaged with the SWIM environment. The issues identified were: using the planning and revision tools, collaborative work and feedback.

> S1: There was the part with the list that we had to mark ✓ each time, right?
> Researcher: The checklists?
> S1: Yes. So I used it also. It puts things in order.
> S2: That's it, it really helped us understand what we did and what we still have to do.
> S1: It [the SWIM environment] also connected between us better, like, I did something and she could see it immediately, this was very useful.

Another group referred to the planning scaffolds options presented in the environment, such as outlines for the introduction and the discussion, guiding questions for the results section etc. In this quote the students described how they used the discussion outline:

> S5: So basically we worked according to the instructions and the examples. We worked with our results opened on the computer and every time we looked at the results and thought why it happened and why we got what we got.
> S6: Also in the table it was written what should be in the first paragraph, the second, really detailed. So we just put in what we need to.
> S5: Yes, we just started to write and it was easy.
> Researcher: According to the template?
> S6: Yes

This group continued describing the writing process raising the issue of the teacher's feedback and their collaboration with each other:

> S5: Afterwards we sent Carol what we wrote and she sent us corrections.
> Researcher: And you corrected your report according to Carol's notes?
> S6: Yes. And we also corrected each other. Like, I wrote something and he read it and changed it a bit.

All the groups indicated that one of the most effective aspects of the SWIM environment was the ability to collaborate with your peers and teammates as well as with the teacher. For examples:

> S3: What's good in the site is that you put something and then the rest of your group can see it, it was easy.
> Researcher: and you feel it helped you write?
> S4: Yes. it was very effective to work like this, he uploads, I see it, correct it and he sees it…

Adoption of the technology by the teacher and the students

The teacher and students' interviews, the log files and the analysis of class observations showed some usability problems in operating the SWIM environment, mainly due to interface issues. Although facing some technological challenges when starting to work with the SWIM environment, both the teacher and the students indicated they have overcame those challenges rather quickly, after a short practice or additional support.

From Carol's perspective, she considers herself as a technological person, so she believed the introduction of new technology to her class would not be difficult. However, as she began implementing the SWIM environment she ran into some operating difficulties. Examples of these difficulties are: Observing and grading the students' exercises and locating files submitted by the students. After Carol expressed her difficulties to the team, we met with her and provided the needed technical support. Following this meeting Carol felt more confident in operating and implementing the SWIM environment. She indicated that working with SWIM greatly facilitated the writing process. This could be observed in the considerable activity Carol and her students did in the environment, as can be seen in the site activity log in Figure 17. Carol mastered the main features of the environment including advanced options such as manually grading an exercise, writing on-line comments to the students and defining working groups within the environment. Carol's change in adopting the technology of the SWIM environment was summed as follows:

> Carol: I thought it would be very easy for me, since I am technological, but it was hard at the beginning. Something really confused me in the way you do things. But I didn't give up; I turned to you and asked for help, remember?
> Researcher: Yes.

Carol: And then, once I got the idea, it was very useful… something pushed me and my class strongly forward towards writing the inquiry-project reports. Afterwards, I never stopped using the platform and the [writing] process went very quickly.

Carol's students also indicated usability difficulties at the beginning, most of them were related to the interface of the SWIM environment. Some of their difficulties were: finding where to submit a draft, visual overload of the homepage, and lack of familiarity with the Moodle interface. Like Carol, her students also overcame their difficulties after a short practice and eventually could see the environment's benefits and contribution to the writing of their inquiry-project reports.

S1: At the beginning we didn’t understand where to upload and how.
S2: We just pushed some button and saw, ah, it's here.
S1: But the whole process later wasn't complicated at all, and after trying once or twice we already knew how to do everything.

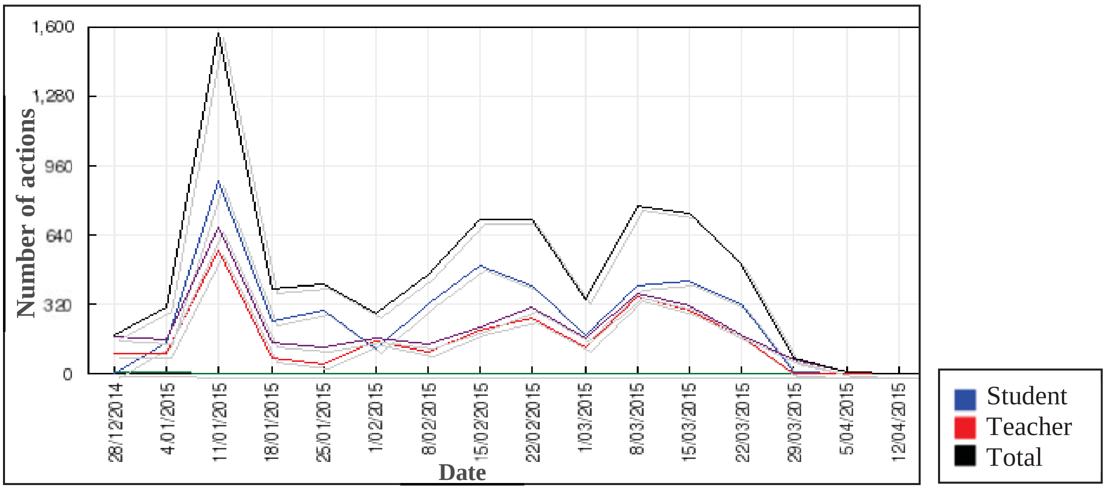

Figure 17. Carol's class activity log in the SWIM 2.0 environment

Sociocognitive apprenticeship steps in the implementation of SWIM 2.0

While implementing the SWIM 2.0 environment in her class, Carol applied apprenticeship tools for instructing her students how to write their inquiry-project reports. Overall, based on the interviews with Carol, class observations, students' interviews and the log files from the environment, I can indicate that Carol used the exercises in the SWIM environment as an anchor and a support for apprenticing her students in scientific writing. For each section of the report, Carol first asked her students to complete an exercise and then summarized the exercise in a class discussion (in most cases). During those discussions, Carol modeled various writing strategies such as planning the introduction. Carol relied mainly on the scaffolds embedded in the exercises for the scaffolding step, together with providing individual and group feedback in the coaching step. The fading step could be seen in Carol's class in several aspects as elaborated below.

Modeling: an example of Carol modeling the planning of an introduction is extracted from a class observation. This modeling was a part of a class discussion that followed the *Good intro – bad intro* exercise.

> Carol: I want to refer to the second part of the exercise now, where you saw the structure of the introduction. So, what do we start the introduction with? The justification of the inquiry. [writing "justification of the inquiry" on the board"]. I'll give you an example: the effect of garlic on bacteria reproduction. Why is it important to investigate it? Does anyone have an idea?
> S1: maybe to know if we can take it when we're sick.
> Carol: right, when we're sick, maybe we could eat garlic as a treatment or to prevent diseases. We should check it. So, each of you have to think what is the justification of your inquiry, why should someone else read your work?
> What next? Background on the organism we're investigating [writing "background on the organism" on the board]. What do I mean by organism? Like: yeast, bacteria, bees, and radish. These are all the organisms you're studying. …

Carol continued with demonstrating the building of the background on the scientific process, the factors that can influence the process and finally the inquiry question, the hypothesis and the scientific merit for the hypothesis. She summarized the modeling in this manner:

> Carol: Now look, how would you describe the structure of the introduction?
> Student: a triangle
> Carol: yes, or like a funnel. The introduction starts from something general and slowly focuses to our inquiry question. It's very important that when you plan your introduction you'll have this funnel in your heads. Because what is the introduction for? to introduce the reader into your study, to lead him into your specific question. If you'll have this in mind, I'm sure all of you will have a good first draft of the introduction

In general, as part of the modeling, Carol believes it is the teacher's role to guide and lead the students to be aware of the resemblance between the inquiry-project report and a scientific article (in this case the APL). She stated that without this guidance, the students would not get to the desired insights and will not fully implement what they are learning from the exercises in their writing.

Coaching and scaffolding: Carol carried out the coaching and scaffolding step in the apprenticeship process mostly by relying on the exercises in the SWIM 2.0 environment and the scaffolds embedded in them. Carol's view regarding the power of the exercises as scaffolding tools is reflected in this quote:

> Carol: The students never wrote am inquiry report. So for them, things like what includes each section, how to write, the order of things, these were very unclear for them. Therefore,

when I gave them an exercise in which they have to separate the wheat from the chaff or find errors for instance, this guides them how to write better their own things.

Carol also referred to the versatile nature the scaffolds should possess. The variety of the scaffolds in the different exercises allowed Carol to match the provided scaffolds to the students' needs. For example, if Carol felt a certain student needs more practice in the methods section she could instruct this student to complete additional exercise.

Carol: I think that every teacher, according to the class, can choose what's appropriate for the whole class, and give the other things to as extra practice for students who want or need it. It's good that there's a wide variety… it's especially good for weaker students that can practice more on their own.

Fading: As the writing process progressed I could see how Carol gradually released the responsibility and the students took more responsibility for their writing. I could classify this responsibility to two aspects: Self-regulation and reflection on learning. Self-regulation is facilitated in the SWIM 2.0 environment by the planning and revision tools the students are encouraged to use. Carol instructed her students to plan certain sections of the report and indeed most of the students planned all sections of the reports by using the planning tools. Eighteen students used the introduction planning tool, 13 used the methods tool, 18 the results and 15 the discussion planning tool (See Appendix 7). In the revision, however, only a small minority of the students had used the tools in the environment. A reason for that could be that Carol did not explicitly instruct the students to complete the checklists and revise their drafts.

The fact that students in Carol's class took responsibility for their writing can be indicated by the reflection on their writing process and its significance:

S4: It gives you the feeling that you see the whole picture in front of your eyes, and you have your own subject, and you see how everything comes together, like plants, photosynthesis, respiration, everything.
Researcher: So, writing down put things together for you?
S4: Yes. You see the connection. I also think when you do it in depth, and you do it yourself… then you understand your work better.
S5: I agree, when you do it from start to finish, and write on your own, it get into your head better.

The case of the teacher Dana

Dana is an experienced biology teacher with 9 years teaching experience. Dana has a bachelor's degree in biology and a master's degree in science teaching. At the time of the intervention, Dana was in her first year of her doctoral studies in science teaching and was a member of the biology research group in the department of science teaching in the Weizmann institute of science, together with this study's researcher. Dana taught a 12th grade class in an urban mid-high socioeconomic state. This was Dana's first time of instructing the inquiry-project. The learning sequence Dana implemented in her class, as well as the apprenticeship steps she applied in this sequence, are summarized in Table 16. Dana's students completed four of the SWIM 2.0 exercises at different stages of the inquiry process.

Table 16. The learning sequence and apprenticeship steps of the teacher Dana

SWIM exercise/ component	Timing	Apprenticeship step
Components of scientific article	After conducting the experiments and before starting the writing process	Scaffolding
Raw vs. processed date	Before writing the Results section	Modeling, Scaffolding
Good Intro-Bad Intro	Before writing the Introduction section	Scaffolding and fading
Learning to write a Discussion	Before writing the Discussion section	Modeling, Scaffolding

Adoption of the genre-process pedagogy by the teacher

I found a strong evidence of Dana's genre-oriented approach for writing instruction as it was reflected in the interviews, as well as in the class observations. Since Dana is researching reading of scientific texts including APL as part of her PhD, it was expected she would adopt the genre-oriented pedagogy while implementing the SWIM 2.0 environment in her class. Dana's strong orientation to genre-pedagogy is evident in Dana' following summary:

> Dana: I think the article is a great tool to work with. I think it should be highlighted, literally, the things that characterize the scientific article and are relevant for the inquiry-project report. So, there are the exercises with the different parts of an article and what's supposed to be in each part and what kind of information I would find in each section of the article, which is great. But, there are other things that maybe should be more emphasized [in the environment].
>
> Researcher: Like what?
>
> Dana: like language. Like connections. How to link the parts? I think today I understand that most of what we call scientific literacy relies greatly on reading and writing of scientific texts, and the content, important as it may be, is not the main thing.

Despite Dana's intensions to teach her students to write through the genre-oriented pedagogy, she felt her student didn't receive most of the advantages the SWIM 2.0 environment has to offer in this regard. The reasons for this were time limitations, Dana's inexperience with the inquiry-project which caused her to focus on the technicality of the project and understanding its demands. For these reasons Dana couldn't execute the lessons plan as she planned. One of the exercises she regretted her students didn't complete was: *Introduction to scientific communication.* She explained her regret as follows:

> Dana: They [the students] didn't see a scientific article in their lives. And then suddenly I tell them, here is an article, and it doesn't mean anything to them, they don't understand. Why are you bringing it to us? Why is it relevant for our reports? So I think it's important the students first be introduced to this genre of scientific article, because they don't understand that their inquiry-report is a kind of a mini-article. So I think this exercise [*Introduction to scientific communication*] is important and could make them see the connection.

Beside Dana's genre-pedagogy, we could also recognize elements of the process approach in her implementation of the SWIM environment. Dana addressed process-related issues such as: the students' writing strategy (i.e., planner or reviser) and the need to teach writing strategies explicitly and according to their writing strategy; the importance of reflection and feedback for better learning and understanding; and the time limitation factor in the writing process.

In the closing interview, Dana reflected on the overall process and came to realize that beside different writing skills, her students also have different writing strategies. She also recognized the importance of teaching the students those strategies, like planning and revising, and practicing them during the writing process.

> Dana: Not everyone is capable or can do it [revise] as good… when they write and then have to revise what they wrote, it doesn't always help them. So there's a need for teaching different writing strategies and let them choose what's right for them.

Moving form draft to draft in the writing process, Dana believes reflection and constructive feedback are very important.

> Dana: I think that reflection is something very important for writing. If you do not understand what you did and why, why did you write something here and not there, so you will never understand what you did wrong. … Then you need to have some kind of reflection that is guided by the person teaches you write, the teacher in this case, to understand what you have done and how can it be fixed the next time you write

Adoption of the genre-process pedagogy by the students

I found evidence that Dana's students adopted several aspects of the genre-process pedagogy. The group interviews, log files and class observations indicated that most of Dana's students appreciated the positive effect the genre-based exercises had on their writing. Examples of the genre-related issues the students referred to are: familiarity with the special structure of a scientific article, focus on relevant and irrelevant information and the formal and accurate language required in a scientific article. These issues can be seen in the following representing quotes extracted from a summarizing group interview:

> S1: The exercises for each section, and the instruction really focused me. In the beginning [of the inquiry project] the only writing structure I knew was the basic lab report that, I came to realize is different than the final structure of the inquiry-project report.
> S2: The website has contributed to my writing process in that I could perform exercises before I write. These exercises helped me understand better what I should refer to in my report and directed me to write the best draft I could.

Dana's students indicated the advantages the SWIM 2.0 environment has in respect to the writing process. Most of the students stated the SWIM 2.0 environment assisted them in monitoring their writing process by easy communication with the teacher, immediate and convenient feedback, tools for collaboration with peers and organized and easy access to files and their previous drafts. In addition to the monitoring benefits the SWIM 2.0 environment holds, Dana's students also referred to writing strategies, such as planning and revising, that they have learned by using the SWIM environment and their impact on their writing:

> S3: The planning step was difficult, because we had to plan exactly what we would write about in each section and how we will write it. But after we finished this step everything flowed, because we already knew what to write, so it was simple.

Adoption of the technology by the teacher and the students

Characterization of the implementation of the SWIM 2.0 environment in Dana's class showed that overall Dana and her students adopted the technology of the SWIM environment and felt comfortable in using it after a short adjustment period. No major technological incidents were observed or recorded during the implementation of the SWIM environment. The usage report (Figure 18) showed a significant activity of the teacher and the students in the environment during the intervention.

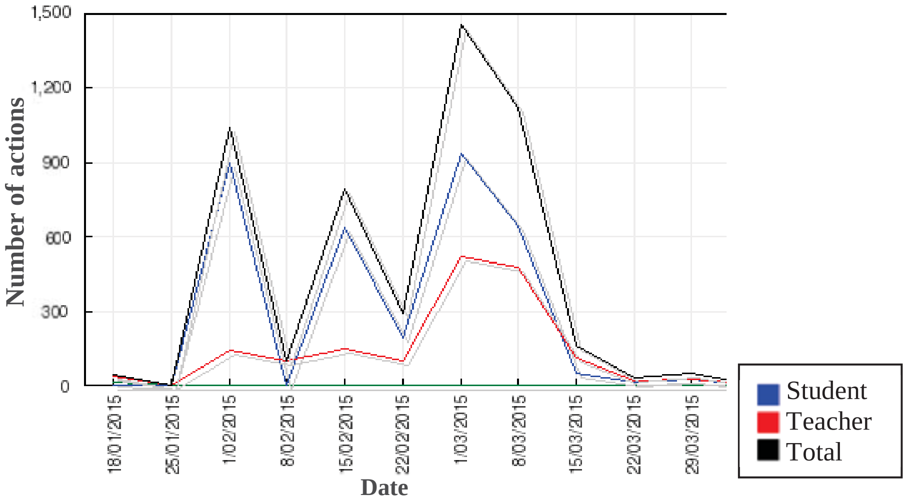

Figure 18. Dana's class activity log in the SWIM 2.0 environment

From Dana's perspective, she indicated that the interface of the website wasn't very clear and a bit confusing at the beginning, but after she explored the SWIM's possibilities and functions by herself, it became much easier to operate the environment.

> Dana: Overall, after I learned how to use the website it was fine. Once I understood all the functions and how to get to them… at the beginning it was more complicated, I don't like the Moodle platform so much. So I had to figure out how to do certain things, but after I got it, it was good. The fact I could get all the students' files in one place, organized by order and date, was very useful for me. I could always know what draft is it. And for them as well, once they got a feedback from me, they could see the process of their writing and go back if they wanted to.

Dana's comfort and confidence in operating the environment was also reflected from the features Dana added to the environment independently. These feature included group forums and rubrics for grading the drafts of each section in the inquiry-project report.

Dana summarized her impression about the experience of her students with the SWIM environment as follows:

> Dana: They [the student] weren't enthusiastic at first, they didn't understand what it good for, but they did it because I asked them to. And by the end everybody got it, and understood how to work with the website. They all uploaded files, saw my feedback and didn't have any problems.

Dana's students described their technological experience in a similar way their teacher did. They also indicated a short practice and explanation were needed for them to familiarize with the SWIM environment and its' various possibilities.

> S4: to someone who doesn't know the website, it not very user friendly. However, after a short explanation and as we used it more, it became very friendly.

> S5: In the beginning it was a little hard to understand where everything is, but after Dana showed us how to use the website and we practice for several days, it was very convenient and easy to work with.

Sociocognitive apprenticeship steps in the implementation of SWIM 2.0

Dana's background and overall approach for writing instruction brought her to perceive the instruction of the inquiry-project report using the SWIM 2.0 environment as an apprenticeship process. In the concluding interview she summarized her position as follows:

> Dana: I see the writing process as an apprenticeship process, in which the students learn how to enter a community of writers, in this case the inquiry-project reports writers, which is a kind of scientific writing. So, first of all I should know how to do it, I'm the experts in their perspective.

I could identify elements of each step of the apprenticeship process during the implementation of the SWIM 2.0 environment in Dana's class.

Modeling: Although Dana believed modeling is an important component of the writing instruction, she indicated this step was not accomplished to her satisfaction, mostly due to time limitations. Because Dana started to implement the SWIM 2.0 environment relatively late in the inquiry project process, the writing instruction was mostly by individual and group instruction rather than a whole class lessons. Before Dana's students started to summarize the results they obtained from their experiments, she asked them to complete the *Components of scientific article* exercise as a homework assignment. In retrospect, Dana realized she should have done this exercise in class, and use it to model her students how to write.

> Regarding this exercise Dana stated: I think, now, this is a very important exercise and I should have started with it. If I'll do it again I will do it in class, as part of a lesson. I would talk with the students about where they were wrong and why and then discuss the things with them – What do we know about the discussion? What should it include? What's the role of the introduction? And do it together. It was wrong to tell them to do it at home, because we forgot about it and they didn't reflect on what they have done.

In addition, similar to Carol's point of view, Dana also believed it is the teacher's role to explicitly make the connection between the APL-based and the students' writing of the inquiry-project report:

> Dana: because they [the student] can't always make the connection between what I give them to do [the SWIM exercises] and its relevance to what they should write, this connection should be more explicit, should be taught by the teacher.

