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Scientific Writing in Undergraduate Science Curricula

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Scientific Writing in Undergraduate Science Curricula

Scientific Writing in Undergraduate Science Curricula

Reading and Analyzing Research Articles to Support Physics and
Biology Students' Written Argument Construction

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door

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te Amersfoort

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CHAPTER 1

Introduction

Reading and writing are inextricably linked to the very nature and fabric of science, and, by extension, to learning science. Take them away and there goes science and proper science learning also, just as surely as removing observation, measurement, and experiment would destroy science and proper science learning.

(Norris & Phillips, 2003, p. 226)

RATIONALE OF THE RESEARCH

Writing is one of the many professional activities in a scientist's practice (Erduran & Dagher, 2014; Norris & Phillips, 2003). Scientists are engaged in writing a variety of text genres¹ to communicate about their research, for instance, research articles for the scientific community or popular science articles for a broader (non-experts) audience (Erduran & Dagher, 2014; Yarden, Norris, & Phillips, 2015; Yore, Florence, Pearson, & Weaver, 2006; Yore, Hand, & Prain, 2002). Yore et al. (2006) emphasized the importance of written communication in research articles:

... [it] documents the detailed associations among evidence, warrants, and claims; makes utterances permanent; allows scientists to share ideas and complement each other's work and to take time to reflect on their thoughts, mental images, claims, and explanations; and establish proprietorship of intellectual properties. (p. 110)

Research has shown that scientists spend a significant amount of their working time on reading and writing of scientific texts (Tenopir & King, 2008; Tenopir et al., 2003; Yarden et al., 2015). Expert science writers apply domain and topic knowledge, have routinized writing strategies (like planning, drafting, and revising activities), have metacognitive skills (e.g., the ability to guide and monitor their writing), and direct their writing to their purpose and target audience (Fox, 2009; Holliday, 1992; Rijlaarsdam et al., 2012; Yore et al., 2002). Text genres that are used in the communication among

¹ A class of text genres that are used in the communication among scientists fall under two broad groups: formative and integrative genres (Goldman & Bisanz, 2002). Formative genres shape a scientist's thinking during research and reflect new scientific knowledge. Examples of formative genres are laboratory notes, conference papers and research articles. The latter two reporting about original research are called primary literature (Day, 1998). Integrative genres are texts that contain syntheses about known and accepted scientific knowledge (so far), like a review article, theoretical paper, or a book chapter. These texts are based on primary literature and are used to present and evaluate an overview of current research findings and identify knowledge gaps (Yarden et al., 2015). Scientists also use text genres to popularize scientific information to a general public, like journalistic reports, or to instruct students, like textbooks. Together with integrative genres, these genres are also referred to as secondary literature (Day, 1998).

scientists, like research articles or literature review articles, are characterized by their argumentative nature. Research findings are presented in a way that convinces the scientific community about the asserted claims. This means that scientific writing has above all a rhetorical and persuasive nature and includes argument construction (Florence & Yore, 2004; Penrose & Katz, 2004; Yore, Bisanz, & Hand, 2003). Argument is defined here as the justification of a claim by data (Toulmin, 1958). These scientific texts have also some other features in common: a typical text structure, high information density, jargon, visual images (figures, graphs, and tables), and scientific language use, like an authoritative passive voice, abstract language (e.g., the use of nominalization), and metadiscourse² (Fang, 2005; Hoadley-Maidment, 2000; Penrose & Katz, 2004; Yore et al., 2003).

Given the prominent role of scientific writing in science, it is expected that undergraduate students pursuing science studies should become able to communicate scientific information to different audiences, both the scientific community and the general public. Therefore, students should not only have knowledge about their scientific discipline, its language (e.g., jargon), and general features of academic writing (e.g., citing literature references), but they should also have an understanding of the argumentative nature of scientific discourse, its text genres and functions, and the corresponding text rules and conventions (Hoadley-Maidment, 2000; Yore et al., 2006). To achieve this goal, university students need to be acquainted with the text genres common in science and need to be trained to use the rhetorical demands needed to write such texts in order to enculturate as member of the scientific community (Yore et al., 2006). Enculturation is defined here as “a process whereby the novice learns what counts in a particular discipline” (Florence & Yore, 2004, p. 642). The importance of supporting students’ writing abilities throughout their undergraduate studies becomes even more relevant, because writing is key and a measure of academic success and professional advancement (Breeze, 2012; Hyland, 2016; Kellogg & Raulerson III, 2007; Meestringa, 2011; Newell et al., 2011; Raad voor de Nederlandse Taal en Letteren, 2015). For instance, writing promotes students’ science concept learning (Choi, Hand, & Greenbowe, 2013). Moreover, as research findings showed, writing supports students’ scientific literacy in terms of understanding scientific research (Jiménez-Aleixandre & Erduran, 2008; Norris & Phillips, 2003; Treacy & Kosinski-Collins, 2011).

However, existing research shows that scientific writing poses challenges to undergraduate students. Kellogg (2008) characterizes it as a complex and cognitively demanding task. Undergraduate students are often not used to writing extensive and coherent texts. Research has shown that undergraduate students are frequently

unprepared to meet the requirements of argumentative writing at university (Hirvela, 2017; Wingate, 2012). As Breeze (2012) argued: “in many countries, undergraduates in the sciences may rarely write continuous text, and those who go on to do research may experience considerable difficulty when faced with the task of writing up their first paper” (p. 31). These writing difficulties undergraduate students encounter are, for instance, structuring and expressing information accurately (Breeze, 2012; Daems & van der Westen, 2008; De Wachter & Heeren, 2011; Galbraith & Rijlaarsdam, 1999; Herelixka & Verhulst, 2014; Raad voor de Nederlandse Taal en Letteren, 2015). As evident in literature, students also encounter difficulties with constructing written arguments (Kelly, Regev, & Prothero, 2008; Newell et al., 2011; Sampson & Clark, 2008). Moreover, undergraduate students may encounter difficulties when entering a new discourse community, such as a specific science community, in which they will come across many different text genres. These difficulties are partly due to a misalignment between faculty members and students in their expectations for writing (Lea & Street, 1998) or the unclear requirements and assessment criteria in writing tasks (Herelixka & Verhulst, 2014).

In some countries, research has been initiated to examine how to support university students’ writing development and how to integrate writing instruction in higher education (cf. Cronje, Murray, Rohlinger, & Wellnitz, 2013; Gamberi & Hall, 2019; Russell, Lea, Parker, Street, & Donahue, 2009). However, in Europe, and more specifically in the Netherlands, which is the context of the study, structurally integrated writing instruction in undergraduate science programs is not common practice yet (Björk, Bräuer, Rienecker, & Stray Jörgensen, 2003; Coil, Wenderoth, Cunningham, & Dirks, 2010; Daems & van der Westen, 2008; Herelixka & Verhulst, 2014; Raad voor de Nederlandse Taal en Letteren, 2015; Tribble & Wingate, 2013). This calls for the need for effective writing education and for a structural embedding of writing instruction in university science curricula (Breeze, 2012; Coil et al., 2010; De Wachter & Heeren, 2011; European Language Council, 2013; Herelixka & Verhulst, 2014; Raad voor de Nederlandse Taal en Letteren, 2015). Therefore, the main purpose of the research presented in this thesis is to explore how undergraduate science students can be supported in developing their scientific writing skills. To address this goal, we developed, implemented, and evaluated a teaching strategy using discipline-specific writing instruction in two undergraduate science courses.

WRITING INSTRUCTION IN HIGHER EDUCATION

Next, we briefly discuss and illustrate the different points of departure to approach writing and its instruction in higher education institutions.

Writing may be considered as a generic skill to be learned and applied in different contexts (Hyland, 2016; Ivanič, 2004; Lea & Street, 1998). Following this perspective,

² Metadiscourse is a term used for linguistic means that help a writer to construct an argument, for example, words that connect statements or words to express a stance (Hyland, 2016).

the focus in writing lies primarily on the product and formal linguistic features, like text structure, grammar, and spelling. In educational practice, such a skill-based perspective is translated to writing instruction teaching students general features of academic writing, like using academic (English) language (Baynham, 2000). Students learn to apply grammar and text convention rules in an accurate way (Hyland, 2016). Traditionally, writing instruction mainly followed this product-based approach, but nowadays students' writing processes are more emphasized (De La Paz & McCutchen, 2011; Ivanič, 2004). Writing is then conceived as an individual problem-solving activity. The cognitive performance of a skilled writer – the processes and knowledge involved during the act of composing – is central (Alamargot & Chanquoy, 2001; Graham, Gillespie, & McKeown, 2013). Frequently used in educational practice is the model of writing developed by Flower and Hayes (1981) and later revisited by Hayes (1996), which considers the role of the writer's cognitive processes during composition. These processes refer to three activities: planning (e.g., goal-setting), translating (i.e., text production) and reviewing (i.e., evaluating and revising). The model developed by Flower and Hayes in addition to other theories about cognitive processes and strategies in writing have had huge influence on L1 (first language) and L2 (second language) writing instruction and led to, for instance, the use of pre-writing, drafting, and revising activities in literacy courses. Generic writing instruction that focuses on students' texts and/or their writing processes often manifests itself in extracurricular support. This could take the form of either individual support offered by writing centers, where (graduate student) tutors support students' writing, or in remedial writing courses. The instruction is often provided by language experts with special attention for international students, or underachieving students, whose participation is based on their results in an entrance language test (Daems & van der Westen, 2008; Herelixka & Verhulst, 2014).

A different point of view on writing is derived from understanding text as discourse. This means that texts are immersed in social actions, reflecting a specific function, which vary across contexts (Galbraith & Rijlaarsdam, 1999). Texts may be divided in different genres based on similarities in text features to attain a specific purpose in a social context (Hyland, 2003; Paltridge, 2014; Swales, 1990). Genres can be described as “abstract, socially recognized ways of using language” (Hyland, 2016, p. 7). In the context of writing pedagogies, this perspective of text genres corresponds to the use of genre-based writing instruction. This instruction aims at giving students control over a genre by familiarizing them with its rhetorical characteristics, goals, and social contexts to gain access to the discourse community (Hyland, 2007). Genre-based writing instruction considers writing as having a social function: text genres have a specific communicative function in a social context. Particularly, genre approaches are taught by language experts in English for Academic Purposes (EAP) university courses for non-native speakers of English to prepare them for academic writing tasks focusing on broad academic text genres (Tribble & Wingate, 2013). Students,

often in small groups, analyze and compare samples of a genre: a process intended to raise students' rhetorical consciousness (Hyland, 2007; Swales, 1990). In some cases, these genre approaches are departing from the product: the written texts. When the social context is highlighted with the influence of personal, social, cultural, and institutional factors, writing is seen as “a social practice rather than as an abstract skill separable from people and the places where they use texts” (Hyland, 2016, “Literacy and Expertise”, para. 1). Hence, writing and knowledge are constructed in a social context, i.e., the discourse community; the language that is used differs according to the function and purposes reflecting the habits, conventions, values and rules in this specific context (Bazerman, 1988; Gibbons, 2002). In educational practice this view is reflected in stimulating dialogues between students about the meaning and practices of disciplinary writing and the variations that exist among disciplines and courses (Russell et al., 2009; Wingate & Tribble, 2012).

There is a growing recognition that academic writing is subject-specific and cannot be taught separated from disciplinary knowledge (De La Paz & McCutchen, 2011; Russell et al., 2009; Wingate, 2011). The development of writing abilities is considered to be tied to a discipline and, therefore, instruction should be directed to the discipline-specific knowledge and its construction. Such an embedded approach marks a shift towards writing to be structurally integrated in mainstream subject-specific courses in connection to teaching and learning disciplinary content. Writing is then “an integral, ongoing part of disciplinary learning for all students” (Mitchell & Evison, 2006, p. 72). In a fully embedded form, writing instruction requires a high involvement of subject lecturers who take on responsibility for supporting students' writing, and it requires writing tasks addressing discipline-specific genres. A benefit of this form is that it offers a mainstream and inclusive writing instruction for all students who follow the program (Ganobcsik-Williams, 2004; Wingate & Tribble, 2012). The subject lecturers are members of a community of practice and therefore could draw on their expertise in writing and enhance the relevance of writing in the discipline to their students (Wingate, 2011). However, such an approach is not without challenges. For example, subject lecturers might be reluctant to teach writing, as they feel not being responsible for teaching literacy skills or they feel not sufficiently competent in teaching writing (Blake & Pates, 2010; Wingate, Andon, & Cogo, 2011). An example of writing and disciplinary content interwoven in a curriculum is the Writing Across the Curriculum (WAC) movement, originating from the United States. Here, writing instruction is embedded in multiple courses of a degree program involving all subject lecturers, thus increasing the frequency and quality of writing and content learning in university curricula (Bazerman et al., 2005; Russell et al., 2009). Within this movement, the emphasis on learning to write in a specific discipline (e.g., what does it mean to write like a biologist?) and applying discipline-specific conventions is referred to as Writing in the Disciplines (WID): discipline-specific writing instruction, generally offered by subject lecturers (Bazerman et al., 2005; Mitchell & Evison, 2006; Wingate & Tribble,

2012). In higher education settings in the United States writing instruction embedded in disciplinary teaching and learning is much more common than in European higher education institutions (Björk et al. 2003; Raad voor de Nederlandse Taal en Letteren, 2015; Tribble & Wingate, 2013).

RESEARCH SETTING

This study took place at the University of Groningen, a large public research university in the northern part of the Netherlands. The Faculty of Science and Engineering offers 13 undergraduate science degree programs, such as Astronomy, Biology, Industrial Engineering & Management, Artificial Intelligence, Physics, Mathematics, and Chemistry. A total number of 2541 students has been registered in the undergraduate degree programs (academic year 2012-2013, the moment the research project started). The number of students has increased during the last years to 3677 registered undergraduates in 2017-2018, mainly due to an increase of international students (Faculty of Science and Engineering, 2019). From the academic year 2019-2020 all programs are taught in English³ and students are required to write in English. This means that the Dutch participants involved in our research are generally L2 students, meaning that English is not their first language.

In the Dutch university system, it is common that students have an early specialization (e.g., an undergraduate program in physics), which is different from colleges and universities in the United States and other countries, where university students have two years of general courses and write in different disciplines. In the United States it is common that students follow a general writing course in their first year: the typical composition course. In our research context, no general composition courses are offered to (first-year) university students in the undergraduate science degree programs. In the first year there is a focus on acquiring subject knowledge and basic laboratory skills. Apart from textbooks, primary literature, such as research articles, is used increasingly at later stages of the programs. In the third and last year of the undergraduate degree programs students plan and carry out a research project in one of the faculty's research groups, write a report – usually their bachelor thesis – and deliver a presentation (Faculty of Science and Engineering, 2019).

3 During the intervention and data collection, the undergraduate degree programs Biology, Life Science and Technology, and Pharmacy used Dutch as the language of instruction. Students following these programs are often required to write in English.

RESEARCH PURPOSE

In response to concerns about the limited writing instruction in undergraduate science programs in the Netherlands and students' writing difficulties, this thesis reports on an investigation about how undergraduate science students in our local research context could be supported in their scientific writing skills. We choose genre-based writing instruction, since international literature suggests it is promising to support students in the rhetorical demands needed when writing in a specific science discipline. Next to that, genre-based writing could be embedded in undergraduate science courses and requires involvement of subject experts to provide meaningful writing tasks. In doing so, we address an underexplored research area in the context of undergraduate science programs in the Netherlands. We decided to select one component of scientific writing – students' written argument construction – because, as we previously discussed, argumentation is an important characteristic of scientific discourse.

For the purpose of this study, we developed, implemented, and evaluated a research-based teaching strategy to support undergraduate science students' written argument construction. In our discipline-specific approach of genre-based writing instruction we used text analysis tasks to introduce students explicitly to the characteristics of a text genre. We were primarily concerned with the research article genre and its argumentation and rhetorical genre characteristics. Working from a reading-writing perspective, we combined reading and writing activities and included reading-based writing tasks drawing parallels between writing and reading. These ideas were translated in a presupposition that was used to develop the teaching strategy and could inform educational practice. Hence, the main research question that guided this research is the following:

How does a teaching strategy using genre-based writing instruction and reading of research articles support science undergraduates' written argument construction?

RESEARCH DESIGN

In this section, we introduce our research approach and the four different research studies. We refer to the corresponding chapters that include the details about each study. In Figure 1.1 we present a schematic representation of the research trajectory.

Figure 1.1. Schematic overview of the research trajectory.

Design Research

We used design research^{4,5} as our overall research approach to respond to the main research question. Barab and Squire (2004) describe design research as “a series of approaches, with the intent of producing new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings” (p. 2). More specifically, it is “a genre of research in which the iterative development of solutions to practical and complex educational problems also provides the context for empirical investigation, which yields theoretical understanding that can inform the work of others” (McKenney & Reeves, 2012, p. 7), like curriculum and course designers. The overall aim of this type of research is to address an educational problem and involves developing, implementing, and evaluating a research-based design, like a teaching strategy or learning materials, in a natural setting. Design research has an iterative character: educational design and research are intertwined and involves cycles of analysis, development, evaluation, and revision (Bakker, 2018; Collins, Joseph, & Bielaczyc, 2004; Plomp, 2013; Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006). The purpose of design research is twofold. On the one hand, design research has a practice-oriented purpose: the approach aims at developing and optimizing an intervention, i.e., a research-based intervention as a solution to a complex educational problem. On the other hand, design research has a theory-oriented purpose: it aims at developing and testing knowledge about whether and why an intervention works to achieve an educational goal in a particular context (Bakker, 2018; McKenney & Reeves, 2012; Plomp, 2013). The resulting theoretical knowledge⁶ of design research is tied to a specific context, and is often of a humble nature. The knowledge is often presented in terms of design principles (cf. Van den Akker, 1999). A design principle can be conceived as a heuristic statement, a guideline, advice, or prediction (Bakker, 2018; Van den Akker, 1999).

For the purpose of this research we developed, implemented, and evaluated a teaching strategy based on ideas from genre-based writing instruction and reading-writing connections to improve local teaching and learning in students' scientific

4 Design research in education could be used as an umbrella term for a related set of research approaches originated from different research traditions and practices, like developmental research, design-based research, educational design research, or design experiments (Bakker, 2018).

5 In contrast to other research approaches, like experiments or surveys, a design research project consists of multiple studies using different approaches. For example, a survey could be used for a needs analysis prior to developing educational material. An experimental design could be used to test and evaluate the effectiveness of an intervention, or a case study approach is used to examine students' processes during the intervention (Bakker, 2018).

6 Dependent on the research tradition, the knowledge is presented as conjecture maps (Sandoval, 2014), a local instruction theory (Gravemeijer & Cobb, 2013), or hypothetical learning trajectories (Bakker, 2018).

writing. To express our ideas and assumptions, we used a presupposition instead of a design principle, which guided the development of the teaching strategy. A design principle suggests a focus on investigating precisely how and why an intervention works, which is not the main purpose of the present research. Instead, the focus of this research was on evaluating the presupposition realized in a teaching strategy by examining students' written texts. Design research enabled us to look at the effects of the teaching strategy itself by means of a systematic evaluation, and allows us to investigate in-depth students' written texts with a focus on their argument construction. We implemented and tested the teaching strategy in two science courses, enabling us to explore the usability of our teaching strategy and the underlying presupposition in different educational settings. In the next sections, we briefly introduce our four research studies reflecting the preliminary, development, implementation and evaluation phases typical for design research. See Figure 1.1 for a schematic overview of the different phases.