Coaching and scaffolding: Most of the scaffolding in Dana's writing instruction was based on the scaffolds embedded in the SWIM environment. Before writing the results section, Dana did the *Raw vs. processed data* exercise in class. She used this exercise also to teach her students how to process their data in Excel. Dana coached her students mostly in individual or group meetings. Another coaching element Dana applied was the group forums she introduced to the environment. In these forums Dana gave each group directions, guidelines and feedback on their work.

Fading: Similar to Carol's class, I could identify in Dana's class the two issues related to the fading step: self-regulation and reflection on learning. Even though Dana did not instruct her student to use the planning and revision tools in the SWIM 2.0 environment, a few students did use them independently (an example of a planning appears in Appendix 7). The reflection of Dana's students on their writing process suggest that they feel they learned from the writing process, they are proud of their accomplishment and take responsibility for it. Three representative quotes are:

> S1: I learned how to locate relevant information, write a report scientifically and continuously and decide what's relevant and what's not.
>
> S2: The stage I like the most was the writing. I like it and it helped me understand my work better and the biological process I investigated.
>
> S3: I leaned I can write well. Find different resources for information and process this information a manner appropriate for a scientific report.

6.3.2.5. The influence of using the SWIM 2.0 environment on students' writing skills

After the preliminary indication of the influence of the SWIM 1.0 environment on the students' scientific writing skills from the first iteration, I wished to further examine this apparent impact. Although the analysis of the drafts of inquiry-project reports using SWAR allowed me to asses different components of scientific writing and their improvement during the writing process, this method is limited in two main aspects: First, since the inquiry-project is conducted in groups of 2-3 students, the analysis of the reports' drafts is an assessment of the collaborative writing and cannot provide an indication of the individual scientific writing abilities of each student. Second, the writing of the initial drafts of the inquiry-project report is carried out after a learning process with the SWIM environment. This enabled me to compare the "starting point" of the writing process in the intervention and the control classes. However, this analysis does not provide any information about the students' initial scientific writing skills, prior to engaging with the SWIM environment. For these two reasons I developed a pre /post-test to examine possible individual improvement in scientific writing of students in the intervention classes.

The *Scientific Writing Skills Test* (See Appendix 3) is composed of a short (one-page) adapted research article and open-ended questions. The article contains a short introduction, methods and a graphic representation of the results, without a description. The discussion is omitted. The questions section is divided to four parts; each part examines different scientific writing skill: (1) Give a title to each paragraph; (2) Identify the research component (i.e. research question, hypothesis, variables and controls); (3) Describe the results; (4) Write a discussion.

In the second iteration I collected data from six classes who answered the scientific writing skills test (Table 17): Four experimental classes (SWIM classes) and two Control classes.

Table 17. Populations for quantitative test in the second iteration

Class (no. of students)	Experimental/control	SWIM	APL	No. of students who completed pre and post test
Carol's class (n=35)	Experimental	+	-	12
Dana's class (n= 25)	Experimental	+	-	22
Control class 1 (n=24)	Control	-	-	13
Eleanor's class (n=29)	Experimental	+	+	23
Frida's class (n=32)	Experimental	+	+	17
Control class 2 (n=26)	Control	-	+	20

Three of the classes were "APL classes" (i.e. classes which study an elective APL-based curriculum called "The Gene tamers" (Falk et al., 2003). Two of these classes were intervention classes (i.e. "SWIM classes" – Eleanor's and Frida's classes) and one was a control ("Non-SWIM class"). The other three classes were "Non-APL classes" (i.e. classes which do not learn the "Gene tamers" curriculum). Two of the Non-APL classes were intervention classes ("SWIM classes" - Carol's and Dana's classes), and the third was a control class ("Non-SWIM"). Two classes were used as controls – one for the APL classes and one for the Non-APL classes. This was done due to differences between the APL and Non-APL classes. Previous experience showed that APL classes usually have higher academic achievement than the Non-APL classes. This was verified by the pre-test results which showed significant differences between the APL and the Non-APL populations (p values between 0.0013-0.048 for the four components of the SWS questionnaire).

Due to absences from class, some students missed either the pre- or the post-test, thus data are included only from students who took both tests as appears in Table 17. Mean scores and standard deviations are shown in Table 18 and Table 19. For the three Non-APL classes: One-way ANOVA with post-hoc Tukey HSD test found no differences between the three non-APL classes in all four components of the SWS test (Titles, Inquiry, Results description and Discussion) in the pre-test. Significant differences ($p<0.01$) were found between the intervention classes and the control class in three of the components: Titles, Results description and Discussion, in the post-test (Table 18, See Appendix 8 for statistical data).

For the three APL classes: In the pre-test, a significant difference was found between the two intervention classes (Eleanor's and Frida's) in the Inquiry and Results description components. No significant differences were found between the intervention classes and the control class in these two components. No significant differences were found between the three APL classes in the Titles and the Discussion components in the pre-test. In the post-test, a significant difference ($p<0.01$) was found in the Discussion component (Table 19, See Appendix 8 for statistical data).

Table 18. Scientific Writing Skills test average scores by condition and time – Non-APL classes

SWS component		Intervention Carol's class (n=12)	Intervention Dana's class (n=22)	Control class 1 (n=13)
		Mean (SD)	Mean (SD)	Mean (SD)
Titles	Pre-test	2.18 (0.94)	2.19 (0.79)	1.92 (1.02)
	Post-test	2.70 (0.67)	2.56 (0.57)	2.15 (1.04)
Inquiry	Pre-test	2.57 (0.73)	2.22 (1.14)	2.01 (1.27)
	Post-test	2.85 (0.53)	2.40 (1.10)	2.31 (0.96)
Results description	Pre-test	3.00 (0.00)	1.91 (0.81)	2.00 (1.00)
	Post-test	2.83 (0.39)	2.36 (0.85)	1.75 (0.96)
Discussion	Pre-test	1.73 (0.79)	1.75 (0.68)	1.74 (0.54)
	Post-test	2.39 (0.55)	2.19 (0.65)	1.31 (0.66)

Table 19. Scientific Writing Skills test average scores by condition and time – APL classes

SWS component		Intervention Eleanor's class (n=23)	Intervention Frida's class (n=17)	Control class 2 (n=20)
		Mean (SD)	Mean (SD)	Mean (SD)
Titles	Pre-test	2.43 (0.70)	2.33 (0.81)	2.51 (0.74)
	Post-test	2.53 (0.73)	2.41 (0.68)	2.48 (0.74)
Inquiry	Pre-test	2.58 (0.83)	2.14 (1.16)	2.37 (1.09)
	Post-test	2.65 (0.75)	2.88 (0.41)	2.54 (0.90)
Results description	Pre-test	2.34 (0.77)	1.59 (1.17)	2.55 (0.76)
	Post-test	2.26 (0.45)	2.53 (0.62)	2.55 (0.60)
Discussion	Pre-test	2.29 (0.63)	1.96 (0.94)	2.09 (0.63)
	Post-test	2.63 (0.44)	2.84 (0.40)	2.18 (0.68)

A Wilcoxon signed-ranked test showed a significant increase in the pre- versus post-test scores for the four intervention classes for most of the SWS components (Figure 19): In Carol's class there was a significant increase in the Titles, Inquiry and Discussion components (W=12, $p<0.05$; W=2, $p<0.05$; W=6, $p<0.001$, respectively). In Dana's class there was a significant increase in the Titles and the Discussion components (W=24.5, $p<0.01$; W=22, $p<0.01$, respectively). In Eleanor's class there was a significant increase in the Discussion component (W=33, $p<0.05$). In Frida's class there was a significant increase in the Inquiry, Results description and Discussion components (W=0, $p<0.001$; W=15, $p<0.05$; W=9, $p< 0.001$, respectively). There were no significant differences in the two control classes, except a significant decrease in the Discussion component in the non-APL class (W=5, $p<0.05$).

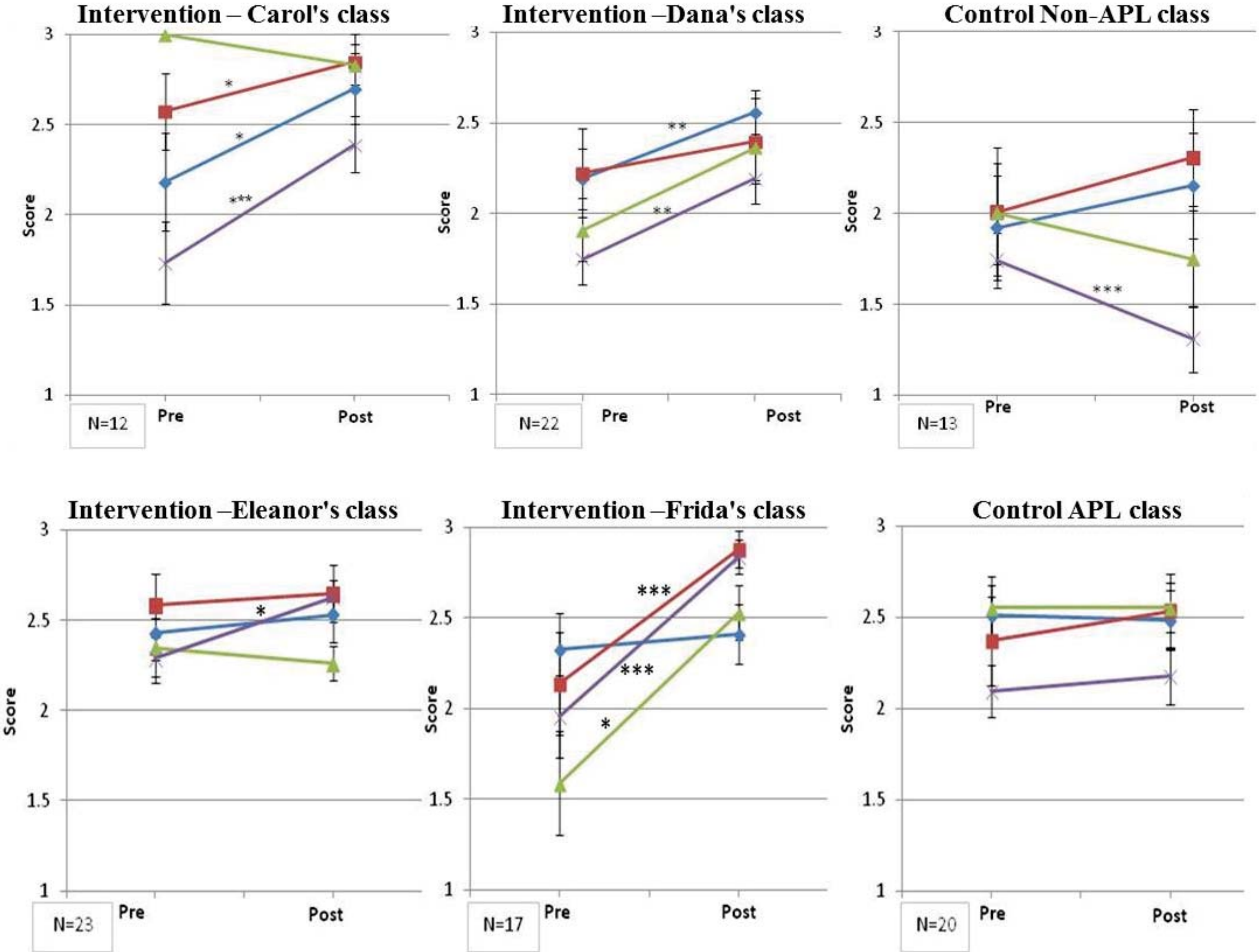

Figure 19. Pre- versus Post-test scores of the scientific writing skills test.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$, **** $p<0.0001$. Bars represent standard errors.

Comparison of the differences between the post- and the pre-test scores (△ scores) (Figure 20) revealed that the intervention classes (i.e. the APL-SWIM and the Non-APL-SWIM classes) improved in all four component of the SWS test (0.2-0.6 points improvement). In contrast, the control classes (i.e. the APL-Non SWIM and Non-APL-Non SWIM classes) showed a smaller improvement or a decline in the test scores (-0.4-0.2 points difference). The most significant improvement was in the Discussion component, for both APL and Non-APL classes who used SWIM 2.0 in the writing process. Results of the Mann-Whitney *U* test for non-parametric analysis showed significant differences between the average delta-scores of SWIM-APL classes and Non-SWIM APL classes (Z-score was 2.344 and the p-value was 0.019) in the Discussion component. The average delta scores of the SWIM Non-APL classes were significantly higher than the control class in the Results description and Discussion sections (Z-score=2.001, p=0.044 and Z-score=3.846, p=0.001, respectively).

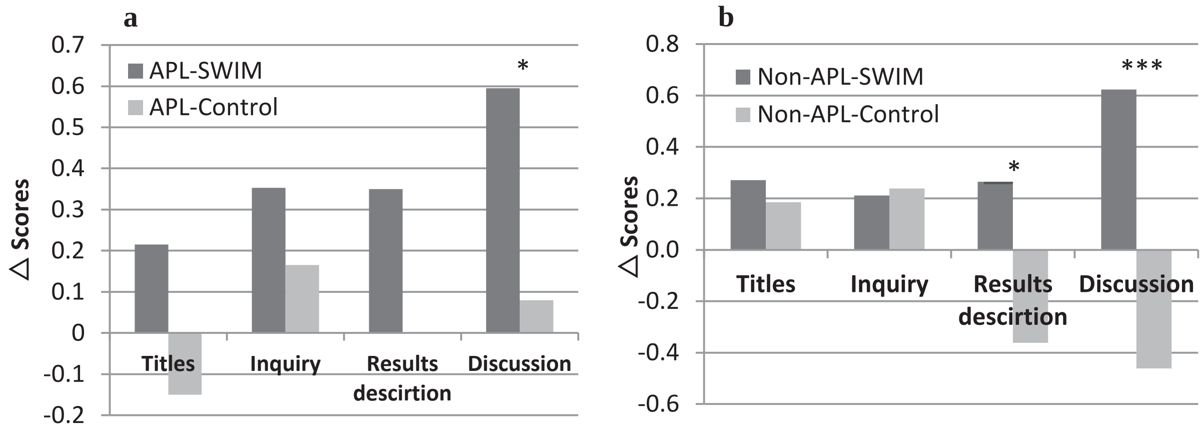

Figure 20. Delta scores of the SWS test of APL (n=40) (a) and Non-APL (n=34) (b) classes using SWIM 2.0 compared to control classes (APL-control, n= 20; Non-APL control, n=13). * p< 0.05, ** p<0.01, ***p<0.001 in A Mann-Whitney U test.

6.3.2.6. Teachers' orientation to writing instruction and feedback

The third question asked in the second iteration was: How does the teachers' orientation the writing process? To answer this question I performed an in-depth analysis of the writing process of the inquiry-project reports focusing on the feedback provided by the teachers and the students' responses to the teachers' feedback. For this aim, each teacher chose one novice-level report and one proficient-level report. Three drafts of each of the four reports were coded and analyzed. The teacher's comments were numbered by one researcher and coded by two researchers. Each comment was coded for the following codes (See Appendix 5. Feedback analysis for the coding scheme): Draft number, Section in the report, Comment type (Content / Genre), Scientific writing component, Comment nature (Statement / Imperative / Question / Revision / Deletion / Insertion), Explanation (Does the teacher provide an explanation to the comment or correction?), Solution (Does the comment or correction give the students the solution to the error?), Implementation (what was the impact of the comment? – No implementation / Partial implementation / Implementation). An example of the coding of representative comments can be found in Appendix 5.

By this analysis I wished to examine questions such as: Does Carol's and Dana's approach to writing instruction is reflected in the way they review their students' writing? Does the fading step of the apprenticeship model can be detected while students proceed from the first to the final draft? Do the teachers consider possible differences between the students as they review their writing and provide feedback? How do the students react to their teacher's feedback? And, is there a certain type of feedback that is more effective than others?

Number of comments:

The total number of comments in the three drafts of the four reports was 593. Overall, Dana gave more comments for the novice, as well as for the proficient reports, than Carol did (Figure 21a). A significant difference ($\chi 2 = 20.96$, $p<0.0001$) was found between the number of comments Carol gave for the novice-level report (n=106) and the number of comments she gave for the proficient-level report (n=49). There was no significant difference in the number of comments between Dana's novice and proficient reports. The number of comments decreased from the first to the third draft in all the reports analyzed (Figure 21b). This decrease was statistically significant for all four reports (Carol Novice - $\chi 2 = 23.17$, $p<0.0001$, Carol proficient - $\chi 2 = 12.53$, $p=0.002$, Dana novice - $\chi 2 = 25.41$, $p<0.0001$ and Dana proficient - $\chi 2 = 14.84$, $p=0.001$).

The decrease in the number of comments from the first to the third draft could be an indication of the fading process.

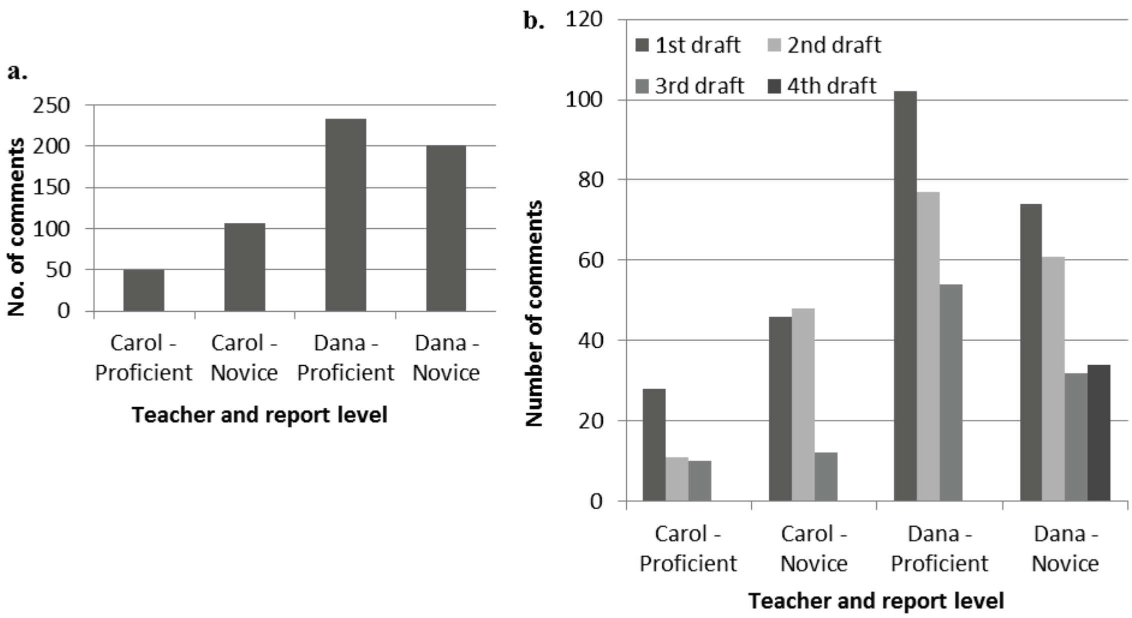

Figure 21. Total number of comments (a) and according to drafts (b) of drafts of inquiry-project reports.

Content / Genre:

The teacher's approach to writing instruction was examined by three criteria: the type of comments (Genre / Content); Explanation provided or not; and Solution provided or not. I expected that a teacher with a genre-oriented approach for writing instruction will give more genre-related comments and will revise more the students' writing, which will result in more comments providing solutions. On the other hand, a teacher with a process-oriented approach for writing instruction will focus more on content and on the writing process, which will be expressed in more explanations provided to the comments and less solution-based comments. I also anticipated that a teacher with a process-oriented approach will consider the students' different writing capabilities and adjust the feedback accordingly.

The comments' analysis shows that 55.5% of Carol's comments were content-related and 44.5% were genre-related. Contrary to Carol, the majority (61%) of Dana's comments were genre-related, and only 39% were content-related (Figure 22a). The difference in the type of comments provided was statistically significant ($\chi 2 = 12.88$, $p<0.0001$). These results were according to our predictions and represent the different approach for writing instruction the two teachers hold. Analysis of the comments' type in the two levels of the inquiry-project report revealed that both teachers gave to the novice level reports more genre-related comments and less content-related comments compared to the proficient level reports (Figure 22b). However, this difference was not statistically significant.

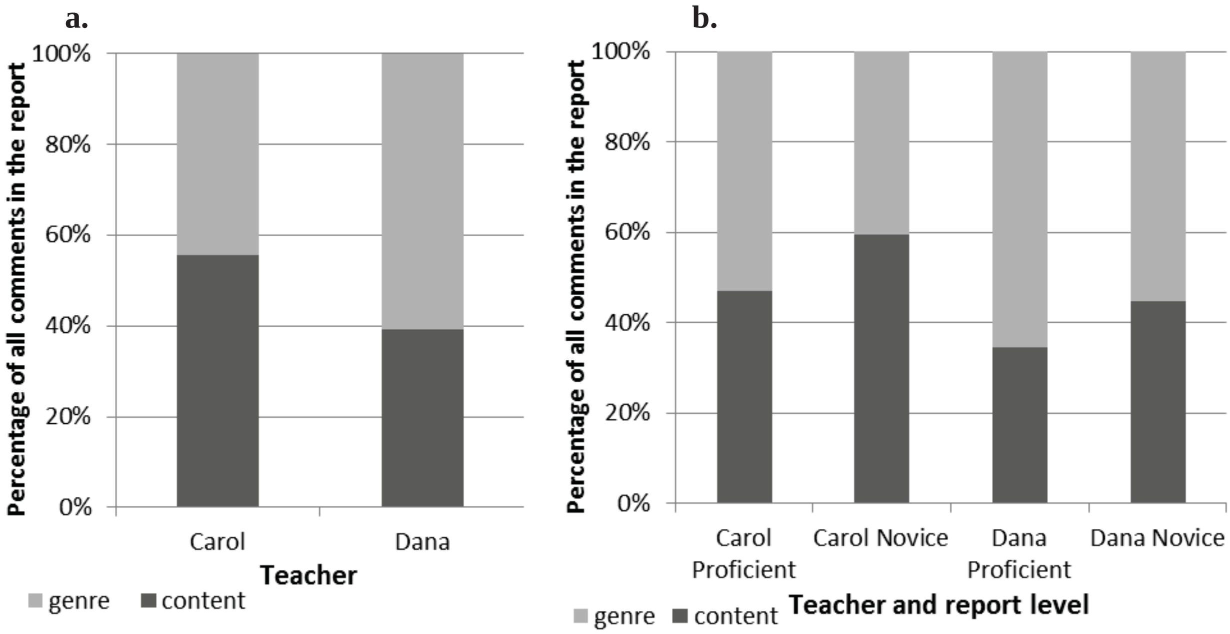

Figure 22. Content / Genre – related comments in the inquiry-project reports according to teacher (a) and report level (b).

Nature of comment (Solutions and Explanations):

When I examined the nature of the comments provided by the two teachers with regards to Solutions and Explanations provided by the teachers as part of the comments, I found significant differences between Carol and Dana. In general, Carol's comments provided fewer solutions than Dana's (38% vs. 65%, respectively, Figure 23a). This difference was significant ($\chi2$ =33.55, $p<0.0001$). Comparison between the two report levels of each teacher showed no significant differences (Figure 23b).

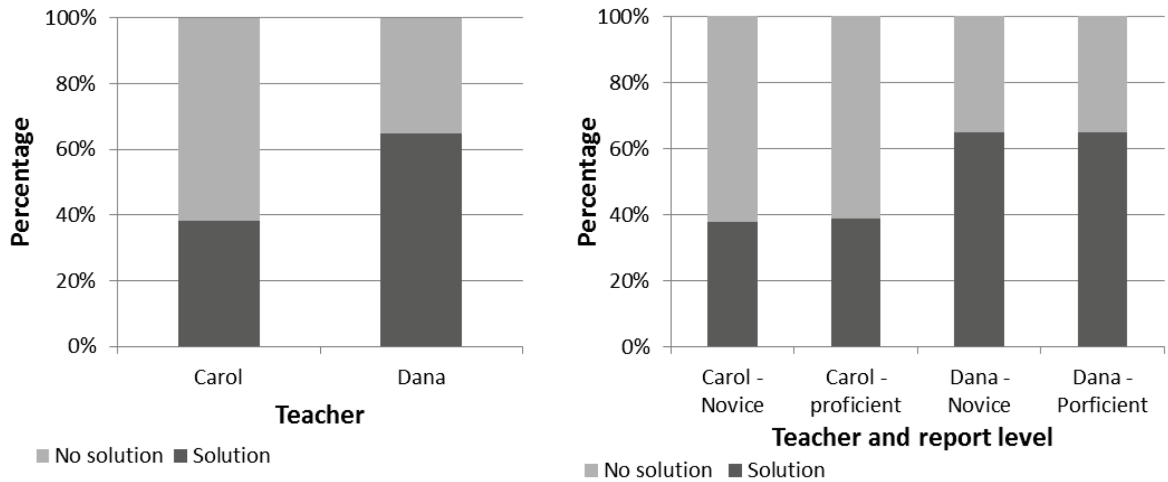

Figure 23. Percentage of comments providing solutions to the errors, according to teacher (a) and report level (b)

Opposite results were found regarding the explanations the teachers added to their comments. Carol provided more explanations than Dana, as 48% of her comments were accompanied by explanations, compared to 31.5% of Dana's comments (Figure 24a, χ2 =9.36, p=0.002).

While no significant difference was found between Dana's two report levels regarding the explanations provided, there was a significant difference between Carol's two report levels (Figure 24b). Carol explained her comments more in the novice level report than in the proficient level report (57% and 29%, respectively, χ2 =10.55, p=0.001).

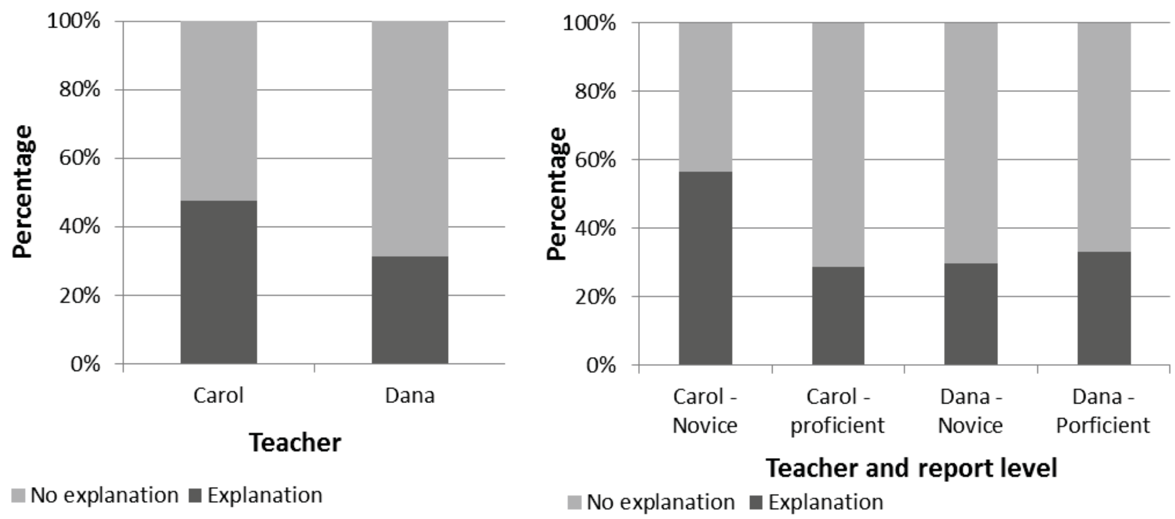

Figure 24. Percentage of comments accompanied by explanations, according to teacher (a) and report level (b).

Implementation:

Next, I wished to explore the impact of the teacher's comments. For this, I examined the implementation of the teachers' comments (i.e. revisions made by the students, following a certain comment, in the succeeding draft).

The results show that Carol's students tended to implement her comments more than Dana's student's (Figure 25a). This difference was significant (χ2 =13.6, p=0.001).

Overall, the teachers' comments were significantly more implemented in the proficient-level reports than in the novice-level reports (Figure 25b, χ2 =12.55, p=0.002 for Carol's reports and χ2 =152.8, p<0.001 for Dana's reports). There was no significant difference between the two proficient-level reports (In both reports 88% of the comments were implemented by the students). On the other hand, in the novice-level report from Carol's class, a significantly higher percent of the comments were implemented (60%), compared to the reports from Dana's class, in which only 31.5% of the comments were implemented by the students (Figure 25b, χ2 =45.22, p<0.001).

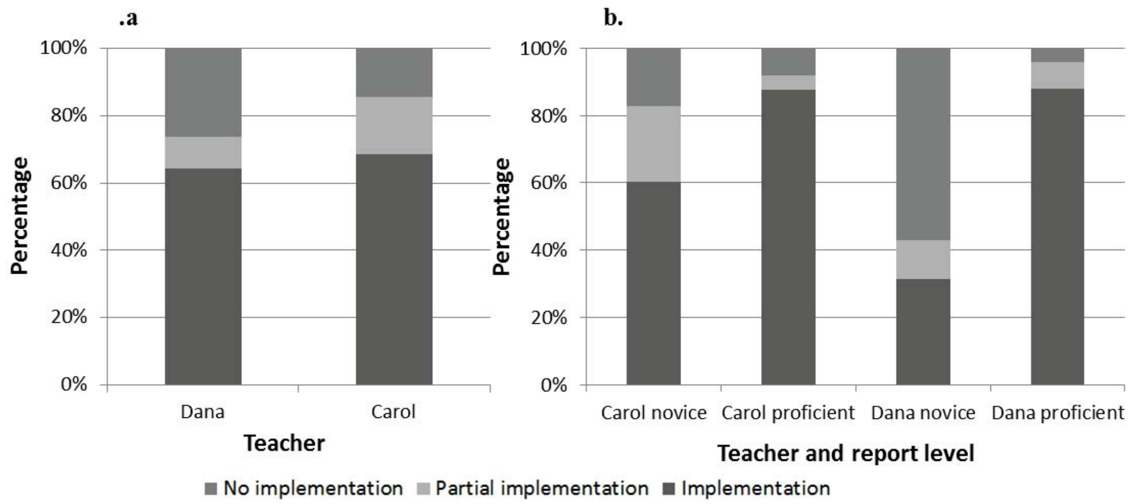

Figure 25. Implementation of the teacher's commnets by the students, according to teacher (a) and report level (b).

A possible explanation for the differences in the implementation of the comments could be the nature of the comment. Therefore, I examined the connection between the implementation of the comments and their nature, regarding solutions and explanations. The results presented in Figure 26 show the distribution of implementation level (Implementation, Partial implementation and No implementation) according to the four types of comment's nature (N.S. N.E. – No Solution, No Explanation; N.S. E. – No Solution, Explanation; S. N.E. – Solution, No explanation; and S. E. – Solution, Explanation). This analysis showed that in all the reports the students implemented comments with explanations more than they implemented comments without explanations. This difference was more profound in the novice-level reports. Because of the small sample size, these differences were not statistically significant. There was no significant difference between the implementation of comments with solutions and those without solutions in all the reports, except in Dana's proficient-level report.

These results could explain the difference in implementation observed between Carol's novice report and Dana's novice report. Since Carol provided more explanations to her comments for the novice report than Dana did (Figure 24b), it is possible that this was the reason that Carol's novice level students implemented more of her comments than Dana's novice-level students.

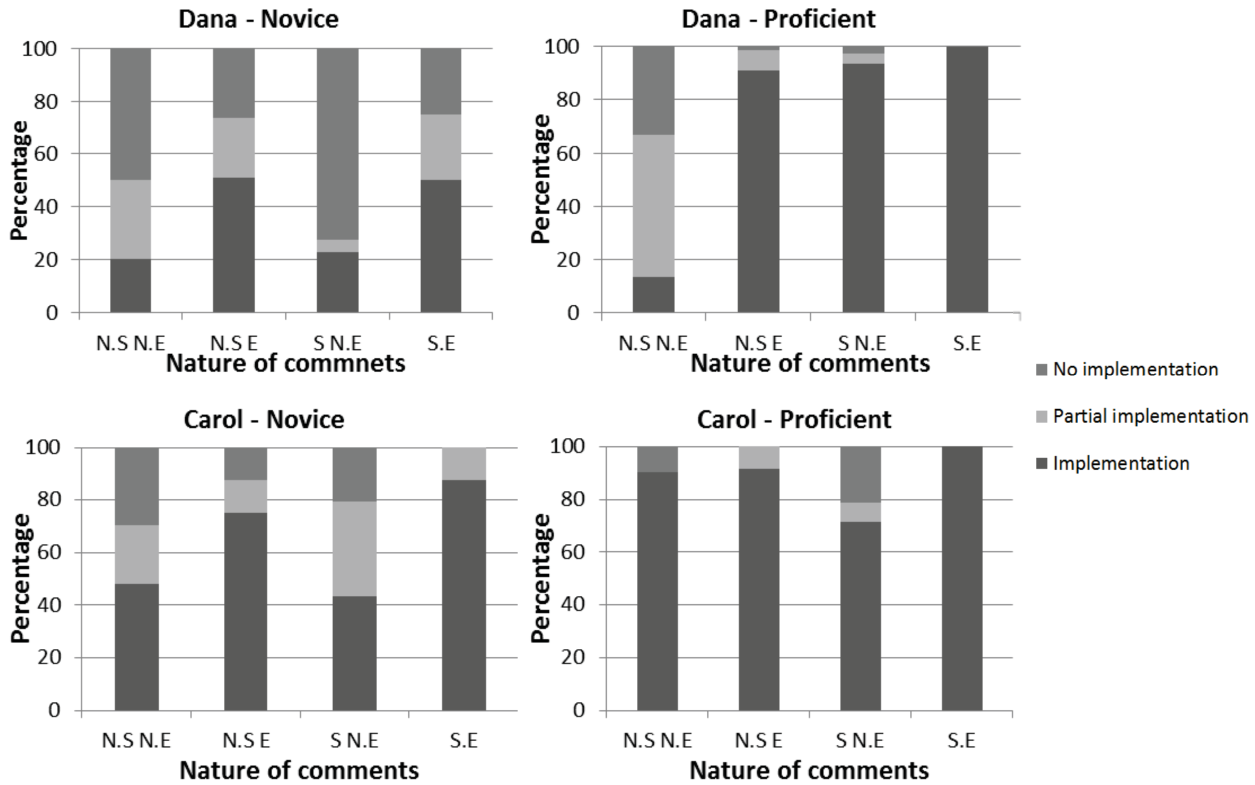

Figure 26. The connection between the comments' nature and their implementation.

6.3.2.7. Writing To Learn: The outcomes of using the SWIM environment on learning, understanding and attitudes of high-school biology majors towards writing in science

Although the possible influence of the learning environment on students' understanding, attitudes and other learning outcomes was not the focus of this research, interesting findings regarding these issues did emerge in the course of the research. I will present the initial results in this chapter.

The research question asked was: How does the SWIM 2.0 environment influence high-school biology majors' attitudes towards writing, understanding of biological concepts and learning processes? The data sources for this research question were: Students' interviews, class observations and students' attitudes questionnaire.

I examined the students' attitudes towards writing in general, writing in science and writing with computers with the Likert-type *attitudes towards writing questionnaire*. This instrument consisted of the following six scales: (1) Writing self-efficacy; (2) Importance of writing; (3) Importance of writing in science; (4) Learning to write in science; (5) Writing to learn with computers; (6) Writing with computers – affective factors.

The questionnaire was distributed in the four intervention classes (Carol's, Dana's, Eleanor's and Frida's classes) prior to the implementation of the SWIM 2.0 environment and following it. Due to absences from class, some students missed either the pre or post-test and so data is included only from students who took both tests, resulting in 70 students who completed both pre- and post- tests, out of 121 students.

The means and the paired t-test results are presented in Table 20. A significant increase was observed in all scales excluding the *Learning to write in science* scale. The results suggest that supporting the writing process of the inquiry-project reports with the SWIM environment improved the students' self-efficacy for writing and their perceptions regarding the importance of writing to their lives. A larger increase was observed in the students' perceptions about the importance of writing in science. A significance increase in the students' attitudes towards writing with computers was also observed in two aspects: using computers for writing promotes learning and increases the students' enjoyment and sense of accomplishment.

Table 20. Students' attitudes towards writing

Scale	Pre (SD)	Post (SD)	t	p
Writing self-efficacy	3.20 (0.43)	3.38 (0.45)	2.19	$p<0.05$
Importance of writing	4.06 (0.55)	4.27 (0.61)	1.74	$p<0.05$
Importance of writing in science	3.33 (0.50)	4.05 (0.60)	7.04	$p<0.00001$
Learning to write in science	3.49 (0.43)	3.56 (0.46)	0.86	n.s
Writing to learn with computers	3.01 (0.41)	3.40 (0.86)	3.22	$p<0.001$
Writing with computers – affective factors	3.08 (0.51)	3.80 (0.77)	6.05	$P<0.00001$

N=70

In addition to the quantitative data, a qualitative analysis of students' group interviews during and after the learning and writing process was conducted. The qualitative analysis revealed three main aspects of learning, shown or referred to by the students: (1) *Meaning making and knowledge building;* (2) *Nature of science and epistemological view*s; (3) *Disciplinary vs. generic writing*. Most of the students addressed at least one of these aspects during the interviews. Representative examples for each aspect are shown and analyzed next.

The role of writing in shaping and facilitating learning has been shown extensively in the past. In this research, the students, in meta-cognitive thinking about the writing process they have completed, were able to identify the effect of writing on their learning. Most of the students stated that writing the report assisted them in making meaning of their biological inquiry. The students recognized the importance of writing the inquiry-project report for achieving better understanding of the biological process they investigated in their project. The students also indicated that writing the report made things clearer and more organized for them.

> Researcher: Ok, in general, do you think writing this inquiry-project report is necessary? What do you think is it important to write this report?
> S1: I think it is
> S2: Me too
> R: Why?
> S1: Because it's more **profound**, you **learn more from it**…
> R: What do you learn from it?
> S1: I have learned about all sorts of processes, more deeply
> S2: Yes, the biological basis, what exactly is going on there…
> S1: … It gives you a feeling you see everything in front of your eyes, and you have your research subject, and you see how **everything comes together**…
> R: So writing the report connected everything for you?
> S1: Yes, you **see the connections**, how really everything is built with connections of one thing to the other.
> S2: I think also that when you write it yourself and it's not just things from the internet, then you can **explain your work better** and you can **understand it better**
> S1: I agree. When you do it from start to end, and it's not only theoretical, you do the experiments and then write about it yourself, it also **goes into your head better**.
> …
> S3: I think that writing somehow **organizes things in your head**… so I think it's important to write this report. And when you write you more, like, **make conclusions**, you **learn more and understand better the things you write**.
> S4: I personally, agree very much with that we need to explore and discover on our own. The writing is a little annoying but it does help you **understand all your results better**, because you understand why you got each thing"

Several groups of students referred to writing the report as a problem-solving process. This approach was evident mostly when the students received unexpected results in their investigation and had to find explanations for them.

> R: Do you think you should write this inquiry-project report?
> S5: Yes, we should. Otherwise we **wouldn't have come to these conclusions**.
> S6: Yes, we have to write it. **We wouldn't be able to draw conclusions from our project without the written report.**
> R: Can you explain?
> S5: We had the results, we made the calculations, but if we hadn't summarized everything in writing, we would never have noticed this thing. We looked at the results and we said: we failed, everything is ruined, the results don't make sense, something is wrong… but, when you look here in the final [calculation] in percentage, then you see … it does make sense.

S6: **writing things down and trying to explain it made us look for answers and understand what we did better,** now all of us know our project better, we all know what we did, what we got, and what does it mean".

This student summarized the influence of writing on learning very clearly:

S9: I think that when we were writing we had **to solve a lot of problems** of things we didn't exactly understand, and only when we wrote we had to open it and really get to the bottoms of things.
R: Do you have an example?
S9: It's like **understanding better the biological processes** and what exactly happening and how, so it will be **detailed, correct and accurate.**
R: And you think the writing process demands it?
S9: Yes. It [the writing] clarifies things and organizes them. So, even if I knew it before, now I… I make some kind of order and **organize it in a way that helps me understand**.