Preliminary Phase

For the purpose of this research we first carried out an exploratory study in a preliminary phase, a typical phase in design research. Our aim was to elucidate and explore current writing instruction and student writing abilities in a local context: undergraduate courses in the Faculty of Science and Engineering of the University of Groningen in the Netherlands. With this study we aimed to gain a better understanding of the needs in student writing in order to develop and implement our teaching strategy. We examined faculty members' experiences and beliefs about student writing and writing instruction by interviewing faculty members from four undergraduate science degree programs (astronomy, biology, chemistry, and physics). Next, we analyzed undergraduate biology and physics students' theses to gain more insight into students' abilities in scientific writing, more specifically their argument construction. We present the research study in Chapter 2.

Development Phase

The findings of the exploratory study (Chapter 2) showed that there is a need to integrate writing instruction structurally in the undergraduate science degree programs. In the second phase of the research we developed a teaching strategy aimed at supporting students' scientific writing skills, in particular their argument construction. We formulated a presupposition using ideas from genre-based writing instruction and reading-writing connections that lie behind the teaching strategy, which is formulated as:

Use of authentic research articles with a focus on argumentation and rhetorical genre characteristics combined with reading and writing activities will contribute to students' written argument construction.

We chose to use genre-based writing instruction, a type of discipline-specific writing instruction, in our teaching strategy involving subject lecturers in the course development and teaching. In this way, we draw on their expertise in reading and writing scientific texts in their specific research discipline. Genre-based writing instruction aims at explicitly teaching students about the genre characteristics of a text genre, for instance, by using text analysis tasks. In our teaching strategy, we used the research article genre as a model. The research article is the predominant text genre in scientific discourse, because of its accessibility to peers and the peer review process guaranteeing its quality (Penrose & Katz, 2004; Yarden et al., 2015; Yore et al., 2002). This genre is essential in scientific discourse as "it drives science writing toward the discipline's norms, values and ideology, and a rather narrow set of writing strategies, knowledge representations, and expectations of writing" (Yore et al., 2002, p. 676). Reading research articles is an authentic scientific practice and it can promote scientific thinking (Gillen, 2006; Yarden et al., 2015). Research articles are nowadays used more than ever in tertiary educational contexts, for instance, in journal clubs, in which students present and discuss a research article to fellow students (e.g., Kozeracki, Carey, Colicelli, & Levis-Fitzgerald, 2006). For these reasons, we used authentic (non-adapted and not translated) research articles in the teaching strategy to introduce students to scientific writing.

Genre-based writing instruction concerns explicit instruction in genre characteristics of a text genre. Since we aimed at supporting students' argument construction, we focus on the argumentation and rhetorical genre characteristics of research articles. We were particularly concerned with introducing students to the rhetorical structure: a set of text fragments contributing to the line of reasoning in a research article, which runs from the study's reason and the research purpose towards the claim justified by evidence. This justification of a claim by evidence represents an argument (Connor, Upton, & Kanoksilapatham, 2007; Swales, 1990; Toulmin, 1958; Van Lacum, Koeneman, Ossevoort, & Goedhart, 2016). Recognizing the rhetorical structure of scientific text genres, referred to as rhetorical consciousness, is essential in getting acquainted with a text genre (Swales, 1990; Yarden et al., 2015), and is part of genre knowledge (Tardy, 2009a). Norris and Phillips (2003) stated that for the reading of scientific texts it is crucial that one recognizes and understands the specific text elements, for instance, an inference, a conclusion, and the corresponding evidence. As they stated, "if these general meanings are missed, then the reader not only has read poorly, the reader has failed to grasp the scientific meaning beyond the surface content level and failed to grasp science" (p. 235). To point students to the rhetorical structure of research articles we used a heuristic: the Scientific Argumentation Model (SAM),

⁷ Faculty members are understood here as university academic staff with teaching responsibilities in (under)graduate science degree programs. We refer interchangeably to subject lecturers or subject experts to indicate that they lecture discipline-specific content courses and no language or writing courses, like language teachers or language experts do.

developed by Van Lacum et al. (2016). This heuristic was designed to support life science undergraduates in reading and understanding a research article's argument focusing explicitly on the rhetorical structure of a research article by pointing to specific text fragments with a specific communicative function, for example, a main conclusion (Figure 1.2). We refer to Chapter 3 for a detailed discussion of the SAM heuristic. We assumed that SAM as a heuristic will help students to understand the main argument put forward in a research article by developing their rhetorical consciousness needed for writing a scientific text.

We assume that reading and analysis tasks can help students to construct arguments in their written texts. In turn, practice in constructing arguments may contribute to students' reading skills. This implies a reciprocal relationship between reading and writing. Literature on reading-writing connections suggests the beneficial effects of reading on writing, and vice versa (Brownell, Price, & Steinman, 2013; Grabe, 2003; Newell et al., 2011; Spivey, 1997). More details are shared in Chapters 3 and 4. Our assumption was that reading authentic research articles with the aid of SAM would support students in developing their rhetorical consciousness and that, in turn, might strengthen them in constructing written arguments and developing their scientific writing skills. We believe that SAM could act both as a reading and writing heuristic for undergraduate science students in the process of written argument construction, which has not been explored yet. For this reason, we combined reading and writing activities in the teaching strategy using reading-based writing tasks: a summary of a research article and a synthesis (review) of two research articles. These tasks required students to (re)construct an argument from research articles' content. Herewith, we draw parallels between reading and writing.

Figure 1.2. Scientific Argumentation Model (from Van Lacum et al., 2016).

In short, we assumed the scientific research article genre with its argumentation and rhetorical genre characteristics could serve as a model for science undergraduates to construct a written argument using reading, analyzing, and writing activities. The core of the teaching strategy with its underlying presupposition is presented schematically in Figure 1.3.

To evaluate the presupposition we developed an intervention using an activity cycle that was repeated multiple times. First, the course lecturers introduced the students to the argumentation and rhetorical genre characteristics using authentic research article examples and SAM. They used modeling for the identification and recognition of the characteristics. Second, in individual text analysis tasks students read and analyzed a research article and answered questions about the subject content and the genre characteristics. Third, in group meetings, the students and the course lecturers discussed the research article and the accompanying text analysis tasks. The genre characteristics of research articles are made explicit and become visible to students by guiding them in different stages through the rhetorical structure of authentic research articles. Finally, the students received a reading-based writing task (summary, review). We included also additional pre-writing, drafting, and revising activities in the course.

Figure 1.3. Simplified overview of the teaching strategy with the underlying presupposition embedded in an undergraduate science course with its activities, tasks, and heuristic aimed at supporting students' written argument construction.

Implementation and Evaluation Phase

Our next step was to implement and evaluate the teaching strategy, based on the presupposition, aiming at an understanding of students' written arguments when using SAM. The context for the study was defined by two first-year courses: Physics of Life for physics students and Biomolecular Research (*Biomoleculair Onderzoek 1*) for biology students. The participating students had little or no prior experience in scientific writing and reading of research articles. The lecturers from both courses wanted to support students in their writing of scientific texts and reading of research articles by giving more attention to these skills in the courses. We implemented the teaching strategy with the same course set-up twice in each course. These course editions were implemented in two consecutive years. The first course editions were used as pilot studies to evaluate the course set-up, educational material, and the research instruments. During and after these implementations the course was evaluated and revised for a second implementation. Here, the iterative character of design research becomes evident. By implementing the teaching strategy in two different courses we compared the use of the teaching strategy in different educational contexts and examined its transferability. Chapters 3 and 4 provide a detailed description of the courses and the teaching strategy.

Students' argument reconstruction

The research study conducted in the Physics of Life course was a small-scale case study. Our main purpose was, as a first step in exploring our teaching strategy and presupposition, to examine whether undergraduate physics students could identify and reconstruct a research article's argument in a written summary when following our teaching strategy. We chose a summary as a writing task because it could demonstrate students' argument reconstruction. In addition, we examined how the students perceived the use of SAM as a scaffolding tool for reading and summarizing a research article. In Chapter 3 we report the findings of this research study.

Students' argument construction

Next, we implemented the teaching strategy in the undergraduate biology course Biomolecular Research. Our research interest was to continue testing our presupposition and to replicate testing the teaching strategy. As an extension of the study done in the physics context, we investigated how students construct an argument based on research articles. We explored how the students synthesized two research articles in a literature review when engaged with SAM. The two articles reported different but complementary results. We chose for a brief literature review, because the written text requires including the most important components of the source texts to build an argument: a conclusion should be drawn based on the source texts. In addition, a literature review asks for a critical evaluation of the articles' content, which provides clues about students' critical reading skills, and their article comprehension. Our secondary purpose in this study was to examine the students'

reading and writing experiences using SAM and the course lecturers' perceptions about the students' use of SAM in reading and writing texts. This research study is described in Chapter 4.

Students' scientific epistemologies in relation to their writing

In the fourth study, described in Chapter 5, we aimed at examining students' scientific epistemologies in relation to their writing in the context of the Biomolecular Research course. Scientific epistemologies refer to the beliefs someone holds about the nature of scientific knowledge and its construction (Sandoval, 2005). Prior research has led to different and contrasting conclusions whether students' scientific epistemologies have an effect on students' writing or vice versa (Khishfe, 2012; Neely, 2014; Sandoval, 2005; Yarden et al., 2015). Therefore, we aimed for an examination of the students' evaluation of and writing about two research articles in their review in relation to their scientific epistemologies.

SIGNIFICANCE

This research aims to contribute to the knowledge base about supporting undergraduate science students in scientific writing, and specifically how genre-based writing instruction could be embedded in an undergraduate science course combined with scientific reading activities. The findings have pedagogical implications on how to strengthen students' written arguments and add to existing literature on students' written argumentation at tertiary level. The practical yield of the research is an evaluated and revised research-based teaching strategy to support undergraduates' scientific writing for, initially, our local research context. We tested the transferability of the teaching strategy by implementing it in two undergraduate science courses from different science domains, which may yield insight in using it in other, comparable educational settings as well. In addition, the development of the teaching strategy results in a set of teaching and learning materials to be used and adapted in other science literacy settings, including a general course design and manual, domain-specific reading and writing assignments, and assessment instruments to evaluate and grade students' written texts.

CHAPTER 2

Faculty Members' Experiences and Beliefs
about Scientific Writing Instruction and
Undergraduate Students' Writing Abilities

ABSTRACT

Students pursuing science studies need to be supported in developing their scientific writing skills to become scientifically literate and in enculturating as member of the scientific community. However, writing instruction is often not structurally embedded in undergraduate science degree programs. Our aim in the present study is to examine writing practices in four undergraduate science degree programs of a Dutch research university. We examined faculty members' experiences and beliefs regarding writing instruction and undergraduates' writing abilities. Data were collected by semi-structured interviews with 16 faculty members with teaching responsibilities from four science disciplines and an argument analysis of 10 undergraduate biology and physics theses. Based on our analysis, the findings showed that (a) faculty members recognizes the importance of writing instruction in undergraduate programs; (b) there is little integrated and explicit writing instruction and a lack of curriculum guidelines in the four science curricula; (c) it is not always clear to subject lecturers how to organize writing instruction and who is responsible; (d) undergraduate students' writing abilities are diverse and students experience different difficulties in writing; and (e) an argument analysis showed that the theses consisted of different argument components, but lacked sufficient justification (esp. in biology) or contained redundant information (esp. in physics). We conclude that there is a need for more structural and consistent support for students' writing and writing instruction by faculty members in the examined science degree programs. In addition, the study is a stimulus to further examine how to support science undergraduates' writing and faculty members in providing writing instruction.

INTRODUCTION

Writing has an indispensable role in scientific practice (Yarden, Norris, & Phillips, 2015). Scientists write scientific texts to communicate their findings to their peers and the public, shaping scientific knowledge (Bazerman, 1988; Penrose & Katz, 2004; Yore, Bisanz, & Hand, 2003). Lea and Stierer (2000) stated that what could be counted as good (scientific) writing depends on a writer's understanding of the culture of an academic discipline. In scientific discourse, the research article is the predominant text genre, and:

represents an extended argument in which researchers seek to convince readers that their research questions are important, their methods were sensibly chosen and carefully carried out, their interpretations of their findings are sound, and their work represents a valid contribution to the developing knowledge of the field. (Penrose & Katz, 2004, p. 40)

Thus, an essential characteristic of scientific writing is the use of argumentation: research findings have to be presented in such a way to convince scientific colleagues about the validity and trustworthiness of the asserted claims (Penrose & Katz, 2004). This rhetorical nature of scientific writing is clearly reflected in scientific text genres. A typical scientific text (e.g., a research article) has an argumentative character, follows often a canonical format (i.e., IMRD: Introduction, Methods, Results, and Discussion sections), and is characterized by its complexity, and appropriate scientific language (e.g., formal vocabulary and expressing uncertainty by hedging) (Day, 1998; Yarden et al., 2015).

The development of writing skills in undergraduate and graduate science degree programs has become one of the primary goals in many countries, like the United Kingdom (Quality Assurance Agency for Higher Education, 2015; Yorke & Knight, 2006) and the United States (American Association for the Advancement of Science, 2011). Undergraduate science students should develop writing skills, because good writing abilities promote scientific literacy (Jiménez-Aleixandre & Erduran, 2008; Norris & Phillips, 2003; Treacy & Kosinski-Collins, 2011), science concept learning (Choi, Hand, & Greenbowe, 2013), as well as academic and professional success (Breeze, 2012; Newell et al., 2011; Raad voor de Nederlandse Taal en Letteren, 2015).

Research has shown that undergraduate students struggle most with text structure and writing coherent texts (Herelixka & Verhulst, 2014). Other difficulties, though to a lesser extent, concern the use of academic style, register (i.e., academic language use), grammar, and spelling (Herelixka & Verhulst, 2014; Jerde & Taper, 2004). Another writing problem is argument construction, more specifically, providing adequate and sufficient evidence for claims in a written text (Kelly, Regev, & Prothero, 2008; Sampson

& Clark, 2008). In addition, students entering higher education often are not used to or familiar with the text types common in academic writing, resulting in a poor alignment between students' and lecturers' expectations for writing (Lea & Street, 1998; Meestringa, 2011). University students are frequently unprepared to meet the requirements academic writing (Hirvela, 2017; Wingate, 2012). These concerns about student writing has led educators, administrators, and policy makers to advocate for more attention to writing instruction in higher education institutions (Herelixa & Verhulst, 2014; Raad voor de Nederlandse Taal en Letteren, 2015). Internationally, research has been initiated on how to integrate writing instruction in higher education and to examine how to support university students' writing development and learning (e.g., the Science Writing Heuristic) (Cronje, Murray, Rohlinger, & Wellnitz, 2013). However, in Europe, and more specifically in the Netherlands, which defines the context of the present study, structurally embedded and explicit writing instruction in undergraduate science programs is not common practice yet (Björk, Bräuer, Rienecker, & Stray Jörgensen, 2003; Herelixa & Verhulst, 2014; Raad voor de Nederlandse Taal en Letteren, 2015).

Hence, in light of above issues, in the present study we examine current writing practices in the context of a Dutch research university. We investigate faculty members' experiences and beliefs about scientific writing instruction and undergraduates' writing abilities to identify possible obstacles in implementing structural writing instruction in science degree programs.

THEORETICAL BACKGROUNDS

Key Movements Student Writing

In the last decades there has been an increase in the intake of students entering higher education from diverse (international) backgrounds in many parts of the world (Björk et al., 2003; Tribble & Wingate, 2013). In response to this increased student influx and widening participation two influential key movements originated in the United States and the United Kingdom that address student writing in higher education: Writing Across the Curriculum and Academic Literacies (Russell, Lea, Parker, Street, & Donahue, 2009).

Writing Across the Curriculum

The Writing Across the Curriculum (WAC) movement originated in the United States in the 1970s and has gained great influence in international higher education settings since. It started as a pedagogical reform movement aimed at improving students' learning and writing by increasing the frequency and quality of writing in university curricula and offers professional support to subject lecturers in writing instruction. These WAC programs focus especially on writing (instruction) embedded

in all subject areas (e.g., biology or history), next to a general first-year composition course, common in the U.S. university system. WAC programs are often combined with individual student support by a writing center (Bazerman et al., 2005; Russell et al., 2009).

WAC programs are elaborated by integrating writing to learn and learning to write activities in a curriculum, which are not mutually exclusive, but are complementary (McLeod & Soven, 2000). Writing to learn activities aim at increasing students' content learning through writing (Hand, 2015; Rijlaarsdam et al., 2012). In university and college science courses writing to learn activities are frequently used nowadays, for instance, in writing-intensive courses (Lankford & vom Saal, 2012; Reynolds, Thaiss, Katkin, & Thompson Jr., 2012; Yore, Hand, & Prain, 2002) and the use of the Science Writing Heuristic (SWH), which promotes college science students' conceptual understanding (Burke, Hand, Poock, & Greenbowe, 2005; Poock, Burke, Greenbowe, & Hand, 2007; Rudd, Greenbowe, & Hand, 2001). Research on writing to learn strategies showed, however, thus far inconclusive results on students' learning outcomes (Klein, 1999; Russell et al., 2009). Some studies showed beneficial effects on students' achievement when using writing to learn strategies, but other studies showed minimal effects on students' learning outcomes (Rijlaarsdam et al., 2012).

Learning to write activities are used to introduce students to the discourse conventions. When it is tied to discipline-specific writing, the term Writing in the Disciplines (WID) is used to indicate the relation between writing and learning in a specific discipline (Russell et al., 2009). WID concerns discipline-specific and embedded writing instruction in a disciplinary curriculum, and is generally offered by subject lecturers (Bazerman et al., 2005; Wingate & Tribble, 2012). Scholars in the WID research field investigate the literate activities common in different disciplines, such as the science discipline. For instance, the seminal work by Bazerman (1988) focused on the historical and social development of the research article genre in the sciences. By understanding literacy activities in the sciences WID scholars try to improve scientific writing instruction by providing guidelines about what constitutes good writing in the science discipline (Bazerman et al., 2005; Yore et al., 2002).

Academic Literacies

Academic Literacies, the second key movement on student writing in higher education, originated in the United Kingdom in the early 1990s (Wingate & Tribble, 2012). In contrast to the WAC movement, which was a pedagogical reform movement, Academic Literacies focused on research and theory and is in particular used as a theoretical and research frame. Later on, it started to focus more on pedagogy (Russell et al., 2009). Within this key movement educational research on student writing in higher education can be interpreted and understood according to three perspectives, proposed by Lea and Street (1998): study skills, academic socialization,

and academic literacies. The first perspective, study skills, assumes writing as a set of generic skills that can be learned and transferred to different contexts. This perspective is sometimes viewed as a deficit model of writing. It focuses on general language features, like grammar. In educational practice this manifests itself in, for instance, remedial writing courses for students. The second perspective, academic socialization, takes at its account the disciplinary context and the enculturation of students in academic discourses. It assumes, and is criticized on it, that academic discourse is homogenous. In other words, to gain access to a particular discourse you should learn the discourse conventions and values. The English for Academic Purposes (EAP)⁸ approach to writing instruction, with a focus on text genres, can be understood as an academic socialization approach. This world-wide pedagogical approach in higher education settings, also used within WAC programs, focuses especially on non-native speakers of English using genre analysis (i.e. comparative linguistic text analyses and analyses of social practices) (Wingate & Tribble, 2012). The criticism towards EAP, or other so-called genre-based approaches, is that they are too text-oriented and prescriptive. In the third perspective, academic literacies, writing is seen as a social practice and is approached from an epistemological level instead of a linguistic level. It takes into account the disciplinary differences, emphasizes (student) identities and social meanings that are constructed collaboratively within the discourse (Lea & Street, 1998; Russell et al., 2009; Wingate & Tribble, 2012). In educational practice one stimulates a dialogue between students and a tutor to familiarize students with disciplinary writing practices, and to give them opportunities to express their feelings about the discourse text conventions. Such approaches, however, are often constrained for mainstream writing education due to limited time and teaching staff (Wingate & Tribble, 2012).