The second aspect that emerged from the students' interviews was the impact of writing the inquiry-project report process on the students' *nature of science* views and scientific epistemology issues. Numerous students indicated that writing the inquiry-project report gave them a sense of authenticity in their project. They felt that finally they are doing (and writing) 'real science', in regard to the experiments as well as to writing the report. This aspect of authenticity can be seen in the following three quotes:

R: Why do you think you are asked to write this kind of report?
S10: Ahh… it's obvious … this is a real report, it's really an inquiry-report…
S11: Yes, I think it gives us a **taste of real science** after we learn biology and science a lot of years.

R: What was difficult for you?
S12: It was really annoying; our experiments didn't work, again, and again and again. We tried and it didn't work. It was discouraging.
R: That's frustrating…
S12: But look, this is how even the **greatest scientists are doing**. They never get it the first time.
S13: Actually, I think they **don't know what they are going to get** most of the time, right?
R: That's right

R: In your opinion, does the inquiry-project report is similar to one of the types of scientific texts you came across during your studies? To which one is it more similar – textbook, popular article or research article?
S11: I think research article. Because we make progress and understand things that others may have understood less.
R: What do you think is similar [to research article]?

S11: The whole process of… if it's to start from earlier articles or doing preliminary experiments and then decide what to do in our experiment, … and finally tell others what we have found.

Beside the writing process itself, I found evidence that the SWIM environment also influenced the students' epistemology regarding scientific writing. One example for this is the order in which students write their report. We embedded in the SWIM environment an epistemological principle of scientific writing which is that scientific writing is not conducted chronologically according to the sections of the report (or the scientific article), but in a way that assists the scientists build knowledge and communicate it to the scientific community. In the SWIM environment, the students are instructed to begin writing their reports from the Results and the Methods sections and only then proceed to the Discussion and the Introduction sections, emulating the writing process of scientists. The students noticed this epistemological principle and acknowledged its value. This can be seen in the following quotes:

R: When did you write the introduction?
S1: We wrote the methods first and the Introduction last. This is how Carol told us and how it appears in the site [SWIM].
R: And what do you think of that, is it right to write the introduction last?
S2: Yes, I think so
S1: I think so too, because all the information is already written in the report and the introduction is sort of a summary of that. So [this way] you write only what you need.

S6: We tried to write two pages of the introduction first…
R: And how was it?
S5: It was difficult. What's there [in the introduction] is information that you give throughout the whole report and then you feel you repeat yourself. And, also the introduction is not connected to the experiments… so you don't know exactly what to write there.
R: So, in your opinion, you should write the introduction in the beginning [of the writing process]?
S6: No, no, in the end…

The third aspect I wish to address regarding writing as a learning tool is the aspect of the disciplinary nature of writing versus a generic view of writing. Throughout this research I argue that writing is socially-situated and each discipline has its own unique language conventions, format and structure which represent the way of thinking and knowing in that discipline. However, I also argue that some generic writing strategies such as planning, drafting and revising should be taught explicitly.

In the group interviews, both views of scientific writing were present. Some students indicated that learning to write an inquiry-project report in biology helped them write better reports in other subjects and that they feel they can transfer the tools they have learned to other disciplines.

> S5: This report did give me tools. In my second major, which is economic, I also had an inquiry project, so after I did this report [in Biology]… and we really put efforts in it and the teacher guided us in the process, so that's it, in economic it was much easier, I understood what I have to do, how to write the report. It gave me tools, means.
> R: That's nice. What kind of tools did it give you?
> S5: All sorts of things. Like, writing the introduction and the discussion, finding resources…
> S6: How to present your point clearly
> S5: Also, yes, how to present what I want to say in the report and how to base this on our findings, things like this…

Other students pointed out to the unique characteristics of scientific writing, as opposed to writing in composition or language classes.

> S9: When we started to write I thought I should write the report because I think I write really well. But then I noticed it doesn't really help here, that this inquiry report is not composition, and… after each nice conjunction I wrote I saw a red line of the teacher… So I understood it's better to go here according to the biology rules and tools, the biological writing, and not according to the composition writing. Then we wrote it together the three of us and it worked.

Summary of Iteration II

Findings:

- A positive influence on scientific writing skills and writing strategies was found in the intervention classes compared to the control classes. The most significant improvement was in writing the discussion component of the Scientific Writing Test.
- Both teachers implemented the genre-process pedagogy. However, differences in implementations between the two teachers were observed. These differences reflected the teachers' approach to writing instruction. Carol showed a more process-oriented approach, while Dana showed more genre-oriented approach.
- Both teachers and their students adopted the technology with no major problems. Nevertheless, the teachers and their students indicated that a short period of practice

was needed for achieving full control in operating the environment and some interface modifications are required to increase usability.

- Carol's process-oriented approach to writing instruction and Dana's genre-oriented approach to writing instruction were reflected in the feedback they provided for the inquiry-project reports. An element of the fading step in the apprenticeship model was observed, as the number of comments decreased from the first to the third draft. Both teachers provided feedback according to their students' scientific writing capabilities in some aspects, although this was more prominent in Carol's feedback. The teachers' comments were implemented more in the proficient-level reports than in the novice-level report. Explanations accompanying the comments increased their implementation, mostly in the novice-level reports.
- Following the implementation of the SWIM 2.0 environment the students' attitudes towards writing in general, writing in science and writing with computers, have improved, including the students' self-efficacy for writing and their perceptions of the importance of writing.
- Preliminary qualitative results suggest that the students felt the writing process with SWIM 2.0 promoted their understanding and meaning making of their investigations and biological concepts related to their project. In addition, the students appeared to gained epistemological knowledge about scientific writing and the scientific inquiry process.

Conclusions:

- The SWIM environment can be implemented by teachers with different approaches to writing instruction. However, the integrated genre-process pedagogy should be emphasized to the teachers to create a more complete and effective implementation.
- Some interface modifications are needed to increase usability of the SWIM 2.0 environment.
- Matching the feedback to the students' capabilities and writing strategies can improve the writing process, especially among novice-level writers. It is recommended to provide explanations to the feedback, since novice-level writers tend to implement an explained feedback more than an unexplained feedback. A constructed feedback tool can be added to the SWIM 2.0 environment to improve the teacher's feedback.

6.3.3. Iteration 3 – SWIM 3.0

6.3.3.1. Overview of Iteration 3 and research questions

In the third iteration, the third version of the SWIM environment (SWIM 3.0) was implemented. The SWIM 3.0 can be accesses in the following link, with the user name: **macam2016**, and the password: **macam2016**:
https://st-moodle.weizmann.ac.il/course/view.php?id=168

I revised and redesigned the SWIM 2.0 environment based on the conclusions and insights from the second iteration. Only minor modifications were introduced to the SWIM 3.0 environment to increase its usability. Overall, the main question that was asked in the third iteration was:

1. How was the SWIM 3.0 environment adopted and implemented in a large-scale?

6.3.3.2. Revision of SWIM 2.0

Following the second enactment of the SWIM environment (SWIM 2.0) I introduced a few minor modifications to the environment. All the revisions are summarized In **Table 21** (see Table 10 for the SWIM 1.0 description and Table 14 for the SWIM 2.0 revisions). In SWIM 3.0 all the design principles remained the same as in SWIM 2.0. Modifications were made in the interface of the SWIM 2.0 environment to increase usability: in the homepage, all learning units were introduced into one learning unit - "*Learning to write an inquiry-project report*" (Figure 27), which was redesigned to include all learning exercises (Figure 28). In addition, "*My inquiry-project report"* unit was rearranged to emphasize the planning, drafting and revising stages (Figure 29). In addition, constructed automated rubrics were introduced for each section of the report to improve the teacher's feedback. To assist the teachers to optimize the implementation of the SWIM environment, a teaching sequence planning table was added and the teacher's guide was revised to emphasize the genre-process pedagogy and the rational of the SWIM environment along with practical recommendations for implementation.

Figure 27. The SWIM 3.0 environment

Figure 28."Learning to write an inquiry-project report" unit.

Figure 29. A part of the "My inquiry-project report" unit.

Table 21. Revisions in the SWIM 2.0 environment following the second iteration

Design principles	SWIM 2.0 (Revisions from SWIM 1.0)	SWIM 3.0 (Revisions from SWIM 1.0)
DP1- Construction of genre knowledge by analyzing APL as a model	Six APL-based exercises. • *Good intro – Bad intro* exercise was revised • *Getting to know the introduction* exercise was revised	No revisions
DP2 - Interactive, inquiry-based learning	• All exercises are inquiry-based • All exercises are interactive	No revisions
DP3 - Exercises address specific skills, processes and knowledge	• *Merging resources* exercise was added • *Data presentation* exercise revised • Collaborative writing option was added	No revisions
DP4 - Process-oriented instruction of scientific writing	• The learning unit: *My inquiry-project report* was added, including: - Scaffolds for planning - Checklists for revising - On-line feedback from the teacher - Writing strategy - personality quiz - Collaborative writing	• *My inquiry-project report* unit was rearranged to emphasize the planning, drafting and revising stages • Constructed automated rubrics for each section were added.
DP5 - Flexibility in use	• No revisions	• The interface of the SWIM environment was modified to increase usability. • A teaching sequence planning table was added to support teachers.
DP6 - Technology enhanced learning	• Web-based LMS platform (Moodle) • All exercises with automated feedback	No revisions

6.3.3.3. Implementation of SWIM 3.0 environment

During the 2015-2016 school-year the SWIM 3.0 was implemented in 41 classes (14 11th grade classes and 27 12th grade classes). In those classes, 905 biology majors (11th and 12th grades) learned how to write their inquiry-project reports using the SWIM 3.0 environment. A separate course was created for each class. In the beginning of the year an on-line training workshop for teachers was given. Eighty teachers participated in this on-line workshop from the 170 teachers who registered to the "SWIM 3.0 teachers' course". This course is a SWIM 3.0 learning environment with additional resources and supportive materials for teachers, such as instructions for beginners and a forum. This course also served as a "sandbox" for the teachers to experience the use of the SWIM environment and practice before implementing it in their classes. In addition to this teachers' training course, one regional teachers training workshop was given this year. Due to several limitations, no additional training was given to the teachers who registered their classes to the SWIM 3.0 environment.

It is important to note that during the 2015-2016 school-year the inquiry-project was not a part of the external matriculation exam and was examined internally by the teachers, due to changes in the matriculation exams in the Ministry of Education.

6.4. Phase IV – Reflection

6.4.1. Evaluation of SWIM 3.0

Implementation in 12th grade classes:

The activity completion report embedded in the Moodle environment of SWIM 3.0 was used to evaluate the implementation of SWIM 3.0. I defined that a component in the environment was completed if more than 50% of the students in the class completed it. The analysis of the activity completion report showed that the total average usage rate (i.e. the average number of completed components / the number of components in the SWIM 3.0 environment X 100) was 20%. The average usage rate for the genre-oriented components (i.e. the components in the "Learning to write" unit) was 25% and for the process-oriented components (i.e. the components in the "My inquiry-project report" unit") was 16%.

Eleven teachers showed a more genre-oriented approach (i.e. above 25% usage rate in the genre-oriented components), while 5 teachers showed a more process-oriented approach (i.e. above 25% usage rate in the process-oriented components). Only three teachers showed an integrated genre-process approach (i.e. above 25% in both genre and process components). The other 13 teachers' approach could not be determined, as their usage rate in both genre-oriented and process-oriented components was below 25%.

The implementation rates of the genre-oriented components and the process-oriented components in the SWIM 3.0 environment are presented in Figure 30 and Figure 31 (respectively). For the genre-oriented components, the results show that the exercises that were chosen by more teachers were: *Introduction to scientific communication* (37%), the three exercises in the Methods section (30%-37%) and the *Data presentation* exercise (30%). For the process-oriented components, the results show that 33% of the 12th grade classes completed three of the planning scaffolds (the Results, the Methods and the Introduction). 15-19% of the classes submitted drafts of the sections of the inquiry-project report via the SWIM 3.0. Only few classes (4-11%) used the other process-oriented components (Checklists for revision and the scaffolds for planning, drafting and revising the discussion section).

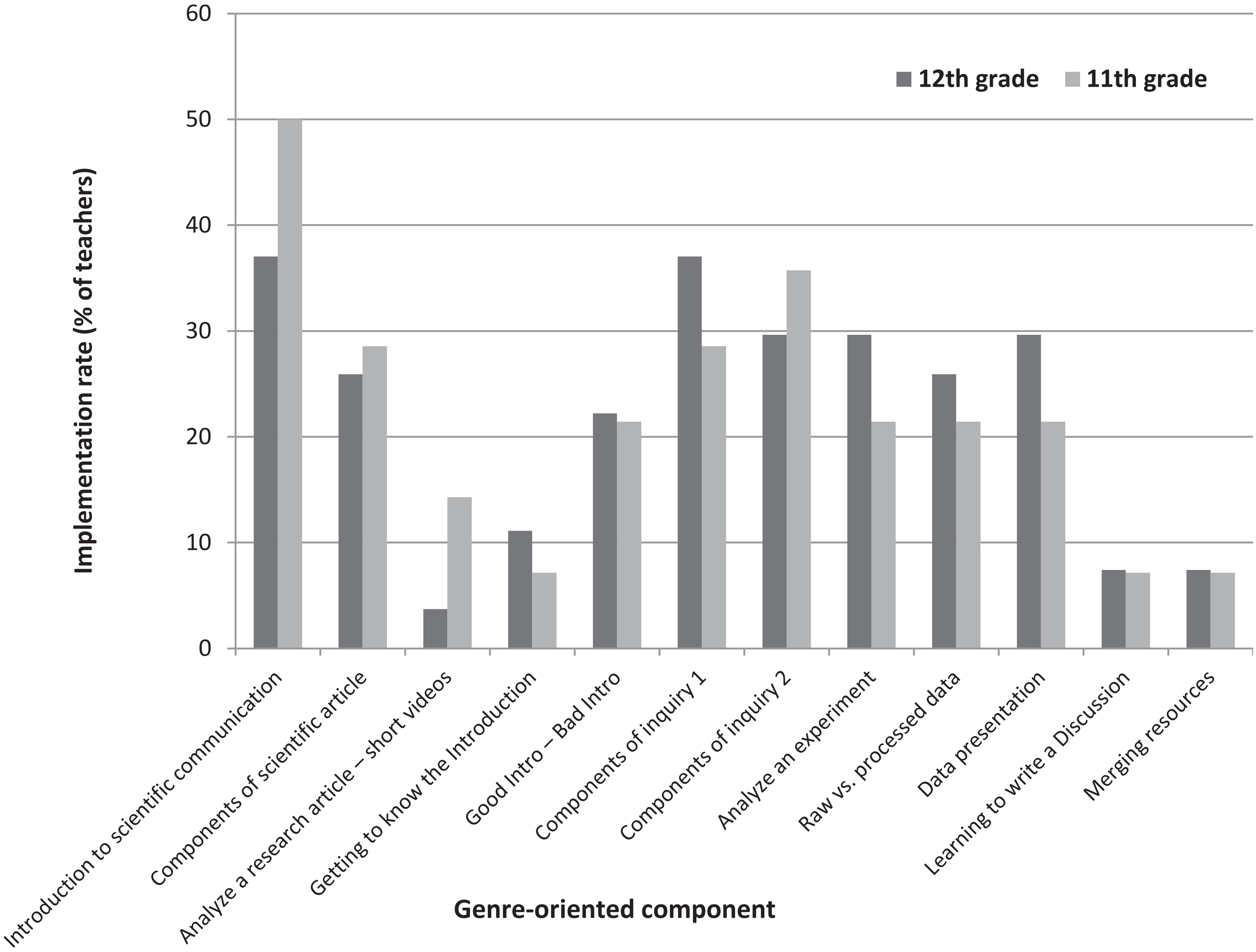

Figure 30. Implementation rate of the genre-oriented components in the SWIM 3.0 environment in 12th grade (N=27) and 11th grade (N=14) classes.

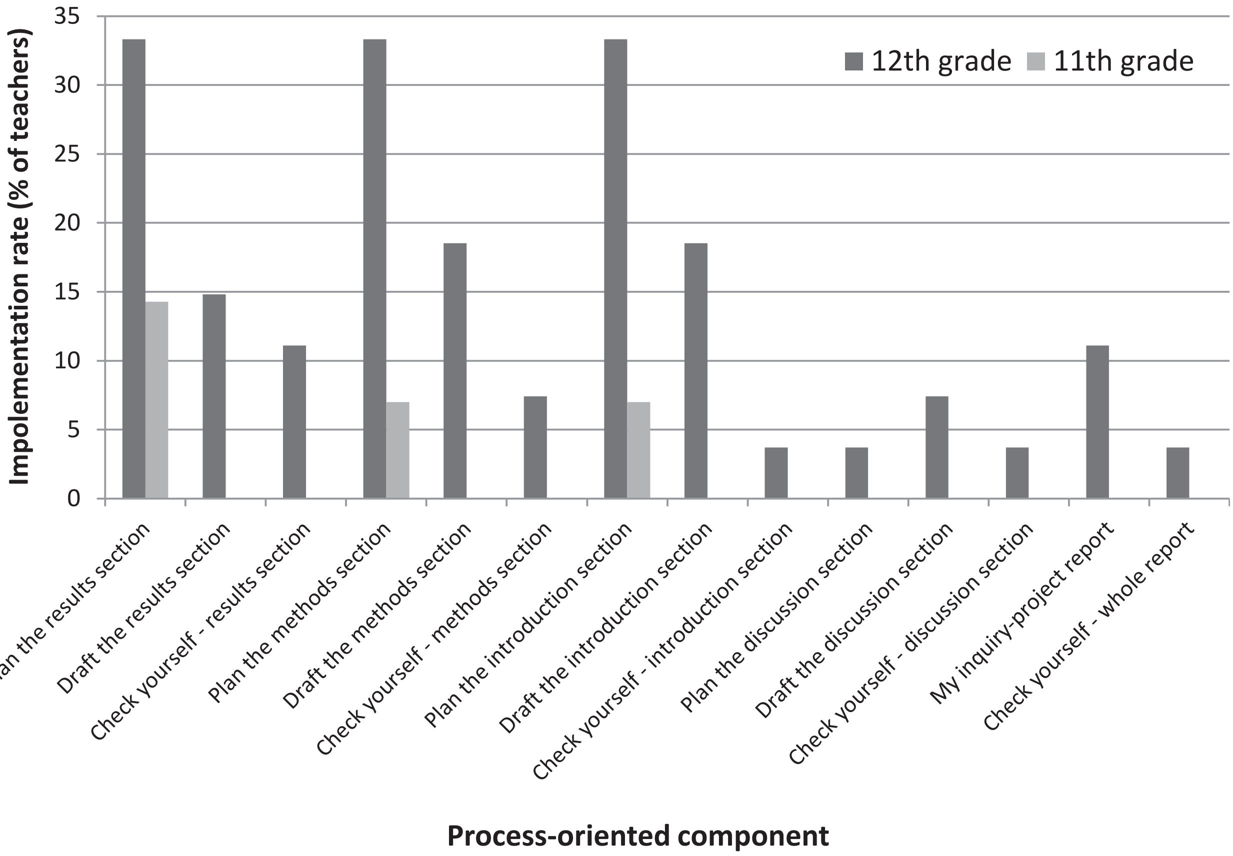

Figure 31. Implementation rate of the process-oriented components in the SWIM 3.0 environment in 12th grade (N=27) and 11th grade (N=14) classes..

Implementation in 11th grade classes:

In the 14 classes that implemented the SWIM 3.0 environment, the total average usage rate was 15%. The average usage rate for the genre-oriented components was 28% and for the process-oriented components was 4%. Five teachers showed a more genre-oriented approach while none of the teachers showed a more process-oriented approach.

The implementation rates of the genre-oriented components were similar to those of the 12th graders (Figure 30). Fifty percent of the teachers implemented the *Introduction to scientific communication* exercise in their classes, 21-36% implemented the three methods exercises, 29% implemented the *Components of scientific writing* exercise and 21% implemented the Good intro – bad intro, Raw vs. processed data and Data presentation exercises.

Contrary to the 12th grade classes, most of the 11th grade classes did not complete the process-oriented components (Figure 31). Two classes completed the planning of the results section, and one class completed the planning of the methods and the introduction sections. These findings are not surprising as most of the 11th grade classes did not complete the inquiry-project in the 11th grade and will write the reports the following year.

In addition to the evaluation of the implementation of SWIM 3.0, the other elements of the fourth phase of the study are reflection of the overall design process to produce final design principles and recommendations for future research. These elements are part of the discussion chapter that follows.

Summary of Iteration III

Findings:

- The SWIM 3.0 environment was implemented in 41 11th and 12th grade classes. In those classes the average implementation rates were 20% in 12th geared and 15% in 11th grade.
- The average usage rates for the genre-oriented components were 25% for 12th grade and 28% for 11th grade.
- The average usage rates for the process-oriented components were 16% for 12th grade and 4% for 11th grade.
- Ten 12th grade teachers showed a more genre-oriented approach, while 5 teachers showed a more process-oriented approach. Five teachers showed a more genre-oriented approach while none of the teachers showed a more process-oriented approach

Conclusions:

- The implementation rate of the SWIM 3.0 environment was relatively low. This is probably due to the fact that the inquiry-project was no longer externally examined and because no sufficient training and support was given to the teachers who implemented it.
- The profile of the usage rates suggests that the genre-oriented components were more implemented than the process-oriented components.
- Teachers tend to show genre-oriented approach or process-oriented approach, but not an integrated genre-process approach. This indicated that the training for SWIM should consider the teachers' approach and emphasize the integration of the two approaches in the environment.

7. Discussion

In this chapter, I discuss the following: (i) I first draw conclusions based on the data presented in the previous chapter, regarding learning to write in high-school biology, (ii) I then present and discuss the SWIM instructional model, as reflected from the findings in this research and in light of existing models of writing instruction, (iii) Next, I refer to the limitations of this research, and (iv) discuss its implications and suggest directions for further research.

Learning to write in high-school biology

In this study I designed and examined a teaching and learning environment for advancing scientific writing skills of high-school biology majors. This research explored, for the first time, how Adapted Primary Literature (APL) can serve as an apprenticeship genre for socialization of students into the scientific discourse community and how technology-based design can support the writing process and the development of students' scientific writing skills.

The high-level conjecture of the SWIM-TELE was that inquiry-based writing in high-school biology requires genre knowledge and writing process strategies that can be gained by using APL as an apprenticeship genre (Figure 32). The design conjecture was that by exploiting elements embedded in the environment, instructors will implement integrated genre-process pedagogy by sociocognitive apprenticeship using APL. The theoretical conjecture was that students' inquiry-based writing skills and strategies will improve due to this apprenticeship processes. I also hypothesized that the students will gain self-efficacy and appreciation for writing in science and a better understanding of the biological processes they investigated.

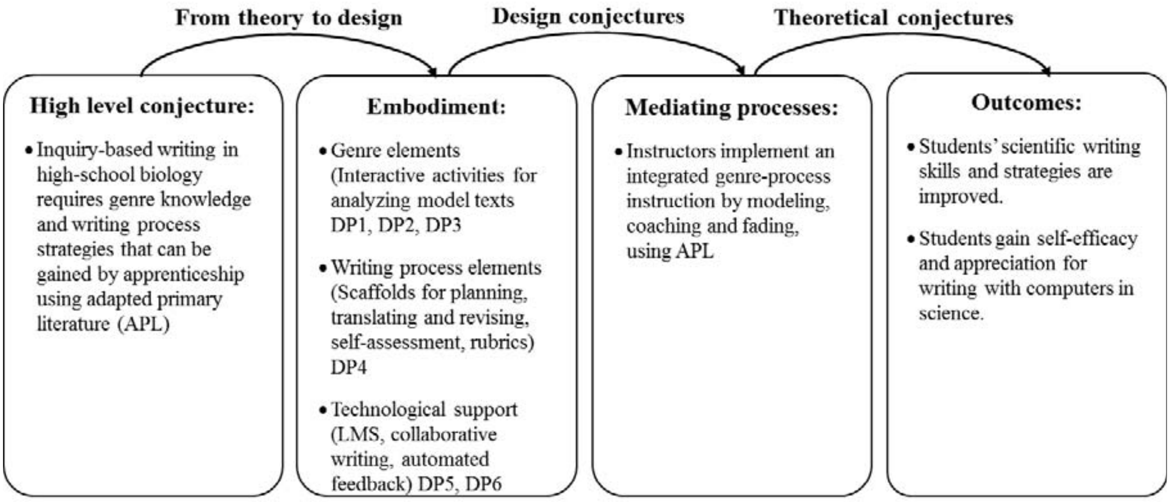

Figure 32. Conjectures mapping of the SWIM environment

The research findings indicate that in classes in which the SWIM-TELE was implemented, the teachers applied the genre-process pedagogy by sociocognitive apprenticeship process using the APL-based elements and process-based features embedded in the environment for this process. The results also show that following the implementation of the SWIM environment the students' scientific writing skills and writing strategies had improved. The students also gained appreciation for writing in science and self-efficacy for writing, as well as a better understanding of the biological concepts underlying their inquiry-project.

As both the design and the theoretical conjectures were verified, I argue that: a) the SWIM teaching and learning environment with its underlying genre (APL-based) and process elements together with the technological support, enabled the teachers to apprentice their students by modeling, coaching and fading using APL as an apprenticeship genre, b) Eventually, these processes enabled students to develop scientific writing skills, including genre knowledge and writing strategies as well as gaining self-efficacy for writing in science and appreciation for the important roles writing holds in science.

In the following sections I will discuss the two main arguments derived from the findings of this research: APL can be used as an apprenticeship genre for instructing writing to high-school biology students; and this instruction should be based on an integrated genre-process approach.

APL as an apprenticeship genre

The initial hypothesis underlying the design of the SWIM environment was that an APL article can be used as a model for adequate scientific writing and therefore can promote the scientific writing skills of high-school students who study using APL articles. However, the results from the first phase of the study showed that an APL-based curriculum did not improve the students' scientific writing skills (Figure 7 and Figure 8). A possible explanation for this observation is that the teachers who taught the APL-based curriculum focused mainly on its content rather than on its genre, and only occasionally pointed out the similarities to the writing of the inquiry-project report. This suggests that reading an APL article is not sufficient for advancing the scientific writing skills of high-school biology majors. Although there is a strong relation between reading and writing (Fitzgerald & Shanahan, 2000; Olson, 2007), the gap between reading an APL article and writing an inquiry-project report is probably too large. I argue that this gap can be bridged by active engagement of the students with the text's characteristics (Rijlaarsdam et al., 2006) and by a sociocognitive apprenticeship process led by the teacher who will emphasize the genre rather than the content of the APL. This approach is reflected in the genre-based pedagogy of the SWIM environment, implemented in the first iteration (i.e. SWIM 1.0).

The genre-based pedagogy, which offers students explicit and systematic explanations of the ways language functions in social contexts (Hyland, 2003), was previously shown to be an effective writing instruction strategy in numerous studies (Cope & Kalantzis, 2014), including the recent meta-analyses of writing instruction (Graham et al., 2015; Graham & Perin, 2007a). The basis of the genre-based pedagogy of the SWIM environment is the concept of APL as an apprenticeship genre. According to Carter et al. (2007), apprenticeship genre is a genre that can encourage socialization into disciplinary communities and therefore it is considered to be a way of doing by which students participate in the ways of knowing in a certain community (Carter, 2007). Drawing from Carter's (2007) definition of the lab report as an apprenticeship genre that encourages socialization into the scientific community, I hypothesized that APL can serve as an apprenticeship genre for introducing high-school biology students into the norms and practices of scientific writing among the scientific community. This hypothesis elaborates on Carter's definition of apprenticeship genre in that it considers the apprenticeship genre as a genre that enables the instructor to apprentice his or her students into the disciplinary community.

The findings from the three enactments of the SWIM environment showed that my hypothesis was corroborated. The teachers implemented the genre-based pedagogy of the SWIM environment by an apprenticeship process. Following this process, the students' scientific writing abilities have improved in specific components of scientific writing (See

Figure 10, Figure 11, Figure 12 and Figure 13). This suggests that APL can be used as an apprenticeship genre which enables the teacher to apprentice the students to the norms and practices of scientific writing.

As was described in the literature review, the APL retains the authentic characteristics of PSL (i.e. the IMRaD structure, argumentative nature of the text and its linguistic features) and serves as a model for authentic scientific communication and reasoning (Ariely & Yarden, Submitted; Yarden, 2009; Yarden et al., 2001). This research shows for the first time that APL can be used for instructing scientific writing. By exploiting the APL as an apprenticeship genre, the teachers advance their students awareness of the language of the discipline and thus facilitate the enculturation of their students into the scientific discourse community.

An integrated genre-process approach to scientific writing instruction

The results of the first enactment of the SWIM 1.0 environment indicated that the apprenticeship process was not as effective as it could be. This may be due to a possible disconnection between the genre knowledge gained and the students' writing process of their own inquiry-project report.

Based on these findings, the conjectures of SWIM were amended and the SWIM environment was revised, integrating a process-oriented approach to create a genre-process pedagogy (Applebee & Langer, 2013; Harris & Graham, 1992; Pritchard & Honeycutt, 2006). The Genre-process pedagogy combines the advantages of the genre-oriented pedagogy along with those of the process-oriented pedagogy (i.e. strategy instruction for planning, drafting and revising, teaching of self-regulation procedures, encourage collaboration and give extensive feedback to multiple drafts to facilitate writing; Badger & White, 2000). The genre-process pedagogy was implemented in the SWIM 2.0 environment, which integrated process elements (e.g. scaffolds for planning, drafting and revising, self-assessment tools, feedback possibilities and collaboration) and enacted in the second iteration.

The findings from the second iteration indicated that the SWIM environment had a positive influence on the students' scientific writing skills and writing strategies (Figure 19 and Figure 20). I also found that following the implementation of the SWIM environment the students' attitudes towards writing in general, writing in science and writing with computers, have improved, mainly, the students' self-efficacy for writing and their perceptions of the importance of writing. Furthermore, the writing process with SWIM promoted students' understanding and meaning making of their investigations and of biological concepts related to their project. Also, the students gained epistemological knowledge about scientific writing and the scientific inquiry process.

The findings from the second iteration also revealed that the teachers implemented the genre-process pedagogy by sociocognitive apprenticeship process using the APL-based elements and process-based features embedded in the environment for this process. However, differences in the implementations between the two teachers were observed. These differences reflected the teachers' approach to writing instruction. While one teacher showed a more process-oriented approach, the other teacher showed a more genre-oriented approach. The teachers' approach was also reflected in the feedback they provided for drafts of the inquiry-project reports. The findings indicated that both teachers provided feedback according to their students' scientific writing capabilities in some aspects, although this was more prominent in the feedback of the process-oriented teacher. In addition, the teachers' comments were implemented more in the proficient-level reports than in the novice-level reports and explanations that accompanied the comments led to an increase in the implementation of the comments, mostly in the novice-level reports.

These findings indicate that the SWIM environment can be implemented by teachers who hold different approaches to writing instruction. However, the integrated genre-process pedagogy should be emphasized to the teachers to create a more complete and effective implementation. Furthermore, matching the feedback to the student capabilities and writing strategies can improve the writing process, especially among novice-level writers, and it is recommended to provide explanations to the feedback, since novice-level writers tend to implement an explained feedback more than an unexplained feedback. These findings corroborated and elaborated the findings of Beach and Freidrich's review (2006), who showed that effective feedback helps students to understand the rhetorical demands of writing tasks and helps them develop the skill of self-evaluation. Also, students prefer feedback that explains problems and suggests specific improvements, and they are more successful in using such feedback in revising (Beach & Friedrich, 2006).

In the third iteration, I examined how the SWIM 3.0 environment was adopted and implemented in a large-scale. Following the results from the second iteration, my conjectures remained the same while minor modifications were introduced to the SWIM environment to increase its usability for optimization of implementation. In the third iteration, 41 teachers implemented voluntarily the SWIM environment in their classes. This large-scale acceptance of SWIM 3.0 suggests that this environment provides a solution to an existing need of high-school biology teachers and students. This need was established in the first phase of this research, in which I characterized the difficulties high-school biology students are facing while they write an inquiry-project report and concluded that they lack the genre knowledge required for writing an inquiry-project report in a way appropriate to the norms of the discipline. In addition, I found that teachers experience difficulties instructing the writing of an inquiry-project report and usually implement an inefficient individual instruction.

To summarize, this research shows that effective instruction of scientific writing of high-school biology students should be based on integrated genre-process pedagogy. In addition to the construction of genre knowledge by the students, achieved by the teacher exploitation of the APL as an apprenticeship genre, the writing instruction process should also include the teaching of writing strategies and self-regulation procedures along with extensive and productive feedback and collaboration.

Scientific Writing Interactive Model

The name given to the instructional model was "SWIM" – which stands for: "scientific writing interactive model". In the following section I will present and discuss the model of SWIM (Figure 33), as it was reflected from the analyses of its enactments in the different phases of the research. Then I will discuss the SWIM model in light of existing models of writing instruction.

The SWIM instructional model consists of three components: the SWIM-TELE, the teacher, and the students (Figure 33). The interactions between these three components are necessary for successful implementation and positive impact on students' scientific writing abilities.

The SWIM-TELE is designed to incorporate genre and process elements, which are based on APL articles. The design of the SWIM environment enables the teachers to apprentice their students into the conventions of scientific writing and to guide them in the process of writing the inquiry-reports of their own scientific investigations. This apprenticeship consists of cycles of modeling, scaffolding, coaching and fading.

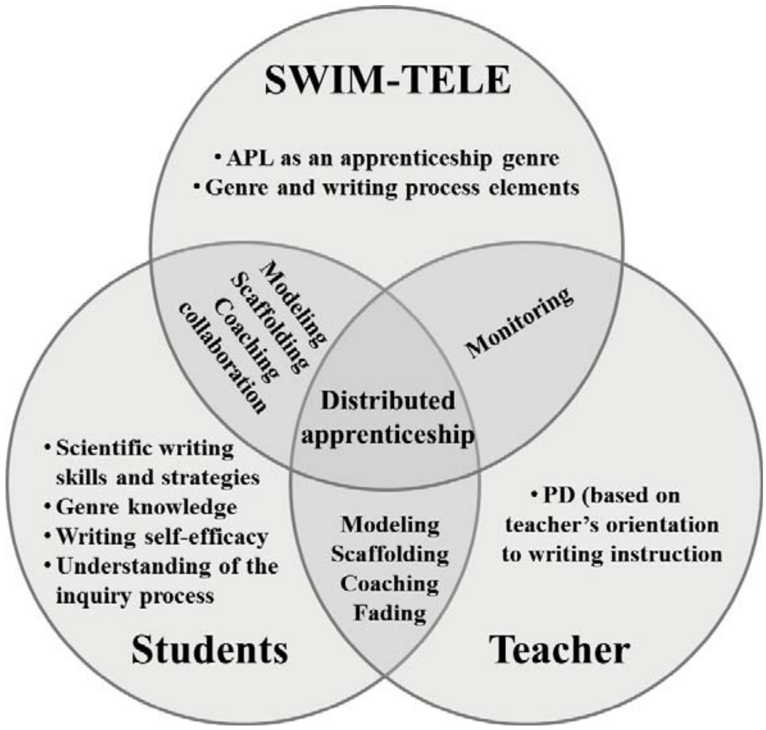

Figure 33. The SWIM instructional model

For teachers to apprentice students into disciplinary ways of writing, the teachers themselves must also be able to know how to write in the discipline (Pytash, 2012), however, many science teachers feel unqualified to teach students how to write in science (Sampson et al., 2013). As I showed in the first phase of the study, 47% of the teachers felt that inadequate scientific writing skills of the teacher pose a difficulty for the teacher in the instruction of writing the inquiry-project report. Also, 63% of the teachers reported insufficient training of the teachers in writing instruction as a difficulty (Figure 6). In light of these findings, and the analyses of the implementation of the SWIM-TELE, I argue that the SWIM-TELE provides the teachers with the essential support they need in order to apprentice their students in the writing process.

The interactions of the teacher with the SWIM-TELE enable the teacher to monitor his or her students' progress (e.g., by using the integrated progress reports), to set goals for individuals or for the whole class and to provide the appropriate feedback. In addition, as the findings from the second iteration indicate, the approach the teacher will take for implementing the SWIM-TELE depends on the teacher's orientation for writing instruction. Therefore, PD courses should acknowledge the different orientations of teachers and emphasize the integrated genre-process approach underlying the SWIM instructional model.

Furthermore, the interactions between the students and the SWIM-TELE take the form of modeling, coaching, scaffolding and collaborating with peers. The SWIM-TELE provides the proper infrastructure allowing these processes. For example, modeling can take place when the students watch a short video analyzing a section of an APL article or analyze a section of an APL as a model. Scaffolding occurs in the SWIM-TELE by automated feedback the students receive on genre-based exercises. For coaching, the students use embedded tools for planning, drafting and revising their inquiry-project reports.

The outcomes of the processes taking place during the interactions between the teacher, the SWIM-TELE and the students are: students improve their inquiry-based writing skills and strategies and gain genre knowledge, students gain self-efficacy and appreciation for writing in science and a better understanding of the biological processes they investigated. The students also possibly gain epistemological knowledge about scientific writing and the scientific inquiry process.

Taken together, I propose that the interactions of the three components of the SWIM model facilitate a *distributed apprenticeship* process (Figure 33). In the classical cognitive apprenticeship model (Brown et al., 1989; Collins et al., 1989) what begins with a teacher-centered discourse in authentic writing activity is succeeded by an interactive and collaborative discourse in which mental activity is distributed and shared between the teacher and students participants (Englert et al., 2006). I argue that in the SWIM model, knowledge and expertise are distributed and shared between the teacher, the students and the SWIM-TELE. This distribution enables the apprenticeship process and eventually the socialization of the students into ways of knowing and understanding within the discipline. This perspective of distributed apprenticeship reveals the close connection between cognitive and sociocultural theories of writing (Klein & Leacock, 2012).

Various models for instruction of writing in general and instruction of writing in science exist (See 3.3.7 for elaboration). Most of the models designed for writing instruction in science focus solely on genre-based pedagogy and the social aspect of writing in science, and tend to disregard the fact that writing is a complex process that makes substantial demands on writer's knowledge, strategies, language, skills, and motivational resources (MacArthur & Graham, 2016). In addition, the models designed for the high-school level (e.g ADI, Sampson et al., 2011; SWH, Keys, 1999; and Klein and Rose's model, 2010) deal mainly with skills such as argumentation and explanation rather than on authentic scientific genres. Furthermore, computerized genre-based models (e.g. LabWrite, Ferzli, Carter & Wiebe, 2005; WRiSE, Mort & Drury, 2012) are designed for undergraduate science students and are not compatible for high-school students. On the other hand, general writing models such as Self-Regulation Strategy Development (SRSD; Harris & Graham, 1992) or the Writing-Pal (McNamara et al., 2014) models tend to focus on the cognitive aspects of writing and consider writing as a set of skills that can be used across content areas. These models do not take into account the disciplinary nature of writing. To my knowledge, the SWIM model is the first model that combines genre pedagogy and process pedagogy in a computerized environment which enables high-school biology teachers to apprentice their students into the norms and practices of the scientific discourse community.

Limitations

The design-based research presented in this thesis was conducted in naturalistic settings, in 'real-world' context, and therefore has some restraints and limitations that have to be taken into account while considering the research conclusions. First, as design-based research focuses on characterizing complex learning / teaching situations and involves multiple dependent variables, it does not attempt to control all possible variables (Barab & Squire, 2004). Although the impact of the SWIM environment was compared to control classes, the experiences of the comparison groups were not controlled, and the teaching that took place in the comparison classes was not observed. Thus, it is possible that other uncontrolled confounds influenced the observed effects. Second, the very nature of design based research in which adjustments can continually be made in the implementation of an instructional intervention, makes it very difficult to know what combination of features of the intervention actually contributed to its success, therefore making it difficult to be generalized (O'Donnell, 2004). In this research the teachers who implemented the SWIM environment showed variations in implementations. These variations make it difficult to know which elements of the SWIM environment were more effective than others, whether there is an effect for the number of exercises implemented and what is the influence of the teacher's orientation with regards to the impact on the students' writing skills. Finally, to test the SWIM instructional model and the mechanism embedded in it, it was implemented in actual classrooms. In the first and second iterations I decided to analyze and compare each class separately, whilst acknowledging that the social norms inside each classroom were probably different. This choice, however, resulted in a small sample size on the classroom level. In addition, assigning a whole class to an experimental condition, instead of randomizing the participants, may produce some limitations, like other uncontrolled variables that could have influenced the obsereved effects.