The three perspectives can be compared with the three models on academic writing developed by Baynham (2000). A skills-based approach assumes that generic skills and strategies for writing, such as referencing, can be taught and then applied in specific disciplines, without considering discipline-specific writing requirements. A text-based approach considers the discipline-specific characteristics of a writing task, like a genre, while a practice-based approach emphasizes the social and discursive practices of a discipline. As Baynham (2000) argued, combining the latter two, a text-based and a practice-based approach has potential for effective writing instruction.

The Academic Literacies movement was initiated by the changing academic landscape in the United Kingdom when a more and diverse student population entered

universities (Wingate & Tribble, 2012). In response to the changes in universities and students falling short in standards for writing, Lea and Street (1998) brought to light the differences in interpretations and expectations on writing tasks by academic staff and students by conducting two case studies in two U.K. universities. They used their academic literacies framework to understand university writing practices. This framework assumes writing as a contextualized social practice and emphasizes meaning making and the nature of power relations and identities in academia (Russell et al., 2009; Wingate & Tribble, 2012). Lea and Street showed that academic lecturers were influenced by specific conceptualizations of their own discipline in their assessment of student writing. For instance, underlying disciplinary assumptions give a specific meaning to "argument" in a text. These subject lecturers were able to describe what constitutes a good written text by a student, but failed to make explicit what a good argument looks like. Students experienced difficulty in writing, because of the conflicting and contrasting requirements in writing tasks among courses and disciplines (Lea & Street, 1998).

Student writing in Dutch higher education

The present study took place in the Dutch context, where no prominent key movements, such as WAC or Academic Literacies exist. In general, although Dutch higher education institutions (universities of applied sciences and research universities) acknowledge the need to support students, language proficiency or discipline-specific writing instruction has been given less attention so far, in particular at research universities (Herelixa & Verhulst, 2014). Herelixa and Verhulst (2014) described three types of policy regarding language education in Dutch higher education. The first type is a narrow approach that focuses on students with deficiencies, for instance determined by an entrance language test, and aims to get rid of deficiencies by remedial teaching (e.g., in a writing center). This policy type can be compared with the study skill perspective by Lea and Street (1998). Here, language instruction is not integrated in the curriculum, but extracurricular. A second policy type focuses on all students and their language development in the degree program. Integration of language instruction here is often limited to collaboration between subject experts and language experts in terms of alignment in language requirements in student assignments (Daems & van der Westen, 2008; Wingate & Tribble, 2012). In the third policy type language instruction is systematically interwoven in the curriculum and language proficiency has a central place in the students' assessment, and attempts to give students autonomy and responsibility about their own language development (Daems & van der Westen, 2008). In general, research universities in the Netherlands do not have a university-wide language policy. Although there are many initiatives for a language policy, in particular led by faculty members, within degree programs or faculty departments, these are mainly restricted to entrance language tests or remedial teaching programs (Herelixa & Verhulst, 2014).

⁸ EAP is a branch of English for Specific Purposes (ESP), an applied linguistic research field, just like English for Occupational Purposes (e.g., English use in business or law contexts). EAP focuses solely on academic settings, it refers to "language research and instruction that focuses on the specific communicative needs and practices of particular groups in academic contexts" (Hyland & Hamp-Lyons, 2002, p. 2).

Beliefs about Writing (Instruction)

A different line of research looks at teacher beliefs about scientific writing, which promises to shed light on the way writing instruction is incorporated in a degree program. Beliefs “generally refer to suppositions, commitments, and ideologies” (Calderhead, 1996, p. 715), as distinct from a lecturer’s knowledge: “factual propositions and the understandings that inform skillful action” (Calderhead, 1996, p. 715). Kane, Sandretto, and Heath (2002) distinguished espoused theories of action (i.e., beliefs), the aims and intentions for a specific teaching practice, and theories-in-use (i.e., enacted beliefs), which actually determine a lecturer’s actions in practice. Following Pajares (1992), a person’s beliefs are part of a broader belief system with interconnected belief substructures, such as educational beliefs that in turn can be subdivided into epistemological beliefs, teacher efficacy, or beliefs about specific subjects (e.g., writing instruction). Beliefs directly impact a person’s teaching behavior and can operate as barriers or drivers in implementing instructional practice (Henderson, Beach, & Finkelstein, 2011; Pajares, 1992). Hence, an examination of those beliefs becomes paramount, because the lack of an embedded writing instruction in research universities may depart from lecturers’ beliefs that students already acquired literacy skills before starting college or university and/or that students develop their literacy skills autonomously in post-secondary education. These beliefs are widespread among most faculty administrators and subject lecturers worldwide (Raad voor de Nederlandse Taal en Letteren, 2015; Russell et al., 2009; Wingate & Tribble, 2012). Further, subject experts can hold a resistance towards writing instruction as they feel a lack of time, or they find themselves not competent to teach writing (skills or efficacy), or are reluctant to teach writing (Boice, 1990; Herelixka & Verhulst, 2014; Wingate, 2011; Wingate & Tribble, 2012). Coil, Wenderoth, Cunningham, and Dirks (2010) conducted a survey among 159 faculty members in different higher education institutions to examine their perceptions about science process skills in life science curricula. The results of this study showed that communication skills, both oral and in writing, were considered among the most important student skills. However, more than half of the respondents indicated they felt they did not spend sufficient time on teaching science process skills: the actual time spent on skills was much less than the time spent on content. The main reason for this, as reported by the participants, were the time-consuming character of teaching these skills and the need to cover subject content. Coil et al. (2010) recommend to teaching these skills in undergraduate programs right from the start integrated in course content to improve academic success and support students’ scientific literacy. Mercer-Mapstone and Kuchel (2015) revealed a lack of explicitness how communication skills are taught and assessed in undergraduate science programs at four research universities in Australia. The researchers call for further research that examines whether this lack of explicitness is representative for other (international) undergraduate science degree programs. Mercer-Mapstone and Matthews (2016) showed in a survey ($n = 635$ undergraduate science students from three year levels) at an Australian research university that the

majority of the students perceived communications skills (scientific writing and oral presentation) as important skills to be learned during the degree program. However, they also thought that these skills were not explicitly included and assessed.

RESEARCH AIM AND QUESTIONS

This introduction showed the importance for scientific writing instruction in undergraduate programs. However, research has shown that structural embedding of writing instruction in Dutch university science curricula is frequently lacking (Raad voor de Nederlandse Taal en Letteren, 2015). To explore the situation in our own research context – a science faculty of a research university in the Netherlands – we will examine writing practices in terms of undergraduates’ writing abilities and writing instruction. The data reported here were collected as part of a larger research project to develop and evaluate educational support for scientific writing instruction. Our research aim was twofold. First, we aimed for a better understanding of the kind of writing instruction that currently takes place in our context and students’ writing abilities by interviewing faculty members about their involvement and experiences in teaching writing. We also tried to infer faculty members’ beliefs on writing and writing instruction since they directly impact their teaching behavior. The research question that guided this study is:

What are faculty members’ experiences and beliefs regarding (current) scientific writing instruction and students’ writing abilities in undergraduate science degree programs?

Second, we aimed for a better understanding of students’ scientific writing abilities at the end of their undergraduate degree program by analyzing students’ bachelor theses. We decided to focus on written argument construction, because it is an important characteristic of scientific discourse and it is often difficult for students. The research question that guided our analysis is:

To what extent do undergraduate students construct an argument in their bachelor thesis?

METHODS

We aimed to explore rather than to draw generalizations about the faculty members’ experiences with and beliefs about (current) writing instruction and students’ writing abilities in science degree programs. Therefore, we followed a qualitative multi-sited case study design (Creswell, 2007; Yin, 2014), the case being defined as the science faculty with a specific focus on four undergraduate science degree

programs (astronomy, biology, chemistry, and physics). Insights derived from this study may be transferable to other comparable (inter)national university contexts. We draw on two sources of data. First, we interviewed faculty members from the four science programs about their experiences with and beliefs about bachelor students' writing abilities and writing instruction. Second, we performed an argument analysis of biology and physics students' theses for an in-depth examination of the ways students present different argument components.

Educational Setting

The study was conducted in 2013 at a large public research university in the Netherlands. Its science faculty offers 13 undergraduate science degree programs, such as Biology, Mathematics, Engineering, and Chemistry with a total amount of 2541 registered students in the undergraduate degree programs (academic year 2012-2013). In the Dutch university system it is common to have an early specialization (e.g., an undergraduate program in physics). In the United States, for instance, university students have two general years of education, write in different disciplines, and follow a general writing course in their first year: the typical first-year composition course. In our research context, no general composition courses are offered to (first-year) students. In the science faculty in this study, all programs are English-taught⁹ and students write mainly in English¹⁰.

Data Collection and Analysis

Faculty members' experiences and beliefs

Participants. Our selection of four undergraduate degree programs represents empirical science disciplines (astronomy, biology, chemistry, and physics) and it was expected that scientific writing practices show some overlap. Participants were selected by stratified sampling with variation in research fields as the main selection criterion. Sixteen of the total invited faculty members were willing to participate in an interview. Four faculty members from each science discipline were interviewed. These are coded as A1-4 (astronomy), B1-4 (biology), C1-4 (chemistry), and P1-4 (physics). The participants (six females, 10 males) were Associate or Full Professor in their research discipline with an academic teaching experience ranging between nine and 31 years. It is important to note that not all participants were directly involved with the teaching of writing within courses. However, all of them frequently supervised students (undergraduate, graduate, and/or PhD students) with their (thesis) writing.

9 At the moment of the study (2013), the undergraduate programs Biology, Life Science and Technology, and Pharmacy had Dutch as language of instruction.

10 Overall, in the Netherlands, students have a very high English proficiency in reading and listening skills (Education First, 2019).

Data collection and analysis. Semi-structured interviews were used to provide in-depth answers about faculty members' experiences and beliefs about writing (instruction). We developed and pilot-tested an interview scheme that included questions on two themes: (a) beliefs (on the relevance of writing (instruction) and desired writing level for undergraduate students at the end of the degree program) and ideas for effective teaching activities; and (b) experiences with current writing instruction (curriculum, teaching activities, assessment) and their perceived students' writing abilities and difficulties. By first asking the interviewees about their opinions and ideas, we tried to infer their beliefs without being influenced by their expression of their experiences later in the interviews. We present the interview questions in Appendix A. The author of the present PhD thesis conducted all the interviews, each lasting about an hour. Audio fragments of the interviews were analyzed and summarized using ATLAS.ti 7 ®. The summaries were verified in terms of adequacy by the interviewees. Our qualitative analysis was informed by a within-case analysis using a matrix display (Miles & Huberman, 1994), in which interviewees' statements were organized in different categories (e.g., writing difficulties were categorized according to their type, such as language use). The author of this PhD thesis and a second researcher discussed the outcomes until agreement.

Argument analysis

Data collection. We focused our analysis on undergraduates' (bachelor) theses, because this text genre forms the aptitude test at the end of the degree programs and could provide indications about the students' acquired writing and argumentation competences. To allow for a detailed analysis we collected theses from two degree programs: biology¹¹ and physics¹². Within our university context, a physics thesis typically consists of a report about a small research project conducted in one of the faculty's research groups. This research report can be viewed as a traditional

11 The learning outcome concerning writing for the undergraduate biology program is formulated as: "The graduate is able to communicate in professional contexts about the research discipline, both oral and in writing" (Faculteit Wiskunde en Natuurwetenschappen, 2012-2013a, p. 1, translated). More specific are the learning outcomes for the biology thesis, which stated, among other aspects, that the student: "is able to develop a clear argumentation for a position or view that is supported by scientific literature in a relevant and effective manner" and "can write a clear, critical and logical structured scientific text of substantial size using clear, effective and academic language" (Faculteit Wiskunde en Natuurwetenschappen, 2013-2014, p. 13, translated). One of the assessment criteria for biology theses is about argument construction: the way students give a consistent argument and justified conclusions.

12 For the physics degree program, only a generic learning outcome regarding writing is formulated: "Bachelor's graduates are able to communicate orally and in writing in academic and professional contexts, with both colleagues and others, in Dutch and in English. He/she is familiar with the relevant means of communication" (Faculteit Wiskunde en Natuurwetenschappen, 2012-2013b, p. xx, translated). There is no explicit reference to written argument construction in the assessment form for physics theses.

thesis type with an IMRD (Introduction, Method, Results, and Discussion) structure (Paltridge, 2002). A biology thesis is a literature review guided by a research question, also a traditional thesis type. It is important to realize that both thesis types have an argumentative character. The required language for physics theses is English, while most biology theses, unless otherwise agreed, are written in Dutch. Students' theses were selected from the university's online public repository. Only theses publicly accessible were used, because access to other theses was restricted due to university regulations. We selected a sample from a pool of 145 biology theses (from 2012 and 2013). The theses on theoretical physics projects were excluded, resulting in a pool of 25 physics theses (from 2009 - 2013). We selected 10 theses (five from biology and five from physics) by systematic sampling with an at random start (Cohen, Manion, & Morrison, 2007). For confidentiality reasons, the selected theses were anonymized by removing all author-identifying information. In Table 2.12 details of the theses are presented.

Data analysis. We analyzed the presence and elaboration of structural argument components in a thesis to gain insight into the quality of students' arguments. A diverse palette of analytical frameworks for arguments has been developed to analyze students' arguments (Sampson & Clark, 2008). A significant amount of research on written arguments has been carried out using Toulmin's argument pattern (Toulmin, 1958). An argument, following Toulmin, is comprised of six components (Figure 2.1 A). Data support a claim, the proposition one wants to justify. The relationship between the data and the claim is justified by warrants, and backings, the underlying (implicit) assumptions behind the warrants. By means of a qualifier the scope and strength of the claim is indicated. A rebuttal is used as a counterargument to indicate under which circumstances the claim would not be true (Toulmin, 1958). Our analysis was partly based on Toulmin's argument pattern, but not exclusively given methodological challenges using this model in analyzing arguments in science education (Erduran & Jiménez-Aleixandre, 2008). For instance, the model could be used to isolate different argument components, such as data, warrant and claim, but distinguishing between different components can be ambiguous. Since warrants and backings are often appealed to implicitly in scientific texts and are tacit (Sampson & Clark, 2008; Toulmin, 1958), identifying and distinguishing these argument components is often not possible. In addition to Toulmin's argument pattern we analyzed the research question or aim in a thesis, because the argument aims at answering the research question. The validity of the conclusion is also determined by the way it is coordinated with the research question. Therefore, given our research context and aim, we analyzed theses on the presence of the following five components: research questions/aim, evidence (we take data, warrants, and backings as a combination, from here called evidence), rebuttals, qualifiers, and claims (Figure 2.1 B).

Figure 2.1. A. Schematic presentation of Toulmin's model of argument (adapted from Toulmin, 1958). B. Model of argument for the analysis of undergraduates theses.

For their identification we used the following indicators: (a) linguistic features, such as the words "to conclude" indicating a claim or a figure reference indicating evidence; (b) organizational features that locate argument components in the text (e.g., typically, the introduction section includes a research question); and (c) content-based features that reveal the function a text fragment (probably) fulfills (e.g., the interpretation of measurement data provides evidence).

Next, we assessed qualitatively to what extent the claim was supported by evidence. We used the criterion about claim justification adapted from the rubric developed by Crotwell Timmerman, Strickland, Johnson, and Payne (2011). The original rubric to assess undergraduate biology students' scientific reasoning skills in laboratory reports consists of 15 criteria (e.g., whether conclusions are based on the data selected and writing quality). For our purpose, we changed hypothesis into research question/aim. The criterion is shown in Table 2.1. The rubric can be used for each topic and for undergraduate students' writing, and therefore, we believe this rubric is appropriate for our analysis purposes. In Table 2.2 we illustrate the way we analyzed the argument from a student thesis. To guarantee reliability, the author of this PhD thesis and a second researcher analyzed independently two randomly selected theses (one biology and one physics). Then they discussed the usability of the analysis steps, including fine-tuning the criterion, and the analysis outcomes until agreement. Thereafter, the author of the present PhD thesis analyzed the remaining theses.

Table 2.1. Criterion used to assess the justification of the claim presented in a student's thesis. Adapted from Crotwell Timmerman et al. (2011).

Criterion	
Claim is clearly and logically drawn from evidence provided. A logical chain of reasoning from research question/aim to evidence to claims is clearly and persuasively explained. Conflicting evidence, if present, is adequately addressed.	
Not addressed – 0	<ul style="list-style-type: none">• Claims have little or no basis in evidence provided.• Connections between research questions/aim, evidence and claim are nonexistent, limited, vague or otherwise insufficient to allow reasonable evaluation of their merit.• Conflicting evidence is not addressed.
Novice – 1	<ul style="list-style-type: none">• Claims have some direct basis in the evidence, but may contain some gaps in logic or evidence or are overly broad.• Connections between research questions/aim, evidence and claims are present but weak.• Conflicting or missing evidence is poorly addressed.
Intermediate – 2	<ul style="list-style-type: none">• Claims are clearly and logically drawn from and bounded by the evidence provided with no gaps in logic.• A reasonable and clear chain of logic from research questions/aim to evidence to claims is made.• Claims attempt to discuss or explain conflicting or missing evidence.
Proficient – 3	<ul style="list-style-type: none">• Claims are completely justified by evidence.• Connections between research questions/aim, evidence, and claims are comprehensive and persuasive.• Claims address and logically refute or explain conflicting evidence.• Synthesis of evidence in claim may generate new insights.

Table 2.2. An example of the argument analysis of thesis Bio 1 (partly shown). The thesis was scored as Novice with respect to the claim justification. The qualifier is indicated in italics.

Argument components			
Research question	Evidence	Rebuttal	Claim
"What effect do the spatial patterns have on ecosystem functioning?" (p. 4)	"Consequences of pattern formation in seagrass meadows on ecosystem functioning are still unclear. Nevertheless, self-organized spatial patterns in seagrass meadows are a good indicator for the health of the ecosystem. Properties of self-organisation react predictably to increased stress in the environment (Fig. 9, van der Heide et al. 2010)." (p. 11)	"Furthermore, field evidence showed that pattern formation affected ecosystem-level processes by improved growth and higher survival rates (van de Koppel et al. 2008). In contrast, the 'sediment accumulation feedback' model of Liu et al (2012) predicted no increase in total blue mussel biomass due to self-organization. (...) Thus, whether self-organized patterns themselves contribute to ecosystem functioning still remains unclear." (p.9)	"In addition, <i>although we lack knowledge of specific effects of spatial patterning for all case studies, we have clear indications [Qualifier] from some organism groups that self-organized spatial patterns have a positive influence on ecosystem functioning.</i> " (p.14)
Score: Novice - 1	Explanation: The claim in the thesis is not entirely drawn from the provided evidence, and is formulated with a certainty that does not follow from the evidence. Connection between the research questions, evidence, and claim is weak. Opposite and contradictory results are given, but these are discussed only to a limited extent. A few studies are discussed, but the limits are not used to draw the conclusion.		

FINDINGS

Faculty Members’ Experiences

Curriculum

The faculty members indicated that students write a variety of products in all four undergraduate programs (e.g., research reports, see Table 2.3), integrated in courses in which the lecturers themselves are involved (as supervisor and/or assessor) or of which they know. Students’ learning to write is mainly integrated in laboratory courses, according to P2. In the third and last year of the programs students write a thesis that typically consists of a report about a short research project conducted in a research group. A biology thesis, in contrast, consists of a literature review, often associated with a prior research project. According to B2 the thesis is for some students their first moment to write individually.