Implications and future directions

High-school biology majors in Israel, as noted in the introduction, are required to write an inquiry-project report that scientifically summarizes their inquiry-project. Many of these students struggle to write in a manner that is consistent with the norms and epistemological commitments of science. This is not surprising due to the fact that most biology teachers do not teach their students how to write a scientific report nor do they pay much attention to texts and to scientific genres, and thus, teachers fail to mentor students in the necessary literate practices, which would help them write in science (Osborne, 2014).

This research suggests a model for teaching and learning scientific writing in high-school biology. Based on the research findings several recommendations for science teachers and science educators can be made:

Scientific writing can and should be taught by high-school science teachers, and therefore, should be included in the curriculum. This also means that writing is disciplinary, and should be embedded in studying each subject in the curriculum rather than treating knowledge as separate from the texts in which it is written, and leaving writing development to each student's intuitions (Rose, 2016).

The teaching of scientific writing in high-school should be based on socio-cognitive apprenticeship, in which the teacher utilizes the special characteristics of APL for modeling, scaffolding, coaching and fading. Moreover, besides focusing on the genre aspect of scientific writing, teachers should also explicitly teach their students writing strategies (e.g. planning, drafting and revising) and provide opportunities for the process aspect of writing, such as providing productive feedback, encourage collaborative writing and peer review and offer the writing of multiple drafts.

Teachers' PD programs should provide teachers with knowledge about the scientific language, the various scientific genres, and the cognitive aspects of writing instruction. Teachers' PD should also consider each teacher's orientation to writing instruction while training them for the integrated genre-process pedagogy.

This research also stresses that learning to write in high-school science classes is also important as a learning tool. This research showed that the writing process with the SWIM-

TELE promoted students' understanding and meaning making of their investigations and biological concepts related to their project. In addition, the students gained epistemological knowledge about scientific writing and the scientific inquiry process.

In this DBR several design-principles have been formulated, which could possibly be exploited for future learning environments or instructional models for writing instruction. These design-principles should be further examined in future research in other disciplines and various settings and contexts. These design-principles are presented in Table 22.

Table 22. Desin principles of the SWIM instructional model

Design principle (DP)	DP title	Meaning of DP
DP1	Construction of genre knowledge by analyzing APL as a model	APL should be used as a model of scientific writing and the basis for genre-oriented pedagogy
DP2	Interactive, Inquiry-based learning	Inductive instructional strategy should be applied. Students should be actively engaged in communicative activities to construct the knowledge themselves.
DP3	Exercises address specific skills, processes and knowledge of scientific writing	Scientific writing instructional model should include explicit instruction, in a form of apprenticeship, of specific skills and scientific writing knowledge, and address specific writing difficulties.
DP4	Process-oriented instruction of scientific writing	This includes strategy instruction (explicit teaching of specific strategies for planning and revising), teaching of self-regulation procedures, encourage collaboration and give extensive feedback to multiple drafts to facilitate writing. This also intended to strengthen the connection between the genre knowledge the students are constructing, and the writing process of their own inquiry-project reports.
DP5	Flexibility in use	The design should be flexible enough to enable the teachers to enact the most appropriate and suitable learning environment for their classes.
DP6	Technology enhanced learning	Writing instruction environments should be technology-enhanced and web-based, complex technological platforms (e.g. Moodle) that provide advantages to writing instruction, such as: automated and embedded feedback options, collaborative and interactive work, revision and editing tools and teacher's monitoring possibilities.

There are other issues that could prove to be fruitful lines of inquiry in the future. The first issue concerns the relationship between how a teacher implements an instructional model, such as SWIM, and what students learn. Following this study, for example, it would be interesting to investigate the choices teachers make in the implementation of SWIM (which elements are selected and why, and which are omitted and why) and how do these choices influence the learning gains made by the students. This line of research could also contribute to identifying which elements of the SWIM model can be altered or adapted by the teachers and which elements must be enacted. Second, it would be interesting to examine how various students' characteristics such as writing strategy (e.g., planner or reviser, see section 3.3.5 and 6.3.2.4 p.99), attitudes and self-efficacy for writing influence what learners do and learn during SWIM enactment, and how can the teacher address each student's writing characteristics.

The results obtained in this research point to the need of developing technology-enhanced environments for teaching and learning of disciplinary writing. Theses environments should provide the teachers the tools to apprentice their students, by advancing the students' genre knowledge and writing strategies, and thus facilitate the enculturation of the students into the disciplinary discourse community.

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9. Appendices

Appendix 1. Scientific writing rubric (SWAR) (Final version)

Criteria	N/A – 0	Novice – 1	Intermediate – 2	Proficient – 3
Introduction				
Justification/ Importance of inquiry Demonstrate a clear understanding of the importance if the inquiry question.	• The importance of the question is not addressed.	• The writer provides a generic or vague rationale for the importance of the question.	• The writer partially explains others would find the topic interesting/ important.	• The writer provides a clear sense of why this knowledge may be of interest to others.
Inquiry question Includes dependent and independent variables and the connection between them	• Inquiry question is not addressed.	• Inquiry question is not written properly.	• Inquiry question lacks a certain detail.	• Inquiry question is clear and well written.
Background Content knowledge is accurate, relevant and provides appropriate background including defining critical terms.	• Background information is missing or contains major inaccuracies. • Background information is accurate, but irrelevant or too disjointed to make relevance clear.	• Background omits information or contains inaccuracies which detract from the major point of the report. • Background information is overly narrow or overly general (only partially relevant).	• Background information may contain minor omissions or inaccuracies that do not detract from the major point of the report. • Background information has the appropriate level of specificity to provide relevant context.	• Background information is completely accurate. • Background information has the appropriate level of specificity to provide concise and useful context to aid the reader's understanding.
Hypothesis Hypothesis is clearly Stated and testable, includes the variables and the expected relation	• No hypothesis is indicated. • The hypothesis is stated but too vague or confused for its value to be determined. • A clearly stated, but not testable hypothesis is provided. • Hypothesis is incorrect	• Hypothesis is not written by the rules.	• Hypothesis is relevant, testable and clearly stated but may contain minor inaccuracies.	• Hypothesis is relevant, testable and clearly stated.
Hypothesis: Scientific merit Biological information to support the hypothesis	• No scientific basis is provided.	• Scientific basis is partial and inadequate.	• Scientific basis of hypothesis is adequate but basic.	• Scientific basis of hypothesis is profound and indicate on understanding.

Criteria	N/A – 0	Novice – 1	Intermediate – 2	Proficient – 3
Methods				
Experimental design Is likely to produce salient and fruitful results (include description of dependent and independent variables).	• Description of experimental design is not present, inappropriate or poorly explained. • Results are presented.	• Major inaccuracies or omissions in the experimental design description.	• Clearly explained. • Few details are missing.	• Clearly explained and accurate. • Contains personal fingerprint.
Replications (biological and technical).	• Replications are nonexistent. • No distinction between biological and technical replications.	• Replication is modest (weak statistical power).	• Replication is appropriate (average sample size with reasonable statistical power).	• Replication is robust (sample size is larger than average for the type of study).
Controls Appropriate controls present and explained**.**	• Controls are nonexistent or inappropriate. • Description of controls is not clear.	• Controls consider one major relevant factor.	• Controls take at least two factors into account. • Two types of controls or more.	• Controls consider all relevant factors and allow differentiating between multiple hypotheses.
Results				
Data presentation Table/graph types are appropriate. Appropriate labels, units, scales and statistical data	• Presentation of data is in an inappropriate format or graph type. • Labels or units are missing • No S.D is presented.	• Contains some errors or omissions of labels, units etc. • Data presented in appropriate format but poorly executed. • S.D is present but contains errors.	• Contains minor mistakes but figure's meaning is clear. • Graph types or table formats are appropriate • S.D is presented.	• Contains no mistakes. • Data presentation is appropriate, original and highlights the relationship between the inquiry variables.
Data selection Data chosen are comprehensive, accurate and relevant	• Raw data presented. • Processed data don't math raw data.	• Some necessary data are missing or inaccurate. • No raw data presented.	• Data are relevant, accurate and complete with any gaps being minor.	• Data are relevant, accurate and comprehensive. • May be synthesized or manipulated in a novel way.
Results description Clear and accurate.	• No description of the results. • Description includes explanation of results.	• Description is not clear and contains major inaccuracies.	• Description is clear and accurate.	• Description is clear, accurate.

Criteria	N/A – 0	Novice – 1	Intermediate – 2	Proficient – 3
Discussion				
Results explanation and alternative explanations Explanation of results is clear and logical. Alternative explanations are considered.	• Results are not explained. • Conflicting results are not addressed. • Alternative explanations are not provided or irrelevant.	• Results are poorly explained. • Conflicting results are addressed but alternative explanations are trivial.	• Results are clearly explained with minor emissions or inaccuracies. • Conclusions attempt to discuss or explain conflicting results. • Alternative explanations are provided.	• Results are clearly and accurately explained. • Conclusions address and logically refute or explain conflicting results. • Discussion of alternative explanations is complete and persuasive.
Conclusions based on results Conclusion is clearly and logically drawn from data provided.	• Conclusions have little or no basis in data provided. • Connections between hypothesis, data and conclusion are nonexistent or vague.	• Conclusions have some direct basis in the data, but may contain some gaps in logic or data. • Connections between hypothesis, data and conclusions are present but weak.	• Conclusions are clearly and logically drawn from the results. • A reasonable and clear chain of logic from hypothesis to data to conclusions is made.	• Conclusions are completely justified by data. • Connections between hypothesis, data, and conclusions are comprehensive and persuasive.
Criticism Conclusion expressed cautiously. Limitations of the data and/or experimental design are discussed.	• Conclusions are overly broad and excessive. • Limitations of the data and/or experimental design are not addressed.	• Conclusions are too general. • Limitations of the data and/or experimental design are discussed in a trivial way.	• Conclusions are cautiously expressed. • Limitations of the data and/or experimental design are relevant, but not addressed in a comprehensive way.	• Conclusions are cautiously expressed. • All inquiry components are critically addressed. • Conclusions take the limitations of data and/or experimental design into account.
General				
Structure and organization Report is constructed properly and presents clear understanding of the role of each section.	• Information is presented in a haphazard way.	• Report is poorly organized and several sections contain inappropriate information (e.g results in the methods sections, conclusions in the results section etc.).	• Structure and organization of the report are adequate, minor inaccuracies appear.	• A clear organizational strategy is present with a logical progression of ideas. This report is easier to read than most.

Criteria	N/A – 0	Novice – 1	Intermediate – 2	Proficient – 3
Language and grammar Grammar, word usage and organization facilitate the reader's understanding of the report.	• Grammar and spelling errors detract from the meaning of the report. • Word usage is frequently confused or incorrect.	• Grammar and spelling mistakes do not hinder the meaning of the report. • General word usage is appropriate, although use of technical language is may have occasional mistakes.	• Grammar and spelling have few mistakes. • Word usage is accurate and aids the reader's understanding.	• Correct grammar and spelling. • Word usage facilitates reader's understanding.
Resources and citation Several reliable and relevant resources are properly and accurately cited**.**	• No resources and references are provided.	• Resources are not reliable or too limited. • Citations are not according to rules.	• Most of the resources are reliable. • Citations are at least partially correctly formatted.	• All resources are reliable and indicate an extensive literature search was performed. • All resources are properly and accurately cited

Adapted from Timmerman, B.E., Strickland, D., Johnson, R.L., & Payne, J. (2011). Development of a 'universal' rubric for assessing students' scientific reasoning skills using scientific writing. Assessment and Evaluation in Higher Education. 36, 509

Appendix 2. Teachers' questionnaires

למורים שלום רב!

פיתוח מיומנויות תקשורת ואוריינות מדעית, ובכלל זה כתיבה מדעית, הפך למטרה עיקרית בהוראת המדעים בארץ ובעולם.
אנו מנסים לפתח סביבת למידה מתוקשבת לפיתוח מיומנויות כתיבה מדעית אצל תלמידי ביולוגיה בתיכון. סביבה זו נועדה לתת מענה לקשיי התלמידים בכתיבת עבודת הביוחקר וקשיי המורים בהנחיית כתיבת העבודה. לצורך המשך הפיתוח והתאמתו לצרכי המורים והתלמידים אנו מבקשים מכם לענות על מספר שאלות הקשורות לכתיבת עבודת הביוחקר ולסדנה מכ״ם לביוחקר שעברתם כעת.

תודה על שיתוף הפעולה,
צוות מכ״ם לביוחקר, מכון ויצמן למדע

מורה בכיתה/ות: __________
ותק בהוראה: ____________

1. **האם הנחית בעבר תלמידים ב<u>כתיבת</u> עבודת ביוחקר/עבודת חקר אחרת? כן/לא**
2. **מהם הקשיים העיקריים שבהם <u>מורה</u> עשוי/ה להיתקל <u>בעת הנחיית כתיבת עבודת</u> הביוחקר/עבודת חקר אחרת? סמן/י X בטור המתאים כדי לציין את מרכזיות הקושי.**

סוג הקושי	קושי מרכזי	קושי משני	לא מהווה קושי
עבודה מרובה למורה			
הכשרה לא מספקת בנושא			
קוצר זמן			
מיומנות כתיבה מדעית של המורה לוקה בחסר			
הנחיות לא ברורות ממשרד החינוך			
מחסור בדוגמאות לכתיבה מדעית תקינה			
אחר, פרט/י:			

3. **מהם הקשיים העיקריים שבהם <u>התלמידים</u> עשויים להיתקל <u>בעת כתיבת עבודת</u> הביוחקר/ עבודת חקר אחרת? סמן/י X בטור המתאים כדי לציין את מרכזיות הקושי.**

סוג הקושי	קושי מרכזי	קושי משני	לא מהווה קושי
שפה וניסוח			
הבחנה בין עיקר לטפל			
יצירת רצף לוגי			
מיזוג מקורות מידע			
ניסוח שאלת החקר			
תיאור מערך החקר			
הבחנה בין סוגי בקרות			
הבחנה בין חזרות וריבוי פריטים			

תיאור התוצאות			
בחירת דרך הצגת תוצאות			
הבחנה בין תיאור תוצאות והסברן			
ביסוס מסקנות על סמך תוצאות			
ביקורתיות			
הצדקת החקר			
בסיס ביולוגי להשערה			
אחר, פרט/י:			

4. מהי האסטרטגיה בה את/ה נוקט/ת להנחיית כתיבת עבודת הביוחקר? סמן/י X בטור המתאים לציין את מרכזיות השיטה.

אסטרטגיה	**מרכזית**	**משנית**	**לא ננקטת כלל**
חלוקת דף הנחיות			
חלוקת עבודות לדוגמא			
הנחייה פרטנית			
חלוקת המחוון			
חלוקת ראשי פרקים לעבודה			
אחר, פרט/י:			

5. מלא/י את המשוב הבא על סדנת מכ"ם לביוחקר (1: במידה מעטה מאוד - 5: במידה רבה מאוד):

שאלה	**1**	**2**	**3**	**4**	**5**
באיזו מידה נתרמת מההשתתפות בסדנא?					
עד כמה היה מבנה הסדנא מתאים עבורך?					
באיזו מידה היוותה הסדנא חידוש מבחינתך ?					
האם תמליץ/י למורה אחר/ת להשתתף בסדנא זו ?					
עד כמה כלי הוראה זה רלוונטי להוראת הביולוגיה באופן כללי ?					
האם תשתמש/י בכלי הוראה זה או בחומרים שהוצגו בפניך בסדנא זו?					
באיזו מידה נראה לך שכלי הוראה זה מתאים לתלמידים שלך?					

6. **בסדנה התנסיתי בפעילות (הקף/י בעיגול):**
   1. פתיחה – השוואה בין כתבה פופולארית למאמר מחקר מעובד
   2. מאפייני המאמר המדעי
   3. מבוא לשיפור
   4. פעילויות אינטראקטיביות לפרק השיטות
   5. דרך הצגת התוצאות
   6. הכרת מאפייני הדיון

7. **תאר/י את התרשמותך מהפעילות**

____

____

____

8. **מניסיונך בהוראה: מה היית משנה בפעילות בה התנסית? ומה היית משנה בכלי ההוראה שהוצג בפניך?**

____

____

____

9. **סכם/י במספר משפטים את החוויה שעברת בסדנא**

____

____

____

10. **ציין/י שלושה דברים חשובים שלמדת בסדנא**

____

____

____

Appendix 3. Scientific Writing Skills (SWS) test

לפניכם מאמר מחקר מדעי מתומצת. קראו את המאמר וענו על השאלות שאחריו:

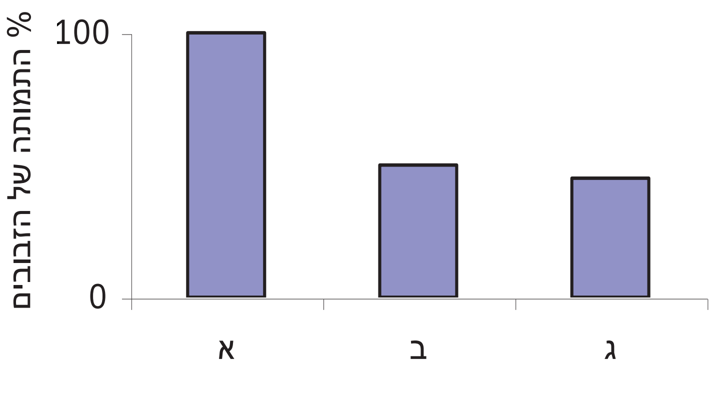
מצבי עקה הם מצבים בהם אורגניזם נחשף לתנאים קיצוניים, כגון טמפרטורה גבוהה או חומרים רעילים לתאים. מצבים אלו עלולים לגרום לשינויים במבנה התלת-ממדי של חלבוני התא, ובכך לגרום נזקים לתא. עקת חום יכולה להתרחש בכל האורגניזמים ועלולות להיות לה השפעות רבות. לכן חשוב לחקור את המנגנונים המווסתים מצבי עקת חום בתא.

בתאים של כל האורגניזמים (כולל האדם) ישנה קבוצת חלבונים ייחודיים לעקת חום. חלבונים הנקראים חלבוני HSP (Heat Shock Proteins), המגִנים על המבנה התלת-ממדי של החלבונים בתא, ובכך מבטיחים את תִפקודם התקין בתנאי עקת חום.

במחקר ביצעו החוקרים ניסוי בזבובי דרוזופילה (זבובי פירות). החוקרים רצו לבדוק האם וכיצד חשיפה מוקדמת קצרה לעקת חום קיצונית (שאינה גורמת למות הזבובים), משפיעה על עמידותם של הזבובים בשלב מאוחר יותר בפני עקת חום קיצונית. החוקרים שיערו שהחשיפה המוקדמת תגביר את עמידותם של הזבובים לעקת חום קיצונית, מכיוון שחלבוני HSP ייווצרו בתאים ויקנו לזבובים עמידות בפני עקה קיצונית.

בניסוי היו שלוש קבוצות של זבובים, לפי הפירוט שלהלן:
קבוצה א - הזבובים לא נחשפו לעקה.
קבוצה ב - הזבובים נחשפו לעקה מתונה, למשך זמן ארוך.
קבוצה ג - הזבובים נחשפו לעקה קיצונית שאינה לתלית (אינה גורמת למוות), למשך זמן קצר.
לאחר מכן נחשפו כל שלוש הקבוצות לעקה לתלית (גורמת למוות), למשך זמן קצר.

תוצאות הניסוי מוצגות באיור 1.



איור 1. השפעת החשיפה לעקת חום מוקדמת על עמידות זבובים לעקת חום קיצונית

1. **תן/י כותרת לכל אחת מהפסקאות** - רשום/י את הכותרת במלבן המופיע בצד הפסקאות.

2. **ענה/י על השאלות הבאות:**

א. שאלת המחקר שנבדקה בניסוי המתואר היא:

ב. השערת החוקרים היא:

ג. המשתנה הבלתי תלוי בניסוי המתואר הוא:

ד. המשתנה התלוי בניסוי המתואר הוא:

ה. הבקרה בניסוי המתואר היא:

3. **תאר/י את התוצאות המוצגות בגרף**

4. **החוקרים כתבו את כל חלקי המאמר שקראת, אך טרם הספיקו לכתוב את חלק הדיון. סייע/י לחוקרים בכתיבת הדיון.** תפקידיו של פרק הדיון במאמר מדעי הם לסכם את המאמר ולקשור בין חלקיו השונים, להציע הסבר לתוצאות שהתקבלו ולמסקנות שנובעת מהן, להציג את מגבלות המחקר הנוכחי ולהציע שאלות מחקר חדשות שמתעוררות מתוצאות המחקר.

לפניכם מאמר מחקר מדעי. קראו את המאמר וענו על השאלות שאחריו:

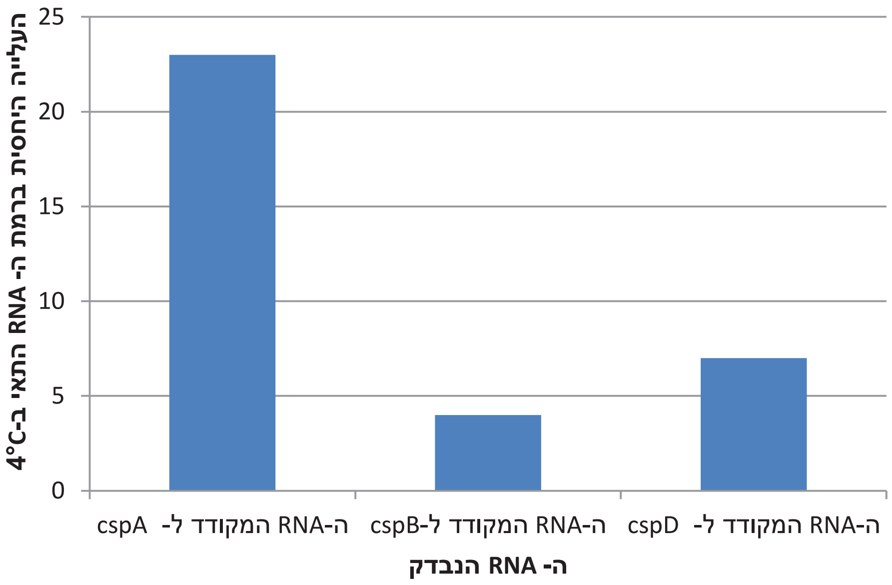
בבדיקה שעשה משרד הבריאות באוגוסט 2011 נמצאו חיידקי ליסטריה בבשר מעושן. חיידק ליסטריה (Listeriamonocytogenes) גורם למחלות מסוכנות ולהרעלת דם, והוא פוגע בעיקר בנשים הרות, תינוקות, זקנים ובאנשים שמערכת החיסון שלהם מוחלשת. מבין החולים שנדבקים בחיידק יש תמותה של 20%-30%, ולכן חשוב לחקור אותו.

נמצא שחיידק הליסטריה עמיד לטווח טמפרטורות רחב. אחד המאפיינים של החיידק הוא יכולתו להתרבות גם בטמפרטורה של 4°C, שהיא טמפרטורה ממוצעת במקררים ביתיים. לחוקרים היה ידוע שהתרבות של החיידקים בתנאי קור מתאפשרת בנוכחות קבוצת חלבונים הנקראת **"חלבוני עקת קור"** – csp. חוקרים גילו שבחיידק הליסטריה יש שלושה חלבוני csp שונים: **A** csp, **B** csp ו-**D** csp.

החוקרים רצו לבחון כיצד משפיע כל אחד משלושת חלבוני ה-csp על יכולת חיידקי הליסטריה להתרבות בטמפרטורות נמוכות. החוקרים שיערו שכל אחד מחלבוני ה-csp יתבטא ברמה שונה ועקב כך השפעתם על יכולת התרבות הליסטריה בטמפרטורות נמוכות תהיה שונה.

לשם כך, החוקרים גידלו חיידקים מזן הבר בשתי טמפרטורות: ב- 37°C וב-4°C. בכל טמפרטורה מדדו את **רמת ה-mRNA** בתאי החיידקים.

בגרף 1 מוצגת **העלייה היחסית** ברמת ה-mRNA של כל אחד מחלבוני ה- csp (cspA, cspB ו- cspD) בתאי החיידקים ב-4°C, ביחס לרמת חלבוני ה-csp ב-37°C (עלייה יחסית = פי כמה עלתה רמת הביטוי של כל חלבון).



איור 1: העלייה ברמת ה-RNA התאי של csp בחיידקי ליסטריה ב-4°C יחסית ל-37°C

1. **תן/י כותרת לכל אחת מהפסקאות** - רשום/י את הכותרת במלבן המופיע בצד הפסקאות.

2. **ענה/י על השאלות הבאות:**

א. שאלת המחקר שנבדקה בניסוי המתואר היא:

ב. השערת החוקרים היא:

ג. המשתנה הבלתי תלוי בניסוי המתואר הוא:

ד. המשתנה התלוי בניסוי המתואר הוא:

ה. הבקרה בניסוי המתואר היא:

3. **תאר/י את התוצאות המוצגות בגרף**

4. **החוקרים כתבו את כל חלקי המאמר שקראת, אך טרם הספיקו לכתוב את חלק הדיון. סייע/י לחוקרים בכתיבת הדיון.** תפקידיו של פרק הדיון במאמר מדעי הם לסכם את המאמר ולקשור בין חלקיו השונים, להציע הסבר לתוצאות שהתקבלו ולמסקנות שנובעת מהן, להציג את מגבלות המחקר הנוכחי ולהציע שאלות מחקר חדשות שמתעוררות מתוצאות המחקר.

Appendix 4. Attitudes questionnaire

שלום!

לפניך מספר משפטים בנושאי כתיבה, מחשבים וכתיבה מדעית. בבקשה סמן/י בעיגול את המספר המתאים ביותר. תודה על שיתוף הפעולה!

משפטים	מסכים בהחלט	מסכים	לא יודע	לא מסכים	לא מסכים בהחלט
1. אני אוהב/ת לכתוב	5	4	3	2	1
2. אני בטוח/ה ביכולתי לכתוב דו״ח מעבדה במילים שלי	5	4	3	2	1
3. אני חושב/ת שאני כותב/ת טוב	5	4	3	2	1
4. אני מעדיף/ה לכתוב במחשב	5	4	3	2	1
5. לפני הכתיבה אני כותב/ת את הרעיונות העיקריים, אך הם לא מלוטשים	5	4	3	2	1
6. במחשב קשה לי לכתוב בשטף	5	4	3	2	1
7. ביקורת של חבריי לכיתה לכתיבה שלי זה בזבוז זמן	5	4	3	2	1
8. כתיבה היא משהו שאני יכול/ה לשפר	5	4	3	2	1
9. מיומנויות כתיבה שנלמדות בשיעורי ביולוגיה יכולות לסייע לי בחיי היום יום	5	4	3	2	1
10. כתיבה באמצעות מחשב גורמת לי להיות יצירתי יותר	5	4	3	2	1
11. קשה לי להבין מה הקשר בין כתיבה מדעית לחיי היום יום	5	4	3	2	1
12. אני מפחד/ת לכתוב כי אני לא בטוח/ה בעצמי	5	4	3	2	1
13. אני מעדיף/ה ללמוד עקרונות כלליים לכתיבה מדעית, בהם אוכל להשתמש גם במקצועות אחזרים	5	4	3	2	1
14. אני נהנה לראות את הדברים שאני כותב/ת בדפוס	5	4	3	2	1
15. הזמן שמושקע בתכנון לפני שאני כותב/ת דו״ח מעבדה עוזר לי לכתוב דו״ח טוב יותר	5	4	3	2	1
16. כתיבה טובה היא יכולת שאנשים נולדים אתה	5	4	3	2	1

17. שימוש במחשבים מאפשר לי יותר שליטה על הלמידה שלי	5	4	3	2	1
18. כתיבה יכולה לסייע לי למצוא עבודה טובה בעתיד	5	4	3	2	1
19. שכתוב פירושו לשנות מספר מילים ולתקן שגיאות כתיב ופיסוק	5	4	3	2	1
20. כתיבה היא מיומנות חשובה	5	4	3	2	1
21. כשהמורה מראה לנו דוגמא של דו״ח טוב אני מנסה בעצמי להבין מה הופך אותו לטוב	5	4	3	2	1
22. במחשב קל לי לתקן את כתיבתי	5	4	3	2	1
23. כתיבה על פי כללים מדויקים הם חלק חשוב מביצוע המטלה	5	4	3	2	1
24. כתיבת עבודות ביד חוסכת זמן לעומת כתיבה באמצעות מחשב	5	4	3	2	1
25. כתיבה עוזרת לי ללמוד	5	4	3	2	1
26. אני נהנה לכתוב עבודות ביד יותר מאשר באמצעות מחשב	5	4	3	2	1
27. אני מעדיף/ה ללמוד כתיבה מדעית באמצעות הנחיות מדויקות	5	4	3	2	1
28. אני יכול/ה לכתוב עבודות טובות יותר כאשר אני כותב/ת אותן במחשב	5	4	3	2	1
29. הזמן שמושקע בשכתוב של דו״ח מעבדה עוזר לי לכתוב דו״ח טוב יותר	5	4	3	2	1
30. שימוש במחשב לצורך כתיבה לא שווה את הזמן והמאמץ	5	4	3	2	1
31. אני לרוב כותב/ת דו״ח מעבדה מההתחלה עד הסוף (לפי הסדר)	5	4	3	2	1
32. כשאני כותב/ת, הטיוטה הראשונה שלי צריכה להיות קרובה לגרסה הסופית ככל האפשר	5	4	3	2	1
33. שימוש במחשב נותן לי יותר הזדמנויות לקרוא ולהשתמש במידע	5	4	3	2	1
34. כשאני כותב/ת עבודה/דו״ח אני כותב/ת סעיף מסוים עד שאני נתקע/ת ואז אני עוברת/ת לסעיף הבא	5	4	3	2	1

35. ללמוד להשתמש במחשב גורם לי תחושת הישג	5	4	3	2	1

ענה/י על השאלות הבאות:

1. האם יש לך מחשב בבית? כן/לא
2. האם את/ה משתמש/ת במחשב הביתי למשחקים? כן/לא
3. האם את/ה משתמש/ת במחשב הביתי לכתיבה? כן/לא
4. האם את/ה משתמש במחשב הביתי לדברים נוספים? כן/לא פרט ________________

Appendix 5. Feedback analysis

מבוא

בעבודת החקר שלנו נבדוק מהי השפעת חומרים מעכבים התפתחות על התרבות החיידק בצילוס סובטילוס, על מנת לבדוק את האפשרות לייצר תרופה המגינה מהתרבות החיידק בצילוס סובטילוס שמרכיבה הוא חומר המצוי בטבע.

החיידק בצילוס סובטילוס נפוץ בעיקר באדמה, במים ובאוויר. החיידק מייצר לעצמו נבגים קשיחים המקיפים את המטען הגנטי בו, המונעים חדירת חום קיצוני, חומרים כימיים, גורמים סביבתיים וקרינה אל פנים התא. להסביר על מבנה החיידק. האם יכול לגרום לנזק לאדם? האם חיידק גרם+ או גרם- ?

הערה [1WU]: D1001

לשם גידול החיידקים נצטרך להשתמש במצע מזון מוצק המורכב מאגר. האגר הוא חומר דמוי ג'לטין המופק מאצות. ממיסים אותו במים חמים, מוסיפים לו את חומרי המזון הנחוצים שהם? לרשום איזה חומרים מוסיפים ומה תפקידם ושופכים לצלחת פטרי. כאשר האגר מתקרר הוא נקרש ומצרת שכבה מוצקה. יתרון האגר הוא שמעט מאוד חיידקים מפרקים אותו, ולכן הוא נשאר שלם והחיידקים גדלים עליו[1], כך מכל לאפשר לחיידק לקבל את החומרים הנחוצים להתרבותו וגדילתו. מה חאים כאשר חיידקים גדלים על אגר? מהי מושבת חיידקים?

הערה [2WU]: D1002

הערה [3WU]: D1003

חסר- מהם שלבי גידול חיידקים? איך חיידק מתרבה?

הערה [4WU]: D1004

~~תחילה, נבדוק מהו החומר איתו נרצה לעשות את הניסוי ומהם החיידקים, ובחנו כמה אפשרויות: האחת שימוש בשמן אקליפטוס ובמיצוי עלים של אקליפטוס, וזאת משום שאקליפטוס הוא צמח אללופתי והוא מפריש לסביבתו חומרים המעכבים גדילה של צמחים או אורגניזמים אחרים בסביבתם במצב שבו המשאבים מוגבלים[2]. מכל להשתמש בחומר זה כדי למנוע את התפתחות החיידקים. האפשרות השנייה היא להשתמש בשמן הזמרין ומיצוי על הזמרין. את הטיפולים הללו יעבה שלושה סוגי חיידקים: אי קולי, סטפילוקוקוס אלבוס, ובצילוס סובטילוס. מתוך התוצאות של ניסוי מקדים זה מכל להחליט עם איזה חיידק ועם איזה חומר להמשיך את הניסויים הבאים.~~ לא רלוונטי, לא שייך למבוא

הערה [5WU]: D1005

לכל שאלה לרשום את השאלה, את ההשערה (לא רשומה) ואת הבסיס הביולוגי

הערה [6WU]: D1006

בשאלת החקר הראשונה נבדוק את השפעת שמן האקליפטוס בריכוזים שונים על התרבותו של החיידק בצילוס סובטילוס. כידוע, שמן האקליפטוס הוא חומר המעכב גדילה ולכן נצפה לראות סביב הדסקית הסבולה בו הילה, שהיא השטח שבו החיידק לא התרבה, ורחוק ממנה מושבות. מושבה היא צבר של חיידקים שמקורם בחיידק אחד. החיידקים יתרבו בצורת הרבייה המכונה רבייה אל-זוויגית (אל-מינית) בה מוצאו של המטען התורשתי של הפרט החדש הוא מחיידק אחד, כלומר - כל הצאצאים המתקבלים מרבייה אל-מינית זהים מבחינה תורשתית ליצור ממנו התקבלו, והם גם זהים זה לזה[5]. ~~בריכוזים שונים מכל לבדוק את מידת היעילות של שמן האקליפטוס על עיכוב גדילת החיידק. את ההילה נמדוד בעזרת מדידת הקוטר של ההילות.~~ אנחנו משערים ש....

הבסיס הביולוגי הוא...

הערה [7WU]: D1007

בשאלת החקר השנייה שלנו נבדוק את השפעת טמפרטורת המיצוי על התרבות החיידק בצילוס סובטילוס. הטמפרטורה משפיעה על קצב הגידול של החיידקים בשני דרכים: היא משפיעה על אנזימים המשתתפים בתהליך הגדילה וההתרבות של החיידקים, ועל קצב הדיפוזיה של חומרים, כמו חומרי מזון וחמצן לתוך תאי החיידקים[4]. עם עליית הטמפרטורות, יעלה גם קצב ההתפתחות וההתרבות של החיידק ובגרף התהליך יהיה בשלב הגידול המעריכי, הלוגריתמי. שלב זה הוא השלב בעקומת הגידול שהחיידקים מתרבים בקצב מהיר וקבוע. טווח הטמפרטורות שבחרנו לבדוק יהיה בין 20- 80 מעלות צלזיוס, שזהו הטווח המשוער של הטמפרטורות שבהן החיידק אכן מתרבה. בטמפרטורות נמוכות מאלה החיידק לא מתרבה הרבה כי ~~הוא מסתגל לבית הגידול החדש שלו~~ טעות, זה לא נכון שהוא מסתגל, ובטמפרטורות גבוהות מאלה החיידק לא מתרבה משום שהוא עובר דנטורציה החיידק אים עובר דנטורציה – המבנה המרחבי של החלבון נהרס[5]. ~~בתוצאות של שאלת החקר השנייה נצפה לראות את ההילות סביב הדסקית, ולפי ההילות להחליט באילו טמפרטורות המיצוי צריך להיות על מנת לפעול באופן מיטבי.~~ אנחנו משערים ש....

הערה [8WU]: D1008

הערה [9WU]: D1009

הערה [10WU]: D1010

הבסיס הביולוגי הוא...

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[1] אתר נחשון ביולוגיה

[2] ויזל, י' (1974). אקולוגיה – עקרונות ותהליכים.

[3] אתר נחשון ביולוגיה

[4] פורטל הכנה לבגרות בביולוגיה, http://www.easybio.co.il/biology-questions-in.asp?num=102

[5] אתר נחשון ביולוגיה

Coding scheme:

Code	Meaning	Code	Meaning
Section of the report		**Explanation**	
I	Introduction	+	Explanation provided
M	Methods	-	No explanation
Res	Results	**Solution**	
D	Discussion	+	Solution provided
Ref	References	-	No solution
Nature of comment		**Implementation**	
S	Statement	N	No implementation
IM	Imperative	P	Partial implementation
Q	Question	IMP	Implementation
REV	Revidion	**Type of comment**	
DEL	Delition	C	Content
IN	Insertion	G	Genre

Coding of the comments:

Comment ID	Draft	Section	Type of comment	Nature of comment	Explanations	Solution	Implementation
AL3D1001	1	I	C	IM	+	-	P
AL3D1002	1	I	C	Q	+	-	P
AL3D1003	1	I	C	Q	+	-	IMP
AL3D1004	1	I	C	S	+	-	IMP
AL3D1005	1	I	G	DEL	+	+	IMP
AL3D1006	1	I	C	IM	-	-	N
AL3D1007	1	I	G	REV	-	-	P
AL3D1008	1	I	C	DEL	+	-	N
AL3D1009	1	I	C	S	+	-	N
AL3D1010	1	I	G	REV	-	+	N

I – Introduction, C – Content, G - Genre, IM – Imperative, Q – Question, S – Statement, DEL – Deletion, REV – Revision, IMP – Implementation, P – Partial implementation, N – No Implementation

Appendix 6. SWIM vs. Non-SWIM - Mann-Whitney test

	Initial Drafts						**Final drafts**					
	SWIM		**Non-SWIM**				**SWIM**		**Non-SWIM**			
	Mean	**SD**	**Mean**	**SD**	**U-values**	**p**	**Mean**	**SD**	**Mean**	**SD**	**U-values**	**p**
Introduction	1.779	0.447	1.089	0.495	23.5	**0.014**	2.660	0.336	1.886	0.640	0	**0.006**
Methods	1.833	0.206	1.130	0.251	22	**0.011**	2.533	0.808	1.952	0.360	4	**0.035**
Results	2.250	0.094	1.222	0.056	16	**0.003**	2.800	0.200	2.286	0.378	9.5	0.222
Discussion	1.881	0.609	0.870	0.479	3	**0.000**	2.033	0.551	1.810	0.149	13	0.516
General	1.631	0.796	0.852	0.740	3	**0.000**	2.600	0.173	1.881	0.180	0	**0.006**
Justification	1.357	0.949	0.611	0.651	32.5	0.059	8.657	12.912	5.793	9.971	3	**0.023**
Inquiry question	2.464	0.634	1.778	0.795	30	**0.040**	8.187	12.029	5.581	9.245	12.5	0.465
Background	1.464	0.571	1.000	0.433	34.5	0.075	6.311	8.518	4.387	6.638	10.5	0.289
Hypothesis	1.964	1.117	1.389	0.697	40.5	0.165	2.249	1.983	1.866	1.586	8	0.144
Hypothesis: Scientific merit	1.643	1.008	0.667	0.559	27	**0.025**	2.249	1.983	1.904	1.711	0	**0.006**
Experimental design	1.714	0.378	1.111	0.601	27	**0.025**	11.483	18.224	11.204	12.980	5	0.051
Replications	1.714	0.914	0.889	0.928	34	0.072	10.696	16.748	10.461	11.925	16.5	0.936
Controls	2.071	0.730	1.389	0.858	37	0.107	12.113	19.406	10.233	13.983	0	**0.006**
Data presentation	2.179	0.992	1.167	0.791	27	**0.025**	14.017	22.943	9.257	17.484	15.5	0.810
Data selection	2.357	1.082	1.222	1.202	27.5	**0.028**	9.754	14.977	6.699	11.387	12.5	0.465
Results description	2.214	0.726	1.278	0.667	23	**0.013**	9.754	14.977	11.794	11.209	8.5	0.168
Results explanation	1.929	0.514	0.778	0.667	9.5	**0.001**	11.956	19.110	12.662	13.716	10.5	0.289
Conclusions based on results	2.464	0.499	1.389	0.417	7	**0.000**	12.905	20.881	14.047	15.070	10	0.254

Criticism	1.250	0.803	0.444	0.464	34	**0.049**	9.754	14.977	13.244	12.040	15	0.749
Structure and organization	2.036	0.692	1.222	0.507	23.5	**0.014**	9.911	15.271	10.893	11.037	7	0.105
Language and grammar	2.143	0.413	1.333	0.559	18.5	**0.006**	8.500	12.618	10.046	9.354	9	0.194
Resources and citation	0.714	0.893	0.000	0.000	36	0.064	4.280	4.819	8.781	7.483	7	0.105

Appendix 7. Examples of students' planning

Student's plan of the discussion section (Carol's class):

לאחר שסיימתם את הפעילות "הכרת פרק הדיון", אתם מוכנים כעת להתחיל את כתיבת פרק הדיון של עבודת הביוחקר שלכם. תכננו את פרק הדיון על פי החלקים שהכרתם בסעיף הקודם. בכל אחד מהחלקים רשמו נקודות/ראשי פרקים אותם אתם מעוניינים לכתוב. לאחר מכן, הרחיבו כל אחת מהנקודות וכתבו פסקאות מתאימות, במילים שלכם. הקפידו על המאפיינים של כתיבת הדיון: כתיבה רציפה תוך קישור בין הפסקאות, ביקורתיות והסקת מסקנה תוך התבססות על התוצאות והסברן (הקפידו להפנות לתוצאות הרלוונטיות.)