Writing instruction and practice seems to be not structurally embedded in the biology, chemistry, and physics programs, according to seven interviewees. From the other nine faculty members, including the four astronomers, we did not receive explicit indications of an absence of structural writing instruction. Based on the astronomy faculty members’ experiences, we assume that there is yet no structural embedding of writing instruction in the astronomy undergraduate program as well. The biology curriculum is loaded with content learning with minimal space for writing, as was indicated by B2 and B3.

Table 2.3. Writing practice and instruction in the four science degree curricula indicated by the faculty members.

Writing practice and instruction		Faculty members
Writing tasks	Undergraduate thesis	A1, A2, A3, A4, B2, B3, C1, C2, C3, C4, P1, P2, P3, P4
	Research report (e.g., practicals)	B1, B2, B3, B4, C1, C2, C3, C4, P2, P3
	Mini thesis in a course	A1
	Exams (open questions)	A1, P1, P2
	Short literature review	A1, C2
	Short essay	P2
	Proposal for observation	A3, A4
	Poster	A4, B4, C1, C3
	Abstract	C1, C3
	Laboratory notebook	C1
Tutorial about writing a report		B1, B3
Module with writing instruction		C2
Minimal attention for writing instruction, not structurally embedded		B2, B3, C1, C3, C4, P2, P3

Note. Faculty members from Astronomy (A), Biology (B), Chemistry (C), and Physics (P).

Teaching and supervision

From the interviewees’ statements it became clear that students are supported in learning to write by feedback on their written products in all four science programs (Table 2.4). Two faculty members mentioned the time-consuming character of providing feedback. Sometimes the feedback and supervision is carried out by PhD students or post-doc researchers. Feedback on students’ writing is given mainly on their texts: text structure and argument, main points, language use, and content. The feedback is given both orally and written, often combined. When talking about the bachelor thesis, 12 faculty members indicated they discuss text drafts multiple times with their students to provide them with interim feedback. C4 mentioned that students sometimes complain that they receive hardly feedback on their writing. A1 told that at the start of a writing task he pays more attention to the text structure, while more at the end he provides feedback on language use and scientific content. The faculty members mentioned a variety of pre-writing activities they used themselves to support students in their writing, like writing an outline, preparing a presentation, or splitting up writing in different sections. Five faculty members indicated that they give examples of well-written reports or research articles to their students as a writing model. A faculty member advised students to read articles:

sometimes we will advise some people to read, read some more research articles, because then you automatically pick up the style of writing. [It is an advice] that I sometimes give and then it is also very clear that they [students] have not done that often. Or when they did, they do not have a clue that they also should [write] in that way. (C3)

B3 uses his own writing as an example. He shows students, when they require help, how he approaches his writing. Also, in one of his undergraduate courses he assigns students to write a results section using data and background information from a video-experiment. Other or similar writing exercises were not indicated in the interviews.

Table 2.4. Current activities to support student writing mentioned by the faculty members.

Activities	Faculty members		
Feedback	Focus points	Text structure/argument	A1, A2, A4, B2, C4, P2, P4
		Main points (gist)	A2, A4, B2, C4, P1, P2
		Language use (grammar, spelling)	A1, A2, A4, B2, B3, P4
		Scientific content	A1, B4, C2, C4
		Writing processes	B1, C1, C2, C4
		Differentiation between students	A1
		Oral and/or written	A1, A2, B1, B2, B3, C1, C3, P1, P3, P4
		Time investment	A2, B4
		Interim feedback on text drafts	A1, A2, A3, A4, B1, B2, B3, C1, C2, C3, C4, P1
		Given by PhD students or post-doc researchers	C3, C4, P4
Pre-writing activities and exercise (e.g., outline)			A2, A3, A4, B3, C2, C3, P1, P2, P4
Model/example			B1, B3, C3, C4, P2
Instruction/manual			C1, C4, P2
Determining student's writing level at start			A1, A2

In all four undergraduate degree programs the assessment of theses is formalized by a protocol and an assessment form. The faculty members mentioned various criteria they found important when assessing students’ texts (see Table 2.5). Most criteria were about the written product. Criteria regarding the (writing) process, such as the feedback use by the student, were mentioned to a lesser extent.

Table 2.5. Assessment criteria for students’ texts indicated by the faculty members.

Assessment criteria			Faculty members
Product	Scientific content	(English) language use	A1, A4, B3, B4, C2, C3, C4, P1, P4
		Completeness information	A1, A3, C1, P1
		Writing style (voice, clarity)	C3, C4
		Goal-oriented/effectiveness (message)	A3, B1, B4, C3, C4
		Argument (validity of claim)	A1, A3, B1
	Text structure	Text structure	B1, B3, C1, C4, P1, P4
		Lay-out	A1, C1, C3, P1
		Degree of independency student	B3, C3
		Writing process	A4, B3
		Critical stance	P2
Process	Degree of feedback use by student		A4
	Degree of revision by subject lecturer		B2, C1, P1, P2, P3
	Originality		B3, P2
			P3

The adequacy and correctness of scientific content is emphasized in the assessment. C2 focuses in her assessment mainly on scientific content, because she believes it is important that students learn to present scientific content correctly. She tries to assess the content separately from the text characteristics. The argument in the texts is another frequently mentioned criterion. The difference between a high and low grade is determined by the extent to which a claim is justified, as P1 mentioned.

Student abilities and difficulties

Ten faculty members stated that there is a high diversity in students’ writing skills (Table 2.6 A). Some of them expressed positive experiences with students’ writing and noticed little problems with students. However, seven faculty members, from all four degree programs, express concerns about undergraduates’ writing skills. According to two of them (B1 and B2), for some students the thesis, and the research report at the end of their degree program, are only their first or second time writing an extensive scientific text. P1 mentioned that half of the graduating students, even during their master phase, have difficulty writing a report. P2 frequently experienced that students did not reach the writing level required in secondary education. Four faculty members mentioned potential causes for the diversity in students’ writing abilities: the different students’ abilities between degree programs, individual differences (e.g., student’s personality), or poor writing instruction in secondary schools.

The faculty members mentioned a range of difficulties students experience in writing, most often on structuring and language use (Table 2.6 B). Students struggle with text structure, for instance, with separating the description of research findings and their interpretations (P1). Writing a discussion section in a thesis is also a challenge for students, as was indicated by B1: “it shocked me that almost 50% [of the students] was not able to do that without much help”. Seven faculty members indicated that students often repeat text fragments resulting in redundancy. It also happens that students do not select information in a written report, resulting in superfluous information on experimental failures. Five interviewees found that students have difficulty with constructing an argument. However, P3 indicated that students are quite able in supporting their claims. Ten faculty members reported that students have difficulty with and/or a lack of (English) language use and with translating their thoughts and ideas to written texts. However, P3 noted that students’ English proficiency is good.

Table 2.6. Student abilities and difficulties (A: general, B: specific) mentioned by the faculty members.

A

Student abilities – general	Faculty members
High diversity in student writing level	A1, A2, A4, B1, C1, C3, C4, P1, P2, P4
Positive experiences with student writing	A2, A4, B2, B3, C1, P3
Concerns about student writing	A3, B1, B2, B3, C4, P1, P2

B

Student difficulties and abilities – specific		Faculty members
Argument (line of reasoning, logical writing)		A2, B2, C1, C4, P2, P3 ⁺
Text structure and text sections	Difficulty in structuring text	A3, B2, B3, B4, C1, P4
	Redundancy and repetitive writing	A2, A4, B2, C4, P1, P2, P4
	Knowledge of thesis’ structure	P3 ⁺
	Writing introduction/discussion section	B1, C3
	Difficulty describing experiments and data	B2, B3, C1, P2
	Not knowing how to describe figures	B3
	Mixing description and interpretation of results	P1
	Writing inconsistently (e.g., numbering figures)	P1
	Difficult extracting gist (main points)	C3, P1
	Language use	A1, C3, P3 ⁺
Language use	Translate thoughts to text	A1, A4
	Spelling, grammar, vocabulary	A3, B2, B4, C1, P3
	Write accurate and clear (correct formulation)	C2, C4, B4
	Literature use	B1
	Using text fragments from different sources (risk of plagiarism, lack of structure)	B2
Writing process and supervision	Writer’s block, not know how to start	A1, A3, C1, P3
	Time management	C1
	Attitude student (limited contact, sloppiness)	B3, C4
Difficulty setting a context of research field		B1, C3
Difficulty addressing different reader audiences		P3, P4
Weak formulation of research questions and lack of motive		C3
Handwriting unclear		C1

Note. + : a positive experience with students’ abilities.

Faculty Members’ Beliefs

Curriculum

Fifteen faculty members acknowledged scientific writing as an important skill to be learned in undergraduate science programs, the most obvious phase for writing instruction according to A1 (Table 2.7). Its importance lies mainly in developing

the writing competences students need for their (science-related) career as a graduate student. In addition, writing instruction becomes more relevant because of the expected increase in the intake of international students with different prior educations and languages, explained A4. Four faculty members (A1, B3, B4, C2) noticed that writing is important for scientific thinking and for expressing research findings. There should be more attention for scientific writing in the undergraduate biology curriculum, emphasized B2, however faculty members from all disciplines indicated a lack of time for instruction and practice in scientific writing.

Table 2.7. Relevance and role of writing in the four science degree curricula indicated by the faculty members.

Relevance and role writing in curricula	Faculty members
Writing important in undergraduate program	A1, A2, A3, A4, B1, B2, B3, B4, C1, C2, C3, P1, P2, P3, P4
Lack of time for writing (instruction)	A1, A3, A4, B2, B3, C1, P4
Start early in curriculum with learning to write	A2, B1, B4
Curriculum debate: content learning vs. skills	A4, P4
Integrate writing with content learning (practicals, research project)	A4, B1, B2, B4, C1, C4, P1, P2, P4
Frequent and regular practice	B1, B3, P1
‘Soft skills’ course in first year	C1
Alignment and coherence in tasks and assessment	P1
Role of writing centre	A4, C1, P1
Role of language teachers	C2
Role of secondary education	A3, P2

Despite the experienced time constraints, three faculty members indicated the importance to start early in the curriculum with teaching and practicing scientific writing. Traditionally, there has been more attention to conceptual learning in the physics degree program and there was a belief that students develop their scientific writing skills naturally, as P4 indicated. This belief could explain the minimal attention for writing instruction in the physics program (see Table 2.3 in section Faculty Members’ Experiences). Another faculty member said: “... I think it is more important that [undergraduate students] have thorough knowledge (...) that they can think in a certain [mathematical and abstract] way and apply [that knowledge]” (P3). Besides, he mentioned that nowadays students are more capable in writing when entering university. Therefore, a strong emphasis on writing in the curriculum is less necessary, although it should not be neglected. The discussion about the emphasis on conceptual knowledge versus skills also dominates in the astronomy curriculum, according to A4. He endorses the value of extracurricular writing support for undergraduate students. Nine faculty members suggested integrating writing practices with content and conceptual learning, like in students’ own research projects instead of, for instance,

a writing course. B1 stated that students will only learn to write by doing it, preferably by writing about their own research findings. Though, P4 noticed that writing tasks about physics content are empty activities for first-year students, because they do not have sufficient subject knowledge yet. C1 preferred a soft skills course with attention to writing, presenting, and searching and using literature sources. However, it was also stated by four faculty members that writing instruction is not their responsibility, but that of a university writing centre or language teachers. Two faculty members stated that students should learn writing in secondary school.

Teaching and supervision

The faculty members mentioned three activities most frequently to support undergraduate students in writing (Table 2.8). First, student should practice writing regularly and frequently. B1 compared learning to write with learning to make music, you need practice. Secondly, feedback either by the supervisor, peers or both, was mentioned by more than half of the faculty members. A1 believed that students learn writing by interaction with an experienced writer who provides constructive feedback. Again six faculty members mentioned the high time investment of providing frequent and extensive feedback. Seven faculty members believed that peer review, in which students give each other feedback, is a valuable activity. Third, a short writing manual is considered to be useful. Other ideas for writing instruction included short writing tasks at the start of the curriculum (e.g., in lab courses), providing and analyzing examples of (parts of) research articles, and writing in multiple rounds. More than half of the faculty members indicated that students should learn to write individually, rather than in a group (collaborative writing). Two faculty members mentioned explicitly they were unsure what pedagogical approaches could or should be used to support students’ scientific writing.

Table 2.8. Activities to support students’ writing mentioned by the faculty members.

Activities	Faculty members
Regular and frequent practice and exercise	A1, A2, A3, A4, B1, C3, C4, P3
Feedback By subject lecturer	A1, A2, A3, B1, B4, C3, C4, P2, P3
Peer review	A2, A3, B1, B2, B4, C3, P3
High time investment	A2, B1, C2, C4, P2, P3
Short instruction/manual (guidelines)	A2, A3, A4, B1, C1, C3, C4, P1, P4
Short writing exercises	B1, C3
Read (and analyze) examples of research articles	A1, A2, P4
Writing in multiple rounds	C4, P3
Individual writing (under supervision)	A2, A4, B1, B2, B3, B4, C1, C2, C3, P3, P4
Collaborative writing (in groups)	A1, A2, C1
Unsure how to support students	C2, P4

A variety of text genres relevant for undergraduate students’ writing were mentioned (Table 2.9). Most frequently mentioned were (short) research articles, research reports, literature reviews, popular science texts, and posters. According to B1, writing a (short) research article has an important pedagogical function, because the text reflects the way of doing research. Two faculty members indicated that writing a popular science article forces students to address a specific reader audience.

Table 2.9. Relevant text genres indicated by the faculty members.

Text genres	Faculty members
Research article (short)	A3, B1, B2, B3, C3, P1, P3, P4
Research report (practicals)	A1, B3, C1, C2, C3, C4, P1
Literature review (e.g., thesis biology program)	A1, B1, B3, B4, C1, C4, P1
Popular science text (short)	A3, A4, P1, P2, P3
Poster	A3, A4, B2, B4, C1
Oral presentation (e.g., about research article)	A1, C1, P4
Newspaper article	C3, P1
Review of research article	A1
Research proposal	C2
Position paper (about ethical issue)	B3
Abstract	C1
Laboratory notebook	C1

The majority of the faculty members recognized the importance for students to develop the ability to justify claims (Table 2.10). A faculty member said:

I think the logic is the most important. Grammar and spelling can be improved more easily [by students], but the logic in what to write first and second and how to construct a logical argument is most important [to be learned]. (A2)

Table 2.10 shows an overview of the other mentioned topics to address in the undergraduate programs. The text structure (e.g., a research article) is another important part to be learning, as most of the faculty members indicated. A1 mentioned that it is important to let students read examples, like research articles and students’ theses, to recognize different text structures, text genres, and writing styles. Further, the faculty members reported a variety of components related to content and textual issues, such as consistency in a text (P1), describing experiments to verify a study and justifying conclusions (C1 and C2), and being critical (B2). To a lesser extent, the faculty members indicated language use, writing style, context, reader audience, ethics, and literature use as important for undergraduate students.

Table 2.10. Relevant topics of scientific writing indicated by the faculty members.

Topics	Faculty members	
Argument construction	Justification of conclusions, building a logical argument	A1, A2, A3, B1, B2, B3, B4, C1, C2, C4, P1, P2, P3, P4
Text structure	What is the structure of a report or research article? What content in which sections?	A1, B1, B2, B3, C1, C2, C4, P1, P4
Content and textual components	Consistency text (e.g., numbering figures)	P1
	Describe experiments exactly and completely	C1, C2
	Describe (contrasting) research results	A3, B3
	Data processing in text	B2
	Difference assumptions and conclusions	C4
	Describe motivation research study	P3
	Knowing and extract your main message	C3, P4
	Being critical (e.g. writing a discussion)	B2
	Convey enthusiasm	A3
	Formulate research questions and identify promising research topics	C3
Language use	Learning about the scientific approach	C3
	Translate ideas	A1, B4
	Language use	C1, P2
	Vocabulary (nuance, jargon)	A1
	Formulation (grammar)	C2
Writing style	No use of uncertain language	B1
	Write objectively	P1
	Write short and concise	B4, C2, P2
	Active and clear style	B1
	Clear, efficient and logical	A2
Research context	Write accurate	P2
	Developing a personal and scientific style	A1
	Start developing a context, and state of the art knowledge within a research field	C3
	Being able to have an outlook from your own frame of reference ('helicopter view')	P4
Reader audience	Taking account of the reader audience	A3, A4, P3
	Write for scientists	C1
	Write for different audiences	C2, P1
Ethics	About scientific fraud and plagiarism	B1, B2
Literature use	How to refer to primary literature in texts?	A4

Learning outcomes

The faculty members indicated that students should be able to write different text genres, like a research report at the end of their undergraduate program (Table 2.11). B1 stated that in a literature review students should be able to synthesize literature, for instance in the undergraduate thesis the student should show his/her interpretation of research articles and weigh their relative importance. Other important desired learning outcomes, mentioned by the faculty members, are accounting for the purpose and target audience, writing in a structured way, writing a logical and clear text, and correct (English) language use. One faculty member mentioned: “I expect that [undergraduate students] can explain scientific ideas in a logical way (...), explain scientific arguments. I always expect to see this in an undergraduate thesis” (A2). However, at the end of the undergraduate programs you cannot expect that students place their own research in a broader scientific context, C2 added.

Table 2.11. Desired student learning outcomes indicated by the faculty members.

Learning outcomes		Faculty members
Text genres	Observation proposal	A3
	Summary of couple of research articles	B2
	Research article (e.g., description research results)	A3, C3
	Research reports (thesis, practicals)	C1, C2, C4, C3, P2
	Literature review	C4
	Newspaper article	C3
	Popular science article	A3
Skills	Structured writing (text order)	A4, C1, C4, P4
	Argument construction (logical line)	A2, B3, C4, P1, P4
	Correct language use (grammar, English)	A4, B4, C2, P3
	Taking account of reader audience (laymen)	A3, A4, C3, P2, P4
	Synthesizing literature sources	B1
	Describing results section	B1, B3
	Translate and formulate ideas clearly	A1, B4, C2, C4
	Write short and concise	A4
	Own contribution to text (no plagiarism)	C4, P3
	Indicate relevance research	C3
	Adequate lay-out	C4, P1

Students’ Argument Construction

To study the nature of students’ arguments in written texts we selected five physics and five biology bachelor theses. The five physics theses consisted of the typical IMRD text sections of a research report. The five literature reviews in biology did not contain a methods section. So, information about the way the students searched for and used literature was absent. Overall, both biology and physics theses included the five argument components (Table 2.12).

Table 2.12. Overview of the argument analysis findings.

Thesis	Year	Research domain	Amount of words	Language	IMRD	Argument components					Argument quality (rubric score)
						RQ	E	R	Q	C	
BIO 1	2012	Marine ecology	5689	English	IRD	+	+	+	+	+	1
BIO 2	2012	Cell biology	5363	English	IRD	+	+	±	+	+	1
BIO 3	2013	Neuroscience	6105	English	IRD	+	+	±	+	+	2
BIO 4	2013	Molecular genetics	4660	English	IRD	+	+	±	+	+	2
BIO 5	2012	Medical biology	8488	Dutch	IRD	+	+	±	+	+	1
PHYS 1	2011	Nuclear physics	9062	English	IMRD	+	+	+	+	+	3
PHYS 2	2012	Condensed matter	7359	English	IMRD	+	+	-	+	+	2
PHYS 3	2012	Applied (materials)	4815	English	IMRD	-	+	+	-	-	0-1
PHYS 4	2013	Nano devices	11019	English	IMRD	+	+	+	-	+	2
PHYS 5	2012	Nanostructured materials	12024	English	IMRD	+	+	±	+	+	1

Note. Amount of words is determined for the main text (excluding front page, index, appendices, and the reference list). IMRD sections: presence of Introduction, Method, Results, and Discussion sections. RQ: Research question/aim, E: Evidence, R: Rebuttal, Q: Qualifier, C: Claim. + : component present, - : component missing, ± for Rebuttal: rebuttal present, but not elaborated sufficiently in text. Rubric criterion: 0: not addressed, 1: novice, 2: intermediate, 3: proficient.

All theses provided claims that answered the research questions, except in PHYS 3, whose thesis did not contain a clear research question and claim. The conclusion section was rather an outlook with practical implications and contained statements suggesting findings of the study, while they were not:

Nowadays, many research is done on the use of drag reducing coatings for airplanes, cars and ships. The promising riblet structure cause [sic] a drag reduction up to 18%. Unfortunately, despite of the great advantages of this products [sic], riblets are not on great scale commercial [sic] producible and they are hard to attach to surfaces. (PHYS 3, p. 17)

The theses included evidence for the claims and almost always rebuttals. However, the rebuttals in five biology theses were frequently limited to mentioning contrasting findings without further elaboration in the text, and were therefore insufficiently included in the way the claims were formulated. Qualifiers, statements about the scope and strength of the claim, were present in eight theses. In a biology thesis the student did include limitations of the claim:

Overall, finding an animal model that suits all the validities and displays the exact development pattern as seen in schizophrenic patients is an illusion. However, more and more models increase face, construct and predictive validity. Though this last aspect has yet to be investigated in many models. (BIO 3, p. 18)

Although the claim in this thesis was not fully justified (score intermediate), the student demonstrated an argument by listing different evidence findings:

The first evidence is derived from [emphasis added] the observation that schizophrenic patients are hypersensitive to apomorphine, as of course APO-SUS rats are as well. (...) *All these data taken together provide strong evidence* [emphasis added] for a high face and construct validity of the APO-SUS strain (...). (BIO 3, p. 14-15)

However, we observed that the claims, especially in the biology theses, were not always fully justified by the provided evidence, and therefore a novice or intermediate level for justification was assigned, despite the presence of the argument components (Table 2.12). The conclusions were not justified because they were based on a limited amount of studies or on studies with contrasting findings, which was not further explained by the students. In BIO 1 the student addressed three research questions of which two were answered and justified by the given evidence. But, for the third (and main) research question, the claim was not based on the presented data and evidence (use of limited studies and contrasting findings). Still the claim was formulated very certain, including a qualifier: “In addition, although we lack knowledge of specific

effects of spatial patterning for all case studies, *we have clear indications* [emphasis added] from some organism groups that self-organized spatial patterns have a positive influence on ecosystem functioning" (BIO 1, p. 14). A similar case was found for BIO 2 about the possible protective effects of medicines on radiation-related lung and heart injuries. The student described one study about lung injuries, but did not include evidence from studies about heart diseases; instead, evidence from a study about kidney-related injuries was described. The student claim about radiation-related injuries was rather general and did not reflect the presented evidence. Thesis BIO 5 aimed at convincing readers about the importance of preventing a metabolic syndrome. The student provided a financial reason – without referencing to a source – as main evidence. The remaining part of the thesis is about potential ways to prevent diabetes mellitus II, including a description of various studies. Probably, the student had another aim in mind, for instance, examine possible ways to prevent diabetes, which was not explicated in the text. This finding suggests that this thesis contained at least two arguments, and thus lacked a clear focus. Above exemplars relate to the difficulty students could have with constructing an argument, issues that were also mentioned by the faculty members.

In three physics theses (PHYS 1, 2, and 4) we observed that claims were clearly justified with the presented evidence (Intermediate or Proficient level). Thesis PHYS 1, for instance, contained a full justification, though the main evidence exists of only one figure. All (raw) measurement data was also included in the text, resulting in redundant information. The corresponding claim in PHYS 1 related to the study's objective, however, the student did not interpret or discuss its significance. Also, the objective was presented at a rather late stage in the text, not in the introduction, as one would expect. We also noted redundant information in other physics theses. An example is PHYS 4, in which many measurement data was given without an explanation about the relation to the research aim. Another thesis (PHYS 5) contained data from small experiments that did not belong to the study's main research aim, information about what went wrong during the experiments, and laboratory notes. This phenomenon of presenting redundant information was also indicated by some faculty members (section Faculty Members' Experiences - Student abilities and difficulties).

DISCUSSION AND CONCLUSIONS

In response to concerns about the limited writing instruction in higher education institutions and students' writing difficulties, we examined faculty members' experiences and beliefs about (current) writing instruction and students' writing abilities at a science faculty of a research university in the Netherlands by interviewing faculty members from four science disciplines (astronomy, biology, chemistry, physics) and analyzing undergraduate students' theses.

The interviews with faculty members showed that students write a variety of products in the undergraduate programs (e.g., research reports or short literature reviews), and mainly as part of laboratory courses. Students' writing frequencies during their degree program vary between programs and individual students. The faculty members did not mention the use of specific writing pedagogies (e.g., discipline-specific writing instruction from a Writing in the Disciplines tradition) or a specific writing curriculum. In the present situation, undergraduates' writing skills development is mainly guided by incidental support, like feedback on written products, pre-writing activities, manuals/lectures, and text examples. The faculty members have probably their individual approaches and use, apart from standardized assessment forms, individual assessment standards. The faculty members did, for instance, elaborate on the criteria they believed are important when supervising and assessing students' texts and theses. In assessment forms (data not shown) and during the interviews we observed that assessment criteria are rather general. For instance, what meaning do supervisors and students give to "argument" or "structure"? The faculty members' beliefs could therefore influence their assessment and feedback practices and these practices probably differ between supervisors. It might lead to different expectations between supervisors resulting in confusion among students about what is expected during a writing task, a similar phenomenon as found by Lea and Street (1998). Given the interview findings and since there are no general or discipline-specific writing courses offered in our educational context, we believe that there is little structural embedding of explicit and consistent writing instruction in the four undergraduate science programs. It seems likely that there is no mutual alignment of formal guidelines between and among faculty members, or from faculty administrators, on supporting students' writing in terms of supervision and feedback guidelines, and curriculum standards. The absence of a consistent and embedded writing instruction according to consistent guidelines in these science curricula corresponds to a national trend, indicated by Herelixa and Verhulst (2014), who reported about the limited attention for integrating and researching language education in Dutch research universities. The interview analysis showed further that the faculty members currently experience a high diversity in undergraduate students' writing abilities. They have pointed out that undergraduate students encounter all kinds of difficulties, like structuring written texts, and language use. These difficulties are in accordance with findings from other studies (e.g., Galbraith & Rijlaarsdam, 1999; Herelixa & Verhulst, 2014).

The faculty members, overall, recognized the importance of integrating writing instruction in the science undergraduate curricula, right from the start, and expect that at the end of the degree program undergraduate students have acquired a range of skills (e.g., argument construction) to write a variety of text genres (e.g., research reports). Despite the assigned value to writing instruction, they experience a lack of resources (time and professional support). It also seems that the faculty members, especially in physics and astronomy, often prefer teaching content, and

give less priority to teaching skills, such as scientific writing. This finding is similar with findings found by Coil et al. (2010) who reported about faculty members of life science programs who experience a conflict between spending time on science content and science skills. The interviewees in the present study expressed their beliefs about how to provide writing instruction: frequent exercise, providing feedback, or integrating writing with content learning. Some faculty members believed that it is not their responsibility to teach students' writing, but that special writing centers should support students in their writing skills or that students should have acquired writing abilities in secondary education. The beliefs expressed by the faculty members are comparable with and confirm previous research (Wingate, 2011; Wingate & Tribble, 2012). For instance, Zhu (2004) examined business and engineering faculty views on academic writing and writing instruction in the US. The faculty members considered academic writing as mainly applying a generic set of writing skills transferable to different contexts. Writing instruction therefore was seen mostly as a responsibility of language teachers. Because educational beliefs are influenced by a person's own prior education (Pajares, 1992), the faculty members' own training as a student could frame their beliefs about what and how their students should be taught. Two faculty members were unsure about how students should be taught scientific writing. Also, this finding implies the importance of providing professional support to faculty members in order to enhance their efficacy for and expertise in teaching writing. A professional development program could include topics like instructional activities, writing assessment, providing feedback, supporting the student's writing process, discussing different academic text genres with students, and stimulating a dialogue with students about the meaning of writing in academic discourse.

The findings of the analysis of the arguments in student theses showed that overall the students presented research questions, claims and evidence in their theses, and most students mentioned rebuttals and qualifiers. Our analysis showed that the students did construct an argument in their texts, but did not always justify their claims sufficiently, in particular in the biology literature reviews. We observed, for instance, that the students formulated rather certain claims without taking into account the limited amount of studies or conflicting results, and did not always use adequate qualifiers. Rebuttals in students' arguments were often not complete and did not always influence their conclusions. Not taking into account rebuttals or not willing or able to generate a rebuttal is a phenomenon known with students (Kuhn, 1991). From literature it is known that university students have difficulty in using epistemic modality in their writing, i.e. using hedges, such as "might" or "probably", to indicate the degree of uncertainty in their claims (Hyland, 1994). In the physics theses we found that students included redundant information about experimental procedures and data, thus distracting the reader from the most important findings. The difficulty students have with selecting information was recognized by some of our interviewees, including three physics faculty members. The selection problem

may be the result of supervisors' expectations that students should be as extensive as possible in their description of experiments or ask to present all data. This writing behavior is also in line with a surface writing approach that university students could have characterized by redundant writing instead of more reflection that belongs to a deeper writing approach (Lavelle & Zuercher, 2001). Reflecting on and weighing the importance of selecting information in a report is a worthy recommendation to include in writing instruction to university students.

The main conclusions from our interviews and thesis analysis can be summarized as follows. First, on a curriculum level, we showed that faculty members recognized the importance of writing instruction in undergraduate programs, but there is almost none integrated and explicit writing instruction according to curriculum-wide standards in the four undergraduate curricula. Second, we conclude that it is not always clear how and by whom to organize writing instruction. Third, on a student level, we conclude that undergraduate students' writing abilities are diverse, students experience different writing difficulties. More specifically, the analyzed biology and physics theses overall showed an argument, but sometimes lacked sufficient justification or contained redundant information. Given these findings, we conclude that there is a need for more attention to writing in terms of support for students and professional support in writing instruction for faculty members in the examined four science programs. There are many good practices of scientific writing instruction that may be used in courses, both national (Herelixa & Verhulst, 2014; Van Dijk, Hajer, Scharren, & de Vos, 2013) and international (Brownell, Price, & Steinman, 2013; Poock et al., 2007; Rice, 1998). Coil et al. (2010) successfully incorporated instruction in science process skills (particularly writing) in a biology introductory program. Undergraduate students who followed this program had positive course experiences and made significant improvements in their scientific writing skills.

Some characteristics of our research design could have affected our conclusions. An important issue is whether the faculty members give an authentic image of their writing instruction in the interviews. To get a fuller understanding and a more comprehensive overview of their instructional practices, we recommend a follow-up study to take the actual teaching practice of the faculty members into account, for instance by using observations or stimulated recall interviews to reflect on their teaching practice (Kane et al., 2002; Pajares, 1992). Another suggestion is to examine current writing instruction by interviewing students from all year levels of a science degree program to get a more detailed view on students' progress, their writing difficulties, and the role of writing instruction. Although the faculty members' experiences and beliefs were derived from a selected sample of four science programs, the diversity in programs gives a broad picture of writing practices and lecturers' beliefs. It is worth considering to examine if the presented experiences

and beliefs will be recognized by other faculty members, both in our institution and in other (inter)national science undergraduate degree programs.

Reflecting on the analysis of the student theses, we must be aware that a number of factors might have served as the cause for the differences in the quality of individual theses. One is the amount and quality of supervision students received during their thesis writing. Some supervisors ask for revisions until the final product is of high quality according to their personal standards. And even, as our interview findings showed, supervisors sometimes revise parts of the students' texts themselves. Further, there are variations in expectations across supervisors and disciplines about what a thesis should look like (Paltridge, 2002). In our study we cannot completely compare physics and biology theses because of their different nature, and because students have more experience in writing research reports. For most biology students the writing of a literature review is a novel experience, as our interview findings showed. In addition, we should be aware that our samples are biased: the theses were selected from publicly available repositories. These repositories do not contain all student theses. Since students decide about uploading their thesis themselves, we suppose that these sets of available theses mainly contain best examples of student theses, probably affecting our results. The above factors and our small sample size might limit our understandings about the quality of argument construction of undergraduate biology and physics students.

Despite these limitations, the findings of this research study illustrate the importance to integrate writing instruction in our local context and to other similar institutions as well. Therefore, we recommend faculty members and administrators to integrate writing instruction more structurally and consistently in the science undergraduate degree programs following, for instance, a Writing in the Disciplines perspective using authentic scientific writing practices, as it is tailored to discipline-specific writing instruction. Also, our findings point to examine the need for professional development for faculty members to support them in gaining, for instance, an understanding about the value of explicit instruction about writing, and/or developing the pedagogical skills to design and enact explicit writing instruction. All in all, this study is a stimulus to further develop and examine how we can support undergraduate students in scientific writing in terms of explicit writing instruction and professional support for faculty members. In our next research study, which we present in Chapter 3, we examined a teaching strategy carried out by faculty members using discipline-specific writing instruction to support undergraduate physics students in scientific writing.

CHAPTER 3

Identification and Reconstruction of Research
Articles' Arguments: A Genre-Based Approach
in Reading and Writing Scientific Texts by
Undergraduate Physics Students

ABSTRACT

Research has provided evidence that undergraduate students experience difficulties in academic writing, like argument construction. In attempting to address this problem, we developed and implemented a teaching strategy for writing scientific texts for first-year physics undergraduates following genre-based writing instruction principles. In the context of the research study, the students engaged in reading and writing activities around research articles, applying the Scientific Argumentation Model (SAM), a heuristic designed to help students understand research articles' arguments. In our study we investigated how a group of nine undergraduate physics students reconstruct a research article's argument in written summaries before and after the teaching strategy. Data were collected through individual interviews, students' work, and a questionnaire. Summaries were analyzed on the presence, completeness, and correctness of rhetorical moves and on use of metadiscourse. The analysis of the data showed that the students included most of the rhetorical moves in their summaries, but that students did not always connect rhetorical moves to a coherent text. The findings add to existing literature on argumentation and have implications for the design of interventions in the context of undergraduate physics literacy courses.

INTRODUCTION

Scientists are frequently engaged in writing texts, such as research articles and reports, popular science texts, literature reviews, posters, grant proposals, and laboratory notes (Yore, Hand, & Prain, 2002). Throughout their undergraduate studies students engage with these text genres (Yarden, 2009). In order to be enculturated into the scientific community, students should learn about the rhetorical and linguistic characteristics of those genres, aiming at becoming scientifically literate in its fundamental sense, meaning the ability to read and write scientific texts (Norris & Phillips, 2003). It is well grounded in literature that students' ability to actively engage with argumentative texts, as much is used in scientific discourse, contributes to their academic success (Newell et al., 2011) and scientific literacy (Glynn & Muth, 1994; Jiménez-Aleixandre & Erduran, 2008; Treacy & Kosinski-Collins, 2011). However, Coil, Wenderoth, Cunningham, and Dirks (2010) showed that writing skills, like other science process skills, were not sufficiently addressed in undergraduate science degree programs. They showed that even though faculty members do acknowledge the importance of these skills in undergraduate programs they do not explicitly address those because of time constraints and priority for content learning. We found similar findings in an exploratory study conducted at a science faculty of a Dutch research university (described in Chapter 2 of this thesis). The relevance to teach writing skills is obvious since undergraduate students encounter writing difficulties, like structuring or argument construction (Galbraith & Rijlaarsdam, 1999; Herelixa & Verhulst, 2014; Sampson & Clark, 2008). Yet, there are ample examples of scientific writing instruction. For example, the Science Writing Heuristic, a scaffolding framework with writing prompts that promoted undergraduate students performance in content learning (Choi, Hand, & Greenbowe, 2013) and in writing (Cronje, Murray, Rohlinger, & Wellnitz, 2013). Other relevant work concerns students' argument writing, because argumentation stimulates scientific literacy (Driver, Newton, & Osborne, 2000; Erduran & Jiménez-Aleixandre, 2008; Kelly, Regev, & Prothero, 2008; Sampson & Clark, 2008; Walker & Sampson, 2013). Despite the importance of writing instruction for undergraduates and the need for implementation of effective teaching strategies to help students understand and apply the discourse of their science discipline, studies examining undergraduate students' ability to apply the rhetorical and linguistic characteristics of scientific texts are scarce. This study aims to contribute to filling this gap by investigating how undergraduate physics students progress in a course based on genre-based writing instruction and ideas from reading-writing connections in which they learn to read and write scientific texts, focusing on their argumentation and rhetorical genre characteristics.

THEORETICAL BACKGROUNDS

Genre-Based Writing Instruction

Genre-based writing instruction considers writing as having a social function: text genres have a specific communicative function in a social context. A genre-based approach aims at giving students control over a genre by familiarizing them with its rhetorical characteristics and social contexts to gain access to the discourse community (Hyland, 2007). In general, genres can be described as:

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. (Hyland, 2003, p. 21)

A genre approach is especially useful for students without much writing experience in a specific genre (Dudley-Evans, 1997). Hyland (2007; 2016) argued about the use of genre-based writing instruction, because it helps students perform the literacy tasks during their degree program and beyond. He strengthened his argument by stating: "the more learners become familiar with the genres and expectations of their target communities, the greater the accumulated store of experiences they can draw on to meet those expectations" (Hyland, 2016, p. 12). Genre-based writing instruction offers students explicit and systematic instruction in the features and social contexts of a genre, and it is supportive in the way the lecturer supports students' learning (e.g., using cognitive apprenticeship, see Collins, Brown, & Holum, 1991; Hyland, 2007). An important underlying belief in genre-based approaches is that explicit knowledge of the rhetorical and linguistic features of a genre will help students learn to write that particular genre (Hyland, 2003; Tardy, 2009b). In universities, genre-based pedagogies aim at supporting students to become more successful readers and writers of academic text genres (Hyon, 1996). Genre-based writing instruction is supposed to develop students' genre knowledge needed to communicate in a specific discourse (De La Paz & McCutchen, 2011; Graham, 2006; Hyland, 2007; Tardy, 2009a). The importance of genre knowledge is also argued by Tardy (2009a), who stated that "in order to communicate actively, appropriately, and successfully within a specific domain or disciplinary discourse community – that is, to communicate as an expert – writers must develop genre knowledge" (p. 19). Genre knowledge is a form of "situated cognition" and is defined as "an individual's repertoire of situationally appropriate responses to recurrent situations" (Berkenkotter & Huckin, 1995, p. ix). Genre knowledge could be conceptualized as a confluence of four knowledge dimensions: (a) formal knowledge of the structural genre elements, like text structure; (b) process knowledge of the practices how a genre is used and applied (e.g., composing process); (c) rhetorical knowledge of intended purposes

and the outcomes of a genre in a specific context; and (d) subject knowledge of the disciplinary content the genre reports about (Tardy, 2009a). De La Paz and McCutchen (2011) argued that, although the importance of students' genre knowledge is growing, there is a lack of empirical research that examines students' genre knowledge. In order to support the development of university students' genre knowledge, a genre approach through which students familiarize themselves with genres commonly used in scientific discourse is "at the heart of learning to write well in higher education" (Andrews, 2010, p. 10).

We can distinguish three genre-based theories with corresponding pedagogical approaches that have evolved from different research traditions, which had influence on L1 and L2 teaching and conceptualize genres differently (Hyon, 1996). Australian Genre Theories, also known as the Sydney School, is a tradition that has originated from the work on systematic functional linguistics (SFL) theory (Hyon, 1996; Martin, 1999). This theory places the relationship between language and its functions within social settings central. A text is seen as the result of a writer's language choices within a specific context (i.e., the situation in which language is used, also referred to as register) (Hyland, 2016). Genre-based approaches in this tradition mainly focus on primary and secondary school and adult workplace settings. Genres are considered as broad and general text types (e.g., narrative, explanation, or argument), which in turn are used to compose macro-genres, like a research report (Breeze, 2012). A well-known pedagogical application is the teaching-learning cycle for genre instruction, in which students follow three phases of modeling, joint construction, and independent construction to learn to write a genre (Hyland, 2003; Hyon, 1996).

A second tradition is New Rhetoric Studies that is more concerned with the situational context of a genre, instead of the linguistic approaches (i.e., formal genre characteristics) common in the other two genre traditions. New Rhetoric Studies considers learning to write as a process of apprenticeship in a new academic setting, enculturating students into the discourse community of, for instance, scientists (Berkenkotter & Huckin, 1995; Galbraith & Rijlaarsdam, 1999; Swales, 1990). The approach focuses particularly on research about the use of genres in specific English-speaking communities. Ethnographic research methods are used to investigate the social actions within a context, such as an academic research community. The seminal work by Bazerman (1988) examined, for example, the historical and social development of the research article genre.

For the purpose of this study we draw primarily on a genre-based approach that evolved from English for Specific Purposes (ESP), an applied linguistic field. Within an academic context one often refers to English for Academic Purposes (EAP), as is the case in our research. It is concerned with the textual and linguistic characteristics of genres. Swales (1990) described a genre as:

a class of communicative events, the members of which share some set of communicative purposes. These purposes are recognized by the expert members of the parent discourse community, and thereby constitute the rationale for the genre. This rationale shapes the schematic structure of the discourse and influences and constrains choice of content and style. (p. 58)

Examples of genres are academic essays, research articles, or a bachelor thesis (Paltridge, 2014). ESP research has paid a lot of attention to the research article genre. The influential work by Swales on his analyses of introduction sections of scientific research articles on the presence of moves has opened the way for further work in this field (Swales, 1990). ESP genre pedagogy mainly focuses on non-native speakers of English (L2) in academic settings, as is the case for the participants in our research studies. It is concerned with teaching explicitly the textual and linguistic genre features (the formal knowledge dimension), using, for example, text analysis tasks (Hyon, 1996; Swales & Feak, 1994). Students, often in small groups, analyze and compare samples of a genre: a process called rhetorical consciousness raising (Hyland, 2007; Swales, 1990). Many educational books are developed in the ESP tradition and are used by (under)graduate students (e.g., Swales & Feak, 2002). In response to criticisms about insufficient attention for the academic or professional discourse communities by which genre knowledge is shaped, the ESP tradition takes the social contexts into account (Hyland, 2003, 2007; Hyon, 1996). The last tradition, of ESP, is most prevalent in the research conducted in this thesis, because of the work done on the research article genre, the genre central in the present research study.

Research Articles' Genre Characteristics

Since the research article is the predominant genre in scientific discourse, we focus on this genre, and more specifically on the formal (i.e., research articles' structural elements) and rhetorical (i.e., intended purposes) knowledge dimensions. In a number of studies, genre analysts have identified genre characteristics. One of the most obvious ones is the canonical organizational text structure of research articles, often referred to as IMRD format, which is closely associated with the rhetorical nature of science. This abbreviation refers to the different sections common in research articles: Introduction, Method, Results, and Discussion (Florence & Yore, 2004; Penrose & Katz, 2004; Yarden, Norris, & Phillips, 2015). This format aids authors to organize their article and is useful in reading (Day, 1998). First, in the introduction authors present the existing knowledge base of the research field using citations to build upon prior work (Hyland, 2000), establish the study relevance and then introduce the goal of the study in the form of a research question or hypothesis (Penrose & Katz, 2004). Then, the methods and results sections are presented. In the methods section authors describe the research design, materials and methods that were used. In the results section research findings are presented, often accompanied with figures and tables (Penrose & Katz, 2004). These two sections together are also referred

to as the experimental narrative of the research article, as it contains no (or little) interpretations by the authors (Gillen, 2006). Nowadays, research articles have the methods section often at the end or it is supplied in (online) supplementary material. In the discussion section the authors interpret their findings, often with references to prior research, draw conclusions, explain and refute anomalies or contrasting findings enabling their readers to evaluate the conclusions on credibility, and propose practical applications and often a future research agenda (Gillen, 2006; Penrose & Katz, 2004).

So, the authors present knowledge claims and justify these claims with supports in order to enable their scientific peers to evaluate the claims for potential acceptance. The typical line of reasoning within a research article from a research question to data and their interpretations to support the claims is denoted as argumentative structure (Bazerman, 1988; Suppe, 1998). The term argumentative structure has no clear and strict definition. Yarden et al. (2015) described it as the text's logic of reasoning. Within the line of reasoning, the authors construct an argument, which we define as the justification of a claim by data, following Toulmin (1958). We could distinguish specific moves in a research article, which are traditionally analyzed in the field of genre analysis. Genre analysis is concerned among other things with the analysis of rhetorical moves that writers use to develop their argument. Rhetorical moves are defined as text fragments fulfilling a specific communicative function, present in the different sections (Connor, Upton, & Kanoksilapatham, 2007; Swales, 1990). John Swales, a linguistic scholar, is well known for his work in genre analysis. He analyzed prevalent moves in introduction sections of research articles (Swales, 1990). Other work comes from Dudley-Evans (1994) who analyzed a discussion section of a master's thesis in biological sciences on the appearance of moves, and Thompson (1993) who analyzed the results section of research articles in biochemistry on recurring moves. A line of reasoning in a research article is reflected in its rhetorical structure¹³, the specific arrangement of rhetorical moves. An example is the research question in the introduction (Connor et al., 2007; Swales, 1990; Van Lacum, Koenenman, Ossevoort, & Goedhart, 2016). See Table 3.1 for an overview of the argumentation and rhetorical genre characteristics.

13 Not to be confused with the rhetorical knowledge dimension that is about the intended purposes and outcomes of a genre, while rhetorical structure and rhetorical moves are seen as structural elements, part of the formal knowledge dimension.

Table 3.1. Schematic overview of the research article genre with its argumentation and rhetorical genre characteristics.

Rhetorical structure			Metadiscourse	
Article sections	Rhetorical moves	Description	Examples	
Introduction	Motive	a statement why the research was important, leads to the objective	"This motion <i>has been suggested</i> earlier in studies, but never <i>observed</i> directly." (RV)	
	Objective*	a statement about what the authors want to know (research question)	"In this experiment scientists tried to <i>show</i> ..." (RV)	
Method	Support (methodological)*	statements to justify the main conclusion (to check the validity or reliability of techniques)	"The particular dyes had consistent results, <i>therefore</i> they were able to <i>conclude</i> ..." (TM, RV)	
Results	Support*	statements to justify the main conclusion (e.g., data, interpretations)	"We <i>observe</i> ..." (RV)	
Discussion	Counterargument*	statement that argues against the main conclusion or a support (like potential errors)	" <i>Thus</i> , these results <i>suggest</i> ..." (TM, Q)	
	Refutation*	statement that weakens a counterargument	"a different dye might <i>affect</i> the step sizes..." (RV)	
	Main conclusion*	statement about the main outcome of the study, relates to the objective, leads to an implication	" <i>Thus</i> , the fluctuation should be of Brownian origin..." (TM)	
	Implication	statement about the meaning of the main conclusion (e.g., practical application)	"Our findings <i>strongly</i> ..." (Q)	
			"our data <i>imply</i> that..." (RV)	

Note. The rhetorical structure is reflected in the IMRD format and the arrangement of rhetorical moves. Another rhetorical strategy is the use of metadiscourse. Reporting verbs (RV), transition markers (TM), and qualifiers (Q) are italicized. The line of reasoning runs from the motive to the implication. Argument components (*) are indicated. Metadiscourse examples are taken from the students' texts collected in the study.

To introduce students to the argumentation and rhetorical genre characteristics of research articles we make use of the Scientific Argumentation Model (SAM), a heuristic to help undergraduates read and understand the argument in research articles (Van Lacum et al., 2016; Van Lacum, Ossevoort, & Goedhart, 2014). SAM consists of a set of seven rhetorical moves that comprises an article's line of reasoning (see Table 3.1 and Figure 3.1). Van Lacum and colleagues used genre analysis to develop the heuristic. Genre analysts describe the communicative purposes of a written genre (i.e., rhetorical moves). They also used argumentation theory, especially Toulmin's model of argument (1958) and the epistemic levels by Kelly and Takao (2002), to indicate relations between rhetorical moves (e.g., the supports build on each other). Van Lacum et al. (2014) showed that the use of SAM helped students to read research articles. The identification of an article's motives, objectives, main conclusions, and implications significantly improved in a group of 108 first-year biology undergraduates after a reading course. However, it remains unclear whether students recognize the article's argument with all its components and can reconstruct the argument in a written text.

Apart from structural features, such as the rhetorical structure, reflected in research articles, scientific discourse is characterized by specific language. Yarden et al. (2015) point to the importance of meta-scientific language to interpret and comprehend a scientific text and its underlying argument. It enables scientists to take an outsider stance in presenting statements and their implied truth status (e.g., an observation statement is offered as truth, while a possible explanation is more uncertain). The use of this language, also referred to as metadiscourse, is an important rhetorical strategy in academic discourse and one of the most important disciplinary and genre-specific conventions (Hyland, 2005; Hyland & Tse, 2004). We can describe metadiscourse as follows: it "enables text producers to frame and organize propositions, to position and engage readers, and to express a stance and enter relationships with their interlocutors (...)" (Hyland, 2005, p. 58). By the use of linguistic features, writers:

Figure 3.1. Schematic representation of SAM representing an article's line of reasoning (Van Lacum et al., 2016), which runs from a motive in the introduction to an implication in the discussion, indicated by the arrows.

seek to offer a credible representation of themselves and their work by claiming solidarity with readers, evaluating their material and acknowledging alternative views, so that controlling the level of personality in a text becomes central to building a convincing argument. (Hyland, 2005, p. 173)

In our analysis of students' written texts we focus on three types of linguistic resources. First, linguistic devices that help to guide a reader through a text, also called interactive resources. An example is the use of transition markers that signal the steps between propositions within an argument (Hyland, 2005). Consequence relations are one type of transition markers that "either tell readers that a conclusion is being drawn or justified (...), or that an argument is being countered" (Hyland, 2005, p. 50), examples are "thus" and "in conclusion". Second, reporting verbs are "one of the most explicit ways of attributing content to another source, and represents a significant rhetorical choice" (Hyland, 2002, p. 116). Reporting verbs can be classified in the following types: research acts, which refer to activities (verbs, like "observe", "show") or procedures ("analyze", "explore"); cognition acts, related to mental processes ("believe", "view"); and discourse acts, which refer to verbal expression ("discuss", "state") (Hyland, 2000). Third, widespread linguistic devices within scientific discourse with some overlap with reporting verbs are qualifiers distinguished in hedges and boosters (Hyland, 2005; Penrose & Katz, 2004; Toulmin, 1958). These interactional resources are words that help to involve the reader in the argument (Hyland & Tse, 2004). Hedges are devices, "(...) which indicate the writer's decision to recognize alternative voices and viewpoints and so withhold complete commitment to a proposition" (Hyland, 2005, p. 52), like "suggest", "might", "probably", or "indicate" (Hyland, 1994; 1998). Hedges are very useful as it is a means to support the author's position, provide a rhetorical stance, and strengthen the argument (Hyland, 1994; Hyland, 2016; Penrose & Katz, 2004). Hedges express tentativeness of a statement, while boosters express certainty in statements, such as "demonstrate" or "obviously" (Hyland, 2005). The argumentation and rhetorical genre characteristics of research articles in scientific discourse outlined above (Table 3.1) inform our study by illuminating what writing in the sciences entails and to what end we should educate science students using a genre approach.

Reading-Writing Connections

Following a genre approach with explicit teaching about the characteristics and social contexts of the research article genre, may give students control over their reading and writing of scientific texts. A longstanding and continued research interest in reading-writing relations has explored the ways reading and writing strengthen content learning, literacy and language development (Grabe, 2003; Newell et al., 2011; Spivey, 1997). It has been suggested in literature that reading of research articles supports students' writing, and vice versa. For example, Rice (1998) showed freshman science students' writing improvement in a course combining reading of research articles and writing of science texts. Brownell, Price, and Steinman (2013) showed that a writing-

intensive course improved biology undergraduates' perception and confidence of their abilities to read research articles and write scientific texts to a scientist and layperson audience. In a practice-based study by Kuldell (2003) university students were helped in writing laboratory reports when they read and collaboratively discussed research articles. However, in a practice-based study by Kroen (2004) with seven college science students the course lecturer's experience revealed that many students made limited connections between reading research articles and writing a paper, although a systematic research-based evaluation of the study was lacking. Although some studies showed that better readers tend to be better writers, that recognizing and using a text's organization results in better writing, and that extensive exposure to texts can lead to better writing in the long run these (practice-based) results have been criticized on sample size and lack of longitudinal results (Bray, Pascarella, & Pierson, 2004; Grabe, 2003). Grabe (2003) calls for more research towards reading-writing relations with more attention to genre knowledge and its uses in academic writing. Built upon this recommendation, we make a theoretical assumption that writing a scientific argument may be strengthened by reading argumentative texts, like research articles, using the SAM heuristic following genre-based writing instruction principles.

RESEARCH AIM AND QUESTIONS

As evident in the review of the literature, a potential means for supporting undergraduate science students in developing their writing skills lays within the development of their genre knowledge. Our hypothesis is that students, after being introduced to the rhetorical structure of research articles using SAM, can identify and reconstruct a research article's argument in a written summary of a research article. Here, we focus on both the formal and rhetorical knowledge dimensions of genre knowledge. The three questions that guided this study are the following:

1. What are the characteristics of undergraduate physics students' reconstructions of a research article's argument in a written summary after being introduced to the argumentation and rhetorical genre characteristics of research articles?
2. What are students' considerations for including information in their written summaries?
3. How do students perceive SAM as a tool for reading and summarizing research articles?

We chose students' written summaries of a research article to answer our first research question, because summaries reveal students' mental representations of the article's argument (Chambliss, 1995). A summary is defined as "a brief version of the gist of the text, those propositions that are deemed most central and essential

according to some criterion” (Spivey, 1997, p. 194). A summary task then allows students to decide what elements of a source text they find important. Students’ capturing of key information from a source text also provides clues for students’ text understanding. For answering the second and third research questions, we used retrospective interviews and a questionnaire.

METHODS

To understand students’ reconstruction of arguments we chose a qualitative single-case study design (Yin, 2014), the case being defined as the group of university students who followed the course. A case study approach allowed us to explore in-depth the way students reconstruct a research article’s argument.

Educational Setting

We implemented a teaching strategy in the Physics of Life course, a small-scale elective course, in 2014, as a pilot, and a revised version in 2015. In this study we report about the teaching strategy of the second intervention, as this edition was more refined. The course lasted 10 weeks in the second semester of the physics bachelor degree program at a large public university in Groningen, the Netherlands. The course aims at introducing students into biophysics and supporting their development of reading and writing skills. The course revolved around modern techniques, like single-molecule microscopy, used to study biological phenomena at molecular scale (e.g., motor proteins).

Teaching strategy

For the purpose of this study we developed the teaching strategy in collaboration with the course lecturer. The core of the teaching strategy relies on reading and analyzing research articles with a specific focus on the rhetorical structure, following an ESP genre approach using text analysis tasks.

Figure 3.2. Schematic overview of the course activities (white) and research activities (light grey). The abbreviation of the rhetorical moves: M: Motive, O: Objective, MC: Main Conclusion, I: Implication, CA: Counterargument, R: Refutation.

The English-taught course consisted of weekly lectures and tutorials (with a total of ~24 hours) (see Figure 3.2). In lectures (90 minutes) students were taught about biophysics topics to provide background information about the research articles, addressing the subject knowledge dimension of genre knowledge. These topics were also discussed during tutorials. In four subsequent classes students were explicitly and gradually introduced to the rhetorical structure of research articles by using SAM. To support students in their learning, we used modeling systematically, one component of the cognitive apprenticeship principle (Collins et al., 1991): the course lecturer showed how he identified rhetorical moves in an example article and constructed a SAM scheme. After each of these four classes, students received a reading task with questions on the article’s physical content (comprehension questions) and its rhetorical structure (rhetorical moves) (Gillen, 2006). The students also received an information sheet about the rhetorical moves (Appendix B). Research articles were selected by the course lecturer from the 2014 course edition in collaboration with the researchers, based on recent research. The articles on single-molecule methods from *Nature*, *Science*, and *PNAS* were not adapted and they were fully available to students. The chosen research articles often do not follow a strict IMRD structure. Rather they consist of a continuous text with a method section at the end and/or reference to supplementary online materials. The Flesch Reading Ease Score¹⁴ indicated that the articles were fairly difficult to read (value range 53.9 - 59.4).

In the first week, students read and summarized the example article (Noji, Yasuda, Yoshida, & Kinoshita Jr., 1997) as pre-test and in the sixth week, after the teaching strategy, they summarized a different article (students read Yildiz et al., 2003 or Yildiz, Tomishige, Vale, & Selvin, 2004 because of a peer review activity) as post-test. The required word range for both summary tasks was 500-750 words (see Appendix C). The summaries were written in English. Though the articles for pre- and post-test differed in subject, they were identical regarding the presence and amount of rhetorical moves. The two post-test articles were from the same first author and about similar studies. The post-test summary was used for our analysis and subsequently revised by the students after peer review and discussion in pairs, as this may improve students’ writing (Hyland, 2016; Nelson, Range, & Burck Ross, 2012). The final product was graded by the course lecturer, based on assessment criteria different from our analysis criteria. Before the post-test summary, students answered comprehension questions about the research article and made a SAM scheme as a pre-writing activity.

14 The Flesch Reading Ease Score (Flesch, 1948) is a measure for text readability on a scale between 0 (very difficult to read) and 100 (very easy to read).

Participants

The participants were nine (six men, three women) physics majors between 17 and 25 years old. All students were experienced users of English (among them seven Dutch and two international students from English-speaking countries). Two students had no earlier experience with reading research articles, while five students had read a few research articles (one to three) and two students had read multiple articles (four to more than 12). All students provided their written consent to participate in the study. The course lecturer, who was not involved in the research, had three and a half years of experience in academic teaching and with courses on science reading and writing. A teaching assistant, a PhD student in single-molecule techniques, led almost all tutorials. The researchers were not involved in teaching or grading.

Data Collection and Analysis

Pre-test and post-test summaries

All summaries were collected via online submission and were anonymized. One student was excluded from analysis, because he did not hand in his first summary, resulting in eight summaries for both the pre-test and post-test. As a reference for analysis of the students' summaries, we developed analytical frameworks of the articles (in Appendix D an example of a framework for a research article is presented), containing the article's main line of reasoning with its rhetorical moves. The frameworks also included additional line(s) of reasoning (i.e., a research line not directly related to a study's main objective) and essential information about the research object and method, which we called information moves to distinguish this information from the rhetorical moves (see Dudley-Evans, 1994). The analytical frameworks were constructed in collaboration with and validated by the course lecturers from both course editions (two experts in biophysics). In the analysis of the summaries we identified the text fragments¹⁵ similar to statements in our analytical frameworks. We investigated whether the information students provided was essential, complete, and correct compared to the article's argument. Further, we categorized text fragments on the rhetorical functions they probably perform by looking at linguistic, organizational, and/or content features using a genre analytic perspective (Biber, Connor, & Upton, 2007). Sometimes, the phrasing of the text could affect the determination of rhetorical moves. A text unit including the linguistic feature "to conclude" indicated at first sight a conclusion. However, when evaluating the content of the text unit we were able to find out that it represented a support using the analytical framework of the corresponding article.

We complemented the analysis, in accordance with the work by Kelly and Bazerman (2003), by exploring how the students formulated the moves and made use of metadiscourse (transition markers, reporting verbs, and qualifiers). Grammar, spelling and other linguistic features were not analyzed. The analysis steps with an example are summarized in Figure 3.3. The analysis was done in two phases to guarantee reliability. In the first phase, the author of this PhD thesis and a second researcher analyzed four summaries (including data from the first intervention) and discussed the outcomes until agreement. In this phase the analysis steps were developed, refined and tested. In the second phase, the author of the present PhD thesis analyzed the other summaries.

Student interviews

Near the end of the course (Figure 3.2), we interviewed all students individually to reflect on their summaries, and how they perceived SAM for reading and summarizing articles (RQ 2 and 3), following a stimulated-recall approach (Gass & Mackey, 2000). The interviews (40-60 minutes) of the eight students, who completed the pre- and post-test, were audio-recorded. During the interviews students had access to their summaries and other materials in print, like the research articles. We asked about their considerations for selecting information in their summaries (e.g., "What information did you include in the summary and why?", "How did you decide what to include?", "Did you use the scheme for writing the summary?"), and their SAM and course experiences. The interviews were transcribed verbatim and were open-coded for students' considerations and course opinions.

Questionnaire

After the last group meeting (Figure 3.2), the students filled out a questionnaire to disclose their opinions about their perception of working with SAM in reading and writing (RQ 3). The questionnaire consisted of five-point Likert items (see Table 3.4). We calculated median scores for each statement.

¹⁵ We have chosen to divide summaries into text units at a sentence level. Often we selected units of multiple, consecutive sentences when they evidently belong together, based on the content and phrasing of those sentences. It may also happen that a phrase within a sentence is taken as a unit, when it contains one separated rhetorical function.

Analysis steps

- 1. Segment summary into text units and code their main (rhetorical) function with reference to the analytical framework of the corresponding research article using linguistic, content, and/or organizational features of the text unit.
- 2. Evaluate whether the information refers to essential aspects of the article (the main line of reasoning, information about research object and methods). Information belonging to an additional line of reasoning is only noticed.
 - a. Evaluate text on completeness by checking which essential components are present compared to the total of essential components in the analytical framework.
- 3. Evaluate text units on correctness in terms of:
 - a. subject content (e.g., measurement values or a protein's function).
 - b. move presentation (i.e., do language cues indicate an information or a rhetorical move and is it presented in a similar way corresponding to the article?).
- 4. Check text units coded as rhetorical move on the presence of metadiscourse and note differences with the research article:
 - a. transition markers (consequence relations) (TM)
 - b. reporting verbs (RV)
 - c. qualifiers (Q) (presence only checked in text units coded as main conclusion)

Analysis example

TEXT UNIT: "In this case, the authors want to characterize a single molecule that acts as a rotary motor known as F₁-ATPase." (student 7, pre-test, unit 2)

Steps:

- 1. Objective
- 2. 1/1
- 3. a. It is not about characterizing, but about direct observation of the rotation.
b. Presented as objective ("authors want to...")
- 4. RV: "to characterize" (in research article: "to observe")

Figure 3.3. Analysis steps for the pre- and post-test summaries, illustrated with an example.

FINDINGS

Move Presence

Students' pre- and post-test summaries were equally long (on average 647 and 641 words, respectively). Table 3.2 gives an overview of the presence of moves in the pre-test summaries. We will mention some of our most notable findings. Most moves were present in almost all summaries. It is particularly noteworthy that students were complete or nearly complete in mentioning the article's supports. Implications were least included in the summaries (two students out of eight). The summaries of students 1, 3, 4, 6, and 7 show that objective and conclusion were not always presented as combination. Counterarguments were mentioned by all students, although in the interview students 1 and 2 both said that they did not mention a counterargument in their summary. This suggests that they were not always aware of the rhetorical function of the information they gave in the summary. Taken together, the article's argument was fully or almost fully reconstructed by the students.

All students included one or more moves that were part of the additional line of reasoning (data not shown in Table 3.2). All students presented information (results and supports) that we considered as not essential for the article's main argument. Half of the students gave much information about the method (percentage of words spent on method information compared to the total amount of words: mean 24.8%, range: 7-47%).

Table 3.2. The presence of information and rhetorical moves in the pre-test summaries.

Student	Information moves		Rhetorical moves						
	Research object	Method	M	O	S	CA	R	MC	I
1	2/2	3/3	1/2	0/1	5/5	1/1	2/2	1/1	1/1
2	2/2	2/3	1/2	1/1	5/5	1/1	2/2	1/1	0/1
3	2/2	2/3	2/2	0/1	4/5	0.5/1	2/2	1/1	1/1
4	2/2	3/3	0/2	0/1	3.5/5	0.5/1	1.5/2	1/1	0/1
5	2/2	2/3	0/2	1/1	4.5/5	1/1	1.5/2	1/1	0/1
6	2/2	3/3	2/2	1/1	5/5	1/1	0.5/2	0/1	0/1
7	2/2	2/3	2/2	1/1	4/5	1/1	1.5/2	0/1	0/1
8	2/2	3/3	1/2	1/1	5/5	0.5/1	2/2	1/1	0/1

Note. For each student is shown the amount of present components compared to the total move components. Some components were split into multiple parts, therefore half components can be present. M: Motive, O: Objective, S: Support, CA: Counterargument, R: Refutation, MC: Main Conclusion, I: Implication.

In the post-test, the students summarized either the article by Yildiz et al. (2003) (students 1-5) or by Yildiz et al. (2004) (students 6-8). The 2003 article contained two main lines of reasoning: about testing two different walking models for the

motor protein myosin, which was the article's main focus, and about the technique development (Table 3.3A). Except for student 3, the summaries reflected the first line of reasoning. More than half of the supports were identified by the students. Students' summaries were least complete in methodological supports (justifying the methods used), counterarguments, and refutations. The main conclusion of the second line of reasoning is missing in four of five summaries. Student 1 mentioned it without corresponding supports, though in the interview he explained that the supports were important. Students 3 and 4 included supports of the second line of reasoning, but did not give the corresponding objective and main conclusion. This incomplete argument reconstruction seems to point at students' problems in disentangling different arguments, probably because the possible presence of multiple lines of reasoning was not discussed in class. The 2004 article (Table 3.3B) was summarized by students 6-8 and contained one main line of reasoning. The line of reasoning from objective to the main conclusion, justified by (methodological) supports, was reflected in the summaries. Supports were almost complete. The counterargument and refutation were only present in the summary by student 6. Taking the two groups together, we notice that the articles' main arguments were largely reconstructed, but that some students (esp. those in group A) incompletely underpinned the conclusions with supports.

Moves belonging to an additional line of reasoning, ranging from one to four, were present in seven post-summaries. Six students included information, mainly results and supports that we considered as not essential. These findings suggest that the students struggled with coordinating evidence and conclusions. Like in the pre-summaries, students included also superfluous information about the method (percentage of words spent on method information compared to the total amount of words: mean 35.5%, range: 20-46%). Student 6, 7, and 8 explained in the interview they found methodological information most important.

Correctness

The analysis showed that the texts in the summaries were largely correct, but still we noted frequently inaccurate or unclear information in all pre- and post-test summaries. Inaccuracies were noted in representation of measurement values, descriptions of types of proteins, or incorrect explanations. For example, in student 4's pre-test summary the protein was called a linear motor, while it was a rotary motor. Student 1 indicated that myosin moves along microtubules, while it moves along actin filaments (post-test). These outcomes indicate that students did not always fully comprehend the information presented in the research articles. This interpretation was supported by the interview and questionnaire outcomes that revealed that the articles were not always clear to students.

Table 3.3. The presence of information and rhetorical moves in the post-test summaries.

A

Student	Information moves	
	Research object	Method
1	2/4	4/6
2	3/4	5.5/6
3	4/4	6/6
4	3/4	3/6
5	3/4	5.5/6

Student	Rhetorical moves										
	Line 1						Line 2				
	M	O	S	MS	CA	R	MC	O	S	MC	I
1	0/1	1/1	3/5	0/2	0/1	0/2	1/1	1/1	0/2	1/1	1/3
2	0/1	1/1	5/5	0/2	0/1	1/2	1/1	1/1	2/2	0/1	1/3
3	1/1	0/1	3.5/5	2/2	0/1	0/2	1/1	0/1	2/2	0/1	1/3
4	1/1	1/1	3/5	0/2	1/1	1/2	1/1	0/1	1/2	0/1	2/3
5	1/1	1/1	3/5	2/2	0/1	0/2	1/1	1/1	2/2	0/1	0/3

B.

Student	Information moves		Rhetorical moves							
	Research object	Method	M	O	S	MS	CA	R	MC	I
6	3/4	4/5	1/1	1/1	2.5/3	2/3	1/1	1/1	1/1	1.5/2
7	4/4	5/5	0/1	1/1	2/3	1/3	0/1	0/1	1/1	1/2
8	3/4	4/5	0/1	1/1	3/3	1/3	0/1	0.5/1	1/1	0/2

Note. For each student is shown the amount of present components compared to the total move components either in article Yildiz et al. (2003) (A) or Yildiz et al. (2004) (B). Some components were split into multiple parts, therefore half components can be present. Article Yildiz et al. (2003) (A) contains two main lines of reasoning. M: Motive, O: Objective, S: Support, MS: Methodological Support, CA: Counterargument, R: Refutation, MC: Main Conclusion, I: Implication.

Identification process

Prior to writing the post-test summary students made a SAM scheme, which shed light on students' identification processes. In each scheme we found three to eight fragments that did not correspond with our analytical frameworks. For example, student 7 mentioned a support that we identified as an implication. Sometimes, the identification of a rhetorical move was difficult because of its lexical cues used in the article. Student 5 identified a text fragment incorrectly as refutation, because of the phrasing in the article "this large distance can be explained by (...)". These findings indicate that identifying rhetorical moves is not easy and it could be questioned whether students were always aware of the function of information presented in

the articles. In the interviews students sometimes stated that they find it hard to identify rhetorical moves. According to the students, supports, counterarguments, and refutations were most difficult. We think that these moves are hard to localize, because they lack distinct identification markers.

To conclude, the students reconstructed the articles' arguments almost completely. It is especially noteworthy that the students almost fully reconstructed the pre-test article's argument. They presented almost completely and correctly the argument's moves. In the post-test summaries, reconstruction was less complete, because some methodological supports, counterarguments, and refutations were absent. Most summaries included much detailed and non-essential information, especially about the method. This finding suggests that students had another understanding of what is essential than our expert analytical frameworks imply.

Move Presentation

A number of differences in move presentation were observed between the original articles and student's summaries (total: nine times). We observed that an implication was presented as an objective, result or counterargument, or a support was presented as a counterargument. We noted that in some cases supports, counterarguments, or implications were formulated as conclusions by using the lexical cue "conclude". In addition, we noted five instances of information moves in the summaries, while this information is actually a rhetorical move (motive, support, or main conclusion) in the article itself. This observation is illustrated by the example given below. The first sentence of the summary by student 2 (left) is presented as a fact (information move: research object), while it is the article's main conclusion (right):

"A single molecule of F_1 -ATPase acts as a rotar [sic] motor. A central rotor of approximately 1 nm is formed by its γ -subunit (...)" (Student 2, pre-test, unit 2)

"We now show that a single molecule of F_1 -ATPase acts as a rotary motor, the smallest known, by direct observation of its motion." (Noji et al., 1997, p. 299)

Although the frequency of these misrepresentations is rather low it supports our observation that students had problems in identifying and understanding moves.

Metadiscourse

We found some important differences between the students' wording of the argument compared with the original article. For example, the students did not use much metadiscourse. In each pre-test summary we found transition markers, ranging from one to five. In seven post-test summaries, we found students using transitions markers, ranging from one to four. Transition markers occurred in the objectives,

supports, counterarguments, refutations, main conclusions and/or implications, and were mostly different from the ones used in the article, though they had the same implied meaning. Due to a sparing use of transition markers, few explicit links between moves appeared in the summaries, resulting in a lack of internal coherence.

In the pre- and post-test summaries all students used reporting verbs (pre-test range: five to 17, post-test range: 11 to 25), but these were frequently different from those used in the article. We observed reporting verbs with different connotation than (likely) meant in the article (total occurrence of 11 in all pre-tests and 15 in all post-tests). A student used the word "show" in a support instead of "observed" in the original article, changing its epistemic status. Another example is the use of "discover", while in the article "observe" or "show" is used.

Considering the qualifiers: in the pre-test article the main conclusion contained "discriminating evidence" as a booster. Four students did not use any qualifier or left out the term "discriminating" in their main conclusion. Two students used the same qualifier or a different one with a weaker meaning ("this provides strong indication"). The two other students did not include the main conclusion in their summary. In the post-test article (2003), the main conclusion contained no qualifier. No qualifiers were present in the summaries by students 1 to 5. In the article by Yildiz et al. (2004) the main conclusion contained "strongly support". Both students 6 and 8 copied this qualifier. Student 7 included another one ("proved"). Although numbers are low, it might mean that students have become more aware of the meaning of qualifiers during the course.

Selection of Information

In the interviews, the eight students explained how they selected information. Some students assigned a great value to the methodological information in the articles. All students saw the importance of including rhetorical moves in their summaries, following the article's line of reasoning. After the course, the students said they were more aware of the presence of rhetorical moves in the articles and did select them for the summary, and most of them used their SAM scheme. Student 4 explained why he preferred his second summary: "Just this, motives and supports, (...) you have more of an idea what has to be in your summary" (interview student 4). All students mentioned considerations that referred to the assignment, like the word limit or target audience, as illustrated by:

the summary as a way to explain to one that does not know anything about the topic, (...). So, it was like OK I am that person, what should I know? I was thinking about myself, like if someone is explaining to me, like what should they tell me? And then I was like OK hmm first of all I do not know what a linear motor is and then yeah... so I was trying to explain it to myself in a way. (interview student 7)

Most students selected information that suits the summary genre, focusing on main points, like student 8 illustrates: "... the essence of the whole research study, well I used that. And not so much the non-essential issues of ... uh ... of further implications or something" (interview student 8). Student 4 based his selection on readability and functionality: "that it is nice to read and not very extensive, because otherwise someone can read the article by himself" (interview student 4). Half of the students indicated that comprehensibility of the research article's content played a role in their writing. Unclear or complex information was left out. Students 3 and 6 explained it as follows: "Some of the analyses were a bit difficult to summarize, so I skipped those parts or mentioned them briefly" (interview student 3) and "Things that were a bit unclear I didn't put in really, in the main conclusion and the results" (interview student 6). Overall, the students mentioned a diversity of reasons that guided their summary writing.

Students' Perception of SAM

The students saw the relevance of SAM when reading, analyzing, and summarizing research articles (Table 3.4). They said it helped them to unravel the article's structure and to know what is important in the text, as student 5 clarified: "I think it helped me as a writer and as a reader to pinpoint the things that are important" (interview student 5). In the interviews, students indicated that making a scheme was hard, a lot of work, and that a really good understanding of the text is required.

Table 3.4. Median scores about the students' perception of SAM (n = 8).

Statements about the use of SAM	Median score (span)
1. It is useful to identify different key elements (e.g., motive) to understand ascientific research article.	5 (4-5)
2. Making a scheme is a helpful tool to understand the structure of a scientific research article.	4 (3-5)
3. Making a scheme is a helpful tool to write a summary of a scientific research article.	4 (3-5)
4. In future I will make a scheme to understand the structure of a scientific research article.	4 (2-5)
5. In future I will make a scheme to prepare writing a summary of a scientific research article.	4 (1-5)

Note. We used a five-point Likert scale (1: *strongly disagree* to 5: *strongly agree*).

DISCUSSION AND CONCLUSIONS

With this research study we explored how undergraduate physics students reconstructed a research article's argument in a summary after having followed our teaching strategy. The teaching strategy was based on genre-based writing instruction and inspired by cognitive apprenticeship (the modeling component) as an instruction methodology in which students were introduced into the rhetorical structure of

research articles by using a heuristic, called Scientific Argumentation Model (SAM). The analysis of the data showed that the students presented the articles' arguments largely complete and correct in accordance with the original articles' arguments, both in the pre-test and in the post-test. However, the students did not use much metadiscourse. In case of a sparing use of transition markers a lack of internal coherence in the texts was observed. This is in line with other research showing that students have difficulty with setting up a coherent structure of conclusion and evidence (Newell et al., 2011; Sampson & Clark, 2008). It can also be questioned if the students were aware of the meaning of specific reporting verbs with a different epistemic status, like "observe", "report", "indicate", and "show". Students may struggle with adequately providing rhetorical references (such as "to show") to relate a claim to the evidence (Sandoval & Millwood, 2005). Further, the students did not always use the correct qualifiers in their main conclusions. Some attention to this linguistic device was given to students in course materials, but it was not the main focus during teaching. So, we see that students were not always aware of the language subtleties used in research articles. We believe that these outcomes are not caused by the students' limited English proficiency¹⁶. Yarden et al. (2015) indicated that "students are taught that scientists are not always certain, but they hardly ever are taught that this uncertainty leads scientists to choose words carefully to distinguish the degrees of certainty they wish to express in papers that they write" (p. 37). Since transition markers, reporting verbs, and qualifiers are important features in scientific discourse, it is necessary to draw undergraduate students' attention to these words in reading and writing instruction.

Interviews showed that students' decisions to include information in their summaries were based on the line of reasoning (the rhetorical moves) in the articles and that SAM helped them in recognizing what is important in a research article. However, the analysis of students' SAM schemes revealed that they did not always identify moves correctly. Most difficult for the students were the identification of main supports and combined counterarguments and refutations, as they explained in the interviews. This finding corresponds to those found by van Lacum et al. (2014).

Students sometimes paraphrased text from the original articles in such a way that its rhetorical function was changed. This suggests that students were not always aware of the function of information in the articles. In this, students' epistemological beliefs might play a role. For example, Nussbaum and Kardash (2005) showed that when college students were instructed to write about a certain topic by providing both supports and counterarguments/rebuttals, they were less likely to include counterarguments in their texts, because they thought it would weaken their argument.

16 Studies indicate that Dutch students have a very high English proficiency in reading and listening skills (Education First, 2019).

Although the subject content in the students' summaries was mostly correct, this also signaled that the students did not always comprehend the complete content of the research articles. This can be explained by the construction-integration model by Van Dijk and Kintsch (1983). In this model, the authors distinguish a textbase (representation of a text) and a situation model (representation of the situation or phenomenon referred to by a text). The textbase is the mental representation a reader constructs when reading the text. Basic understanding of the text is necessary for this construction. The adequacy of a student's textbase indicates the extent the student comprehends the text. When constructing a situation model the reader connects the text to his prior knowledge and is able to reflect on the text and criticize it. As novice readers of research articles, our students were hampered in constructing a complete textbase and situation model, because of their lack of knowledge of the field. More experienced and successful readers perform well on identifying the authors' main points and line of reasoning and construct a better situation model (Fox, 2009). This coincides with findings by Von Aufschnaiter, Erduran, Osborne, and Simon (2008) that students' argumentations depend on their familiarity with scientific content. Results from interviews and questionnaires supported our expectation that reading research articles was difficult for the students. The lectures, meant to clarify unknown concepts, did not provide students with sufficient knowledge. Some of the students considered methodological information most important for their summaries. This finding indicates that they, compared to experts, probably had another understanding of the essential issues when reading and summarizing a research article. Students' summaries resembled a miniature version of the article. It is known that in summary tasks students often repeat the structure of a text (Spivey, 1997). This raises the question whether students really reconstructed the research articles' arguments or copied it. The presence of non-essential information and additional moves in students' summaries is in line with the novice reader view described by Scardamalia and Bereiter (1991). They state that novice reading follows a linear process in which each statement in the text is interpreted on its own without taking into account the surrounding information. This leads to a copy-delete strategy by novices in summarization tasks (Brown, Day, & Jones, 1983).

The text analysis showed that students did not improve their summaries during the intervention, and that they even were somewhat better in their argument reconstruction in the pre-test. In the post-test, in particular when they summarized the 2003 article, students gave less underpinning of the conclusions. This suggests that our study did not find a difference or the students already recognized the gist of an article's study at the start of the course and that a ceiling effect has occurred. This notion is supported by our observation that our sample consisted of high-achieving students compared to the whole population of physics majors at our university. Other explanations are the short time span of the intervention, specific features of the articles used in the pre- and post-tests, or the difference in difficulty level of the articles.

Although the interview findings showed that the students intended to present the line of reasoning of the articles in the summaries, indicating that these summaries reflect the student's mental representation of an article's argument, summaries have some drawbacks as an instrument for exploring students' reconstruction of research articles' arguments. First, we found dissimilarities between students' SAM schemes and their summaries. Van Lacum et al. (2014) found that students improved their move identification after using SAM, but this does not necessarily mean that students are able to reconstruct the argument in a correct way. Second, summaries have a narrative character forcing students to select information. This appears to be a difficult task for inexperienced writers and as such a summary may not fully reflect a student's argument reconstruction. Third, novice writers tend to paraphrase, and even copy text from textual sources influencing the way the summary is phrased, a phenomenon often observed in writing from sources tasks (Keck, 2006). Other methods used in the literature to get insights in students' written argument (re)-construction, like think-aloud sessions, have also their drawbacks, for example influencing the process of writing during the session. Finally, we adopted a rhetoric stance in our analysis of students' reconstructions. We did not pay attention to the social interactions of students writing their texts, though seen from a genre viewpoint a text is socially mediated. Therefore, we recommend to including a social stance in further research as well by examining students' writing processes and their interaction with supervisors and peers.

We must be aware that our text analysis was based on allocation of moves to text fragments that probably reflect the moves in the original research article. Research articles are highly contextualized by the original authors making deliberate choices when writing the article (Spivey, 1997). It can be questioned what the students intended with particular text fragments. We tried to discuss their intentions during the interviews, but it was difficult for the students to explain their decisions weeks after having written their summaries. The period between summary writing and the interviews was probably too long, but inevitable for practical reasons. Possibly, students were not always aware of their choices during writing. Although stimulated recall interviews are used frequently in writing research (Gass & Mackey, 2000), we noted some inconsistencies in students' explanations, and therefore the interview findings were restricted in getting understanding of students' considerations in their writing.

In the interviews, the students saw the relevance of using SAM and indicated that SAM helped them in recognizing the important components of a research article and in understanding its structure. The findings of our study showed a difference between the students' perceptions (which is that they benefited from the genre approach) and students' writing products (which is that these did not improve). However, the findings of our study showed that the teaching strategy based on a genre approach

has benefits for students in recognizing the important components of a research article, to unravel and understand its structure. A genre approach, as implemented in this study, is limited as SAM focuses only on structural elements, and less on semantics of an article's content.

Overall, the findings of the study suggest potential of integrating reading and writing argumentative texts using SAM in undergraduate science courses and point to specific implications for theory, research, and practice. First, the analysis showed that the students made little use of metadiscourse. In case of the transition markers it resulted in a lack of internal text coherence. Based on these findings we recommend to emphasize metadiscourse in the conceptualization of argumentation models and making students aware of the role of metadiscourse in scientific text genres. This could help students making their written argument more coherent. Second, our teaching strategy, based on reading and analyzing research articles is promising to investigate further. As reconstruction of arguments was an intermediate step, a next question is whether SAM could help students in constructing a written argument. In future studies we aim to examine how undergraduate students construct an argument based on multiple text sources or own collected research data using SAM. In Chapter 4 we present such a research study where we implemented the teaching strategy in a biology course in which students used SAM to construct an argument using multiple text sources. Third, we must be aware that it is possible that novices might have another understanding of essential issues when reading and summarizing research articles than experts have. Therefore, explicit guidelines in writing assignments and clear assessment criteria are required. Fourth, as the students did not necessarily comprehend the article's text, we should take into account that using SAM alone is not enough, as it focuses on structural aspects, and not on semantics. Therefore, we should provide extra attention to semantics in writing instruction. Finally, important selection criteria for research articles in literacy courses are the presence of clear identification markers (e.g., to recognize counterarguments) and the presence of a single main line of reasoning to avoid complexity.

CHAPTER 4

Reading and Synthesizing Science Texts
Using a Scientific Argumentation Model
by Undergraduate Biology Students

This chapter is based on: Lammers, A., Goedhart, M. J., & Avraamidou, L. (2019). Reading and synthesising science texts using a scientific argumentation model by undergraduate biology students. *International Journal of Science Education*, 41(16), 2323-2346. doi:10.1080/09500693.2019.1675197

ABSTRACT

This study reports about biology undergraduates' writing in a course with genre-based writing instruction. The students read, analyze, and synthesize research articles using the Scientific Argumentation Model (SAM), a tool to make explicit the characteristics of the research article genre. We explored to what extent 21 students make a synthesis when writing a review of two research articles and which research article's genre characteristics (rhetorical moves and qualifiers) they use. We defined a synthesis as a task in which students select, organize, and connect the articles' content. The analysis of students' reviews showed that most students made a synthesis of both articles. The articles' objective, supports and main conclusion were mostly reflected in the students' reviews. Most students did not use a qualifier in their final conclusion, and when they did use a qualifier it sometimes did not correspond to their main text, suggesting difficulties with understanding the rhetorical meaning of qualifiers. We suggest, supported by our interview and questionnaire data, that SAM could be useful for understanding, selecting, and organizing research articles' content when writing a review. We conclude that the use of SAM could be a first step in synthesizing research articles focused on supporting students' rhetorical consciousness.

INTRODUCTION

In scientific discourse the research article is the predominant genre (Penrose & Katz, 2004; Yarden, Norris, & Phillips, 2015). As science writers, scientists need to have knowledge of the content and understanding of the nature of the scientific discourse and its text genres to present their claims in a way that convinces readers. Hence, scientists need to be aware of the rules and conventions used in the discourse of their science discipline appropriate with their writing goal(s) and audience (Yore, Florence, Pearson, & Weaver, 2006). It is then crucial that university students pursuing science studies are supported in developing their scientific writing skills in order to enculturate themselves as member of the scientific community. Developing students' scientific writing skills becomes even more crucial in light of research evidence that scientific writing promotes scientific literacy (Jiménez-Aleixandre & Erduran, 2008; Norris & Phillips, 2003; Treacy & Kosinski-Collins, 2011), science learning (Choi, Hand, & Greenbowe, 2013), as well as academic and professional success (Breeze, 2012; Newell et al., 2011).

However, research has shown that writing science texts is a complex and demanding task for students (Kellogg, 2008; Rijlaarsdam et al., 2012). As well-documented in related literature, students encounter different kinds of writing difficulties, such as structuring, constructing arguments and expressing information accurately (Daems & van der Westen, 2008; Galbraith & Rijlaarsdam, 1999; Kelly, Regev, & Prothero, 2008; Sampson & Clark, 2008). Moreover, students may encounter difficulties when entering a new discourse community in which they will come across many different text genres. Often there is a misalignment between faculty teaching staff and students in their expectations for writing (Lea & Street, 1998). Therefore, university instructors should immerse students in scientific discourse and educate students about the scientific genres and their characteristics. One way to support students in their writing is using genre-based writing instruction to explicitly draw their attention to the goals of discourse and its genres (Galbraith & Rijlaarsdam, 1999; Hyland, 2003; Swales, 1990). However, empirical research examining undergraduate students' science writing abilities using genre-based instruction is limited. This study aims to contribute to filling this gap by investigating the genre characteristics that undergraduate students use in their written science texts, following their participation in a science course that follows genre-based writing instruction.

THEORETICAL BACKGROUNDS

Teaching Practices in Scientific Writing

In higher education writing courses have become common practice over the last decades (Björk, Bräuer, Rienecker, & Stray Jörgensen, 2003; Wingate, Andon, & Cogo, 2011). Of great influence is the Writing Across the Curriculum (WAC) movement in U.S. colleges and universities, where academic writing instruction is embedded in all subject areas next to a common first-year composition course. Students are often supported by a (extracurricular) writing center (Bazerman et al., 2005; Russell, Lea, Parker, Street, & Donahue, 2009). Writing in the Disciplines, an approach within the WAC movement, is particularly concerned with discipline-specific writing instruction. Writing instruction is often delivered by subject lecturers (Bazerman et al., 2005; Wingate & Tribble, 2012). In Europe, such an integration of writing instruction in disciplines is not common practice yet (Björk et al., 2003; Raad voor de Nederlandse Taal en Letteren, 2015). Examples of initiatives to embed writing instruction in science courses have been published. Some focused on writing-to-learn activities for undergraduates to construct science understanding (Reynolds, Thaiss, Katkin, & Thompson Jr., 2012), while others focused on learning to write scientifically (Rice, 1998) or combined both (Cronje, Murray, Rohlinger, & Wellnitz, 2013). However, structural writing instruction is not always explicit or even absent in undergraduate science degree programs (Herelixa & Verhulst, 2014; Raad voor de Nederlandse Taal en Letteren, 2015; Tribble & Wingate, 2013).

Reading-Writing Connections

Writing has often been viewed as an isolated skill, but more recently it is viewed to interact with other literacy skills and especially reading (Breeze, 2012). There has been a continued research interest exploring the ways reading and writing might strengthen content learning and support literacy and language development (Bray, Pascarella, & Pierson, 2004; Grabe, 2003; Newell et al., 2011; Spivey, 1997). Both skills share a set of knowledge (e.g., knowledge about text attributes, such as text organization) and rely on correlated cognitive processes (Fitzgerald & Shanahan, 2000). Writing instruction should therefore be closely tied to reading and content instruction (Breeze, 2012; Grabe, 2001; Leki & Carson, 1997). Grabe (2003) called for more research towards reading-writing relations with more attention to genre knowledge and its uses in academic writing. Understanding and recognizing a text structure in reading a text can improve writing (Grabe, 2001; 2003) and in turn, understanding a text's structure can improve reading comprehension (Grabe & Zhang, 2016). Swales (1990) coined the term "rhetorical consciousness" as the recognition of a genre's rhetorical structure. Swales stated that it is important to point to this structure when learning about a (text) genre. Built within these claims, in this study we combined reading and writing activities in order to support students in developing their rhetorical consciousness. In universities reading-based writing is common, often referred to as writing from

sources (Grabe & Zhang, 2016). An example of a small-scale writing task combining reading and writing is the academic reaction paper, which prompts students to read, summarize, and critically evaluate a research article (Breeze, 2012). A more complex reading-based writing task is the discourse synthesis. It requires students to compose a text by selecting, organizing, and connecting content from multiple sources (Cumming, Lai, & Cho, 2016; Segev-Miller, 2004; Spivey, 1997; Zhang, 2013). In our study we used a synthesis writing task (literature review) in order to integrate reading and writing in a course that follows genre-based writing instruction principles to acquaint students with the genre characteristics of research articles.

Genre-Based Writing Instruction

Learning to write genres is like a process of apprenticeship in a new academic setting (Berkenkotter & Huckin, 1995), enculturating students into the practices of scientists (Norris & Phillips, 2003). Genre-based writing instruction is supposed to develop students' genre knowledge (De La Paz & McCutchen, 2011; Hyland, 2007; Tardy, 2009a). Genre knowledge is a form of situated cognition and is defined as "an individual's repertoire of situationally appropriate responses to recurrent situations" (Berkenkotter & Huckin, 1995, p. ix). De La Paz and McCutchen (2011) argued that, although the importance of students' genre knowledge is growing, there is a lack of empirical research that examines students' genre knowledge. Similarly, Hyland (2003; 2007) argued for the use of genre-based writing instruction, because it helps students perform the literacy tasks during their degree program and beyond. In addition, a genre-based approach is useful for students who do not have much experience in writing (Dudley-Evans, 1997) as is the case for the participants in this study. A genre-based approach aims at giving students control over a genre by familiarizing them with its rhetorical characteristics and social contexts to gain access to the discourse community (Hyland, 2007; 2016). An important underlying belief in genre-based writing instruction is that explicit knowledge of the rhetorical and linguistic features of a genre supports students in learning how to write that particular genre (Hyland, 2003; Tardy, 2009b).

For the purpose of this study we draw primarily on a genre-based approach that evolves from English for Specific Purposes (ESP), largely influenced by John Swales (Swales, 1990). This genre-based writing instruction is mainly focused on non-native speakers of English in academic settings (here referred to as EAP: English for Academic Purposes), as is the case for the participants in this study, and is concerned with teaching explicitly the textual and linguistic genre features (Hyon, 1996; Swales & Feak, 1994). Students, often in small groups, analyze and compare samples of a genre: a process called rhetorical consciousness raising (Hyland, 2007). In the present study we used the research article genre, predominant in scientific discourse, and introduced students explicitly to its characteristics by using a heuristic following the principles of genre-based writing instruction.

Research Article Genre Characteristics

The rhetorical nature of science is reflected in a research article’s text (Florence & Yore, 2004; Penrose & Katz, 2004). Its most obvious characteristic is the canonical text structure, often called IMRD (Introduction, Method, Results, Discussion) (Yarden et al., 2015). The typical line of reasoning within a research article from a research question to data and their interpretations to support the claims is denoted as argumentative structure (Bazerman, 1988; Suppe, 1998). Within this line of reasoning, the authors construct an argument as the justification of a claim by data (Toulmin, 1958). From a genre analysis perspective, a line of reasoning in a research article is reflected in its rhetorical structure, the specific arrangement of rhetorical moves. Rhetorical moves are defined as text fragments fulfilling a specific communicative function, present in the different sections playing an important role in the argumentation. An example is the research question in the introduction (Connor, Upton, & Kanoksilapatham, 2007; Swales, 1990; Van Lacum, Koeneman, Ossevoort, & Goedhart, 2016).

As reported in previous work, a way to support undergraduate students’ rhetorical consciousness in reading is to make use of the Scientific Argumentation Model (SAM) (Van Lacum et al., 2016; Van Lacum, Ossevoort, & Goedhart, 2014). This heuristic was developed to help science undergraduates read and understand the argument in research articles focusing explicitly on the rhetorical structure of a research article. SAM consists of a set of seven rhetorical moves in research articles and their characteristics, and a scheme that shows the relationships between the moves (Van Lacum et al., 2016). Van Lacum et al. (2014) found that the use of SAM helped students to read research articles. The identification of an article’s motives, objectives, main conclusions, and implications significantly improved in a group of 108 first-year biology undergraduates after a reading course. The rhetorical moves and the scheme are presented in Figure 4.1.

Apart from structural features, such as the rhetorical structure, metadiscourse is an important rhetorical strategy in academic discourse and one of the most important disciplinary and genre-specific conventions (Hyland, 2005; Hyland & Tse, 2004). An example is the use of qualifiers, distinguished in hedges and boosters (Hyland, 2015; Toulmin, 1958). Hedges are devices, “(...) which indicate the writer’s decision to recognize alternative voices and viewpoints and so withhold complete commitment to a proposition” (Hyland, 2005, p. 52), like “suggest”, “might”, or “indicate” (Hyland, 1994). Hedges express tentativeness of a statement, while boosters express certainty in statements, such as “demonstrate” or “obviously” (Hyland, 2005).

Figure 4.1. Scientific Argumentation Model (adapted from Van Lacum et al., 2016).

RESEARCH AIM AND QUESTION

In the present study, we implemented genre-based writing instruction and SAM in an undergraduate biology course to explicitly draw students’ attention to the research article’s genre characteristics to support their writing of scientific texts. Our assumption was that reading the research article genre with the aid of SAM supports students in developing their rhetorical consciousness and that, in turn, might support them in developing scientific writing skills. The writing task for biology undergraduates was a literature review of two research articles. In our analysis, we particularly focused on students’ use of rhetorical moves and qualifiers in their written texts, and we aimed to respond to the following research question:

To what extent do first-year biology students make a synthesis of two articles in a written review following their engagement in SAM?

A synthesis was defined as a task in which students select, organize, and connect (research articles’) content. Our secondary purpose was to examine the students’ reading and writing experiences using SAM and course lecturers’ perceptions about the students’ use of SAM in reading and writing science texts.

METHODS

We used a case study in a natural setting that uses a mixed-methods approach to data collection and analysis (Denscombe, 2014). Case studies are particularly focused on gaining deep insight in social phenomena (Denscombe, 2014). This approach was appropriate given that the knowledge base regarding this topic is scarce; hence a case study would allow for an in-depth exploration of students' use of SAM when writing a scientific text that can be used as input for large-scale studies. We did not intend to generalize our findings to a larger population, but we aimed at an analytical generalization. Case studies serve "as a descriptive or exploratory foundation that helps with the development of theory, and it is in this *analytic* respect that the findings from case studies can be generalized" (Denscombe, 2014, p. 69, emphasis in original). Insights derived from this study may be transferable to other comparable university contexts that make use of a genre-based writing instruction using SAM for scientific writing. Data consisted of students' reviews, student and course lecturer interviews, and a student questionnaire. We collected the students' reviews to examine the extent to which the students synthesized two research articles after being introduced to SAM. Next to the students' texts, we took the students' reading and writing experiences using SAM into account using interviews and a questionnaire to enrich and interpret our text analysis findings. We interviewed the course lecturers about their perceived experiences of the students' use of SAM in reading and writing in order to gain a more comprehensive and multifaceted overview of the students' abilities of synthesizing two articles in a review and the role of SAM in it.

Educational Setting

We implemented the teaching strategy in the course Biomolecular Research in 2015 as a pilot study, and again in 2016. We only report about the data collected in 2016, because this course edition was more refined compared to the first implementation. The course lasted three weeks ($\pm$ 51 hours) in the second semester of the first year at a large public research university in the Netherlands. The course focused on research into Parkinson Disease, aimed at supporting students in developing understandings about molecular biology, essential basic biomolecular laboratory techniques and practicing with reading and writing scientific texts. The language of instruction was Dutch, though learning material and assignments were provided in English. The course was developed by the researchers in collaboration with the two course lecturers.

Teaching strategy

The core of the teaching strategy was an explicit instruction on research articles' genre characteristics (i.e., the rhetorical structure and qualifiers) by using SAM and practice with reading and analyzing research articles about Parkinson Disease (first two weeks of the course, course meetings: $\pm$ 19 hours). Recent articles from their own research

area were selected by the course lecturers. The Flesch Reading Ease Score (FRES)¹⁷ of the articles had an average of 29.8 indicating that the articles were very difficult to read. Optional (review) articles were available to students for more information. During small-group meetings students were instructed in different topics about molecular biology and Parkinson Disease, addressing students' subject knowledge that helped them in reading and understanding the research articles. In the meetings students were explicitly instructed in the rhetorical structure of research articles using SAM. Students were instructed in distinguishing the structure and moves and the use of metadiscourse in research articles by reading a set of different research articles. In addition, they were taught about scientific writing