שאלת המחקר וההשערה	שאלת החקר הראשונה : <u>כיצד אורך הגל משפיע על קצב הצימוח של הצנון?</u> <u>ההשערה :</u> בכלים שנאיר עליהם בצבעים הכחול והאדום קצב הצימוח יהיה הגדול ביותר. שאלת החקר השנייה : <u>כיצד אורך הגל משפיע על קצב הפוטוסינתזה בצנון?</u> <u>ההשערה :</u> בכלים עליהם נאיר בצבעים שנבלעים ברמה גבוה (אדום וכחול) קצב הפוטוסינתזה בתאי הצנון תהיינה גדולה.
תיאור תוצאות עיקריות	לאחר שבוע של בדיקות התוצאות של אורך נבטי הצנון בממוצע היו: הכלי שכוסה בצלופן סגול אורך נבטי הצנון בממוצע לאחר שבוע היו בו : 5.1 הכלי שכוסה בצלופן אדום אורך נבטי הצנון בממוצע לאחר שבוע היו : 10.13 הכלי שכוסה בצלופן שקוף אורך נבטי הצנון בממוצע לאחר שבוע היו: 7.06 הכלי שכוסה בצלופן ירוק אורך נבטי הצנון בממוצע לאחר שבוע היו : 5.4 הכלי שכוסה בצלופן כחול אורך נבטי הצנון בממוצע לאחר שבוע היו : 7.26 הכלי שכוסה בצלופן צהוב אורך נבטי הצנון בממוצע לאחר שבוע היו : 4.96
מסקנה	באורכי הגל של הצבעים כחול ואדום קצב הפוטוסינתיזה היה מקסימאלי. ולכן קצב הצימוח היה מהיר יותר (בכלי עם הצלופן האדום אורך נבטי הצנון בממוצע לאחר שבוע היה : 10.13, ובכלי עם הצלופן הכחול אורך נבטי הצנון בממוצע לאחר שבוע היה :7.26). ניתן להסיק מכך שקצב הצימוח מושפע מתהליך הפוטוסינתיזה ובכלים אלה אורך נבטי הצנון בממוצע לאחר שבוע היה הגבוה ביותר. אורך גל קצר יותר (כפי שיש לצבעים אדום וכחול) מכיל תכולת אנרגיה רבה יותר, תהליך הפוטוסינתיזה מושפע מאורך הגל : ככל שאורך הגל מכיל תכולת אנרגיה רבה יותר, כך תהליך הפוטוסינתיזה יהיה יעיל יותר וקצב הצימוח יהיה מהיר יותר. וזוהי הסיבה שבגללה ניתן לראות שהכלים שכוסו בצלופן האדום והכחול קצב הצימוח היה המהיר ביותר.
מגבלות המחקר	ערכנו שני ניסיונות למחקר. הניסיון הראשון לא הצליח והסיבה לכך היא שהכלים היו בתנאים לא זהים. עוצמת האור שהגיעה לכלים השונים הייתה שונה. ולכן התוצאות שלנו יצאו שונות מההשערה. בכלים שכוסו בצלופן הצהוב והירוק קצב הצימוח בהם היה מרבי ולעומת זאת בכלים שכוסו בצלופן האדום והכחול קצב הצימוח בהן היה מינימלי.
חשיבות/השלכות המחקר	
שאלת המשך	

Appendix 8. Scientific Writing Skills tests - One-way ANOVA with post-hoc Tukey HSD (Honestly Significant Difference) Test

Non Swim classes: A – Carol, B- Dana, C-Control 1

Titles pre:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	0.0531	0.8999947	insignificant
A vs C	1.6635	0.4755900	insignificant
B vs C	1.9176	0.3743105	insignificant

Titles post:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	1.7623	0.4355968	insignificant
A vs C	6.0115	0.0010053	** p<0.01
B vs C	4.9845	0.0030883	** p<0.01

Inquiry – pre:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.3189	0.2401807	insignificant
A vs C	2.9846	0.0993119	insignificant
B vs C	1.0365	0.7281915	insignificant

Inquiry – post:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	0.5671	0.8999947	insignificant
A vs C	0.1901	0.8999947	insignificant
B vs C	0.3643	0.8999947	insignificant

Results – pre:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	1.3152	0.6160616	insignificant
A vs C	1.0420	0.7260070	insignificant
B vs C	2.5416	0.1823962	insignificant

Results – post:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	3.0513	0.0902520	insignificant
A vs C	4.7353	0.0047375	** p<0.01
B vs C	2.3355	0.2357870	insignificant

Discussion pre:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	3.0308	0.0933092	insignificant
A vs C	0.0683	0.8999947	insignificant
B vs C	2.8682	0.1180424	insignificant

Discussion post:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	1.3758	0.5919481	insignificant
A vs C	6.2521	0.0010053	** p<0.01
B vs C	5.7302	0.0010053	** p<0.01

SWIM classes: A = Eleanor, B=Frida, C= Control 2

Titles pre:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	0.9732	0.7523542	insignificant
A vs C	1.0444	0.7237791	insignificant
B vs C	1.9307	0.3673324	insignificant

Titles post:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	1.2652	0.6347533	insignificant
A vs C	0.5084	0.8999947	insignificant
B vs C	0.7400	0.8456129	insignificant

Inquiry pre:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	4.5620	0.0058127	** p<0.01
A vs C	2.2683	0.2525373	insignificant
B vs C	2.3208	0.2372334	insignificant

Inquiry post:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.2113	0.2699729	insignificant
A vs C	1.1415	0.6842969	insignificant
B vs C	3.2020	0.0692860	insignificant

Results pre:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	3.7271	0.0286844	* p<0.05
A vs C	1.0378	0.7259453	insignificant
B vs C	4.5755	0.0056542	** p<0.01

Results post:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.1356	0.2942874	insignificant
A vs C	2.4054	0.2138898	insignificant
B vs C	0.1587	0.8999947	insignificant

Discussion pre:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.4492	0.2024311	insignificant
A vs C	1.2710	0.6323161	insignificant
B vs C	1.1967	0.6621548	insignificant

Discussion post:

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.0747	0.3147493	insignificant
A vs C	4.8251	0.0033654	** p<0.01
B vs C	6.4836	0.0010053	** p<0.01

Appendix 9. The Ministry of Education's guidelines for writing the inquiry-project report

הנחיות לסיכום עבודת החקר

מבנה העבודה והיקפה

עבודת הסיכום תהיה קבוצתית.

העבודה תכלול דף שער, תוכן עניינים, גוף העבודה, ושלושה נספחים.

בגוף העבודה יופיעו פרקים אלה: מבוא; מהלך המחקר (כולל שיטות וחומרים); תוצאות ; מסקנות ודיון; ביבליוגרפיה.

בפרקים המתאימים יש לשלב הפניות לביבליוגרפיה ולנספחים.

גוף העבודה יהיה בהיקף של **8-12 עמודים מודפסים**. שימו לב לחלוקה פנימית של מספרי העמודים.

חריגה מהיקף העבודה המוצע עלולה לגרום לפגיעה בציון.

יש לכלול בעבודה לפחות **צילום אחד שצולם על ידי כותבי העבודה**. הצילום ייכלל בפרק המתאים.

פירוט פרקי העבודה

א. דף שער

שם העבודה, שמות חברי הקבוצה, שם בית הספר, כיתה, שם המורה ותאריך הגשת העבודה.

ב. תוכן העניינים

יכלול את מספרי העמודים בעבודה.

ג. מבוא

2-3 עמודים

כתבו את המבוא **ברצף,** וכללו בו את הסעיפים האלה:

- נקודת המוצא לחקר - תיאור התופעה או הבעיה שהובילה אתכם לחקר. (מומלץ להוסיף צילום או איור).
- הרקע העיוני - מידע ממקורות מהימנים, הכולל מושגים ותהליכים **הרלוונטיים** לחקר, וכן מידע על האורגניזמים הקשור **ישירות** לנושא שנבדק. שימו את הדגש על גורמים רלוונטיים שונים שיכולים להשפיע על התוצאות, ובפרט על המשתנה הבלתי תלוי והשפעתו הצפויה על המשתנה התלוי.
- פסקה קצרה שתכלול את שאלת/שאלות החקר, ההשערה/ההשערות והבסיס הביולוגי להשערה. אם נבדקו שתי שאלות יש לציין בבירור את הקשר ביניהן.

הערה: ניתן לכתוב את שאלת החקר וההשערה לפני הצגת הרקע העיוני, אם הרצף הגיוני.

שימו ♥:

א. רשמו את השאלה/ שאלות באופן ברור ובולט (<u>קו תחתון</u> או **אותיות בולטות**).

ב. הסבירו בפירוש מה הביא אתכם לבחור בשאלת החקר שבדקתם ("הצדקת החקר").

ג. כתבו את המבוא **באופן רציף כחיבור,** ולא כקטעים שביניהם כותרות משנה.

ד. אם נבדקו שתי שאלות חקר רשמו באופן ברור את שתיהן, שלבו במבוא את המידע הרלוונטי הנוגע לשתי השאלות, והסבירו את הקשר ביניהן.

ה. כללו במבוא רק מידע הנוגע **באופן ישיר** לנושא העבודה.

ו. בכל סעיף או פסקה רשמו **הפניה** אל המקורות עליהם מבוסס המידע. בנספח I מוסבר אופן כתיבת ההפניה.

ז. לגבי אמינות מקור המידע תוכלו להיעזר בנספח II, וכן במורה הכתה.

ד. מערך החקר, כולל חומרים ושיטות

2-3 עמודים

תארו את מהלך הניסוי בקצרה, ובאופן מדויק, כך שהקורא יוכל לחזור ולבצע אותו. בכל שלב ציינו את שיטות העבודה והמדידה. מומלץ להיעזר בסכמה, בטבלה, או בצילומים המבהירים את מערך הניסוי. אם השתמשתם בשיטת עבודה המתוארת בפירוט במקור כלשהו ציינו את עיקר השיטה בפרק זה, והפנו אל מקור המידע.

> פרק זה כולל מידע מפורט על מערך הניסוי. הוא מאפשר לקורא לחזור על את הניסויים המתוארים בו ולהעריך אותו.

הקפידו לכלול את הסעיפים האלה:

- ✓ האורגניזם/מים שנבדק/ו - שם הסוג, ואם ניתן גם מין, זן/גזע.
- ✓ המשתנה התלוי ודרך המדידה שלו – תיאור מפורט וברור, כולל יחידות המדידה.
- ✓ המשתנה הבלתי תלוי ודרך השינוי שלו- יש לפרט מהן קבוצות הטיפול השונות וכיצד הוכנו, ולהסביר מדוע נבדק טווח זה של המשתנה.
- ✓ קבועים- מהם? וכיצד נשמרו?
- ✓ בקרות- מהן?
- ✓ מספר הפריטים בכל טיפול, וכן מספר החזרות.
- ✓ מיקום ביצוע הניסוי, מועד הביצוע ותאריכי המדידות.
- ✓ הסבר על אופן עיבוד התוצאות.

הסבירו כאן מהי <u>התרומה הייחודית/ טביעת האצבע</u> שלכם.
אם נבדקו שתי שאלות חקר יש לכלול בסעיף זה את המידע הנוגע לשתי השאלות.
אם בוצעו **ניסויים מקדימים**, שלבו את המידע שנלמד מהם בפרק זה, והפנו מכאן אל נספח מספר 3 בעבודתכם, שיכלול את תיאור הניסויים המקדימים ואת תוצאותיהם.

ה. תוצאות 2-4 עמודים

> פרק זה מציג בדרכים שונות, את התוצאות המעובדות של הניסוי.

הציגו **רק תוצאות מעובדות,** שיכללו ממוצעים וסטיות תקן, ולפי הנדרש גם עיבודים נוספים. התוצאות יוצגו בטבלאות ובגרפים, שילוו בתיאור מילולי קצר. לכל גרף תצורף טבלת נתונים. ניתן להציג תוצאות <u>גם</u> בצילומים, בסכמות ובדרכים נוספות.
את התוצאות הגולמיות הציגו בנספח מספר 2 והפנו אליו מפרק זה.
שימו ❤:

א. בחלק זה **אין לדון בתוצאות או לפרשן,** אלא לדווח עליהן באופן מדויק. בתיאור יש להתייחס למגמות, לנקודות שינוי של מגמות, ולמקרי קיצון.
ב. הקפידו על בניית טבלאות והצגות גרפיות כמקובל. עיבוד הנתונים והצגתם הגרפית יבוצעו בגיליון אלקטרוני.
ג. הקפידו להציג רק ממצאים רלוונטיים לנושא העבודה.
ד. הימנעו מריבוי איורים וטבלאות שלא לצורך.

ו. מסקנות ודיון 2-3 עמודים

> פרק זה קושר בין חלקי העבודה ומסכם אותה, בראיה רחבה ובהתייחסות ביקורתית.

כתבו את הדיון **ברצף**, וכללו בו סעיפים אלה:

א. רשמו את השאלה וההשערה שנבדקה, וקבעו האם תוצאות הניסוי מאששות את ההשערה או דוחות אותה, תוך הפנייה ברורה לתוצאות התומכות בכך.
ב. נסחו **מסקנה** (או מסקנות) המבוססת על תוצאות הניסוי. הסבירו את המסקנה תוך **קישור לידע ביולוגי מבוסס**.
ג. אם יש מסקנות נוספות, שאינן תשובה ישירה לשאלת החקר, ציינו והסבירו גם אותן, תוך הפנייה לתוצאות.
ד. אם התקבלו תוצאות בלתי צפויות, או שונות מהמדווח בספרות, התייחסו אליהן, והציעו הסבר אפשרי לשוני.
ה. אם בדקתם שאלת חקר נוספת חזרו על הסעיפים א' עד ד' גם לגבי שאלה זו.

בחנו את מסקנותיכם מהחקר שבצעתם **באופן ביקורתי**. התייחסו להיקף החקר (ריבוי פריטים, חזרות, גודל סטיות התקן), ולמערך הניסוי (הטיפולים, שיטות המדידה, הבקרות, הקבועים) וכן למגבלות הניסוי, כולל תקלות שאירעו. לצורך כתיבת סעיף זה תוכלו לשאול את עצמכם: אם היינו מתחילים את הניסוי מחדש על מה חשוב היה להקפיד?
שימו ❤: המסקנות מושפעות מהנכתב בסעיף זה, ומומלץ לשלב אותו בסעיפים הקודמים.

ו. הסבירו את התופעה הביולוגית, או הבהירו את הפתרון הביולוגי לבעיה היישומית שהיוו נקודת מוצא לעבודת החקר. שלבו בהסבר את המידע החדש שצברתם בעבודתכם עם הרקע העיוני, כך שתתקבל תמונה כוללת של הנושא שנחקר. אם בדקתם שתי שאלות ההסבר יכלול התייחסות לממצאים שהתקבלו בשתיהן. אם הדבר רלוונטי התייחסו להבדלים בין תופעות שנצפו בטבע לבין הניסויים שבצעתם במעבדה.

ז. שלבו בפרק זה מידע רלוונטי על הניסויים שמקדימים. אם לא בצעתם ניסויים מקדימים, עליכם להתייחס בפרק הדיון גם **לשאלת המשך החקר**. נסחו את השאלה בבירור, והבהירו את חשיבותה להבנת הנושא שנחקר. הפנו אל נספח מספר 3 בעבודתכם שיכלול תכנון מפורט לבדיקת השאלה.

מבט על:

בחנו את הנושא אותו חקרתם גם בראיה ביולוגית רחבה. בחרו אחד מבין **הרעיונות המרכזיים בביולוגיה** וקשרו אותו לעבודתכם. *רשימת הרעיונות המרכזיים בביולוגיה: ארגון במערכות ביולוגיות, ויסות והומיאוסטזיס, יחסי גומלין וקיום שיווי משקל דינמי, אחידות בעקרונות המבנה והתפקוד ושוני בצורה, התאמה בין מבנה לתפקוד, המשכיות תורשתית ורבייה, העברת מידע מדור לדור, גדילה והתפתחות, תיאורית האבולוציה.* (פירוט של הרעיונות המרכזיים בביולוגיה נמצא בנספח III). תוכלו לקשר את הרעיון לתוצאות הניסוי, לתכנים ביולוגיים רלוונטיים בהם עסקתם בעבודה, או לכל היבט אחר של העבודה.

שימו ♥:

א. לכל ממצא בפרק התוצאות חייבת להיות התייחסות בפרק המסקנות.

ב. בכל התייחסות למידע מהספרות יש לרשום **הפניה** אל המקורות עליהם מבוסס המידע. בנספח I מוסבר אופן כתיבת ההפניה.

ג. את הדיון כתבו באופן רציף כחיבור, ולא כקטעים וביניהם כותרות משנה.

ד. הדיון צריך לתת תמונה כוללת של הנושא הנחקר.

ה. זכרו את מגבלות החקר שבצעתם והימנעו מהכללות **וממסקנות גורפות**.

ז. רשימת מקורות

- רשימת המקורות תכלול לפחות **ארבעה** מקורות מידע מהימנים.
- הרשימה תכתב לפי אחת השיטות המקובלות.
- חובה להפנות אל רשימת המקורות מגוף העבודה.
- אין לכלול ברשימה מקורות שאין אליהם הפניה מגוף העבודה.

בנספח I מובאים כללי כתיבה לרישום המקורות, וכללי הפניה לרשימת המקורות מגוף העבודה.
בנספח II מובאים כללים ו"טיפים" לבדיקת אמינות מקורות מידע, בדגש על מידע ברשת האינטרנט.

ח. נספחים לעבודה

עבודת החקר **חייבת** לכלול את שלושת הנספחים האלה:

נספח מספר 1: תכנון ניסוי לפי דף עזר לתכנון הניסוי (לשאלה אחת או לשתי השאלות).
נספח מספר 2: תוצאות גולמיות של הניסוי.
נספח מספר 3: תוצאות הניסוי המקדים, או תכנון מפורט של שאלת המשך.

אל כל נספח תהייה **הפנייה** מהמקום המתאים בגוף העבודה.

כללי הגשת העבודה

1. העבודה חייבת לכלול תוכן עניינים ועמודים ממוספרים.
2. העבודה תודפס בגופן בגודל 11-13, ותכלול שוליים ורווחים נוחים לקריאה.
3. אין לניילן את הדפים (פרט לתמונות או מוצגים).
4. אל העבודה יצורפו דפים אישיים של כל אחד מכותבי העבודה, ודוחות סיור של כל הכותבים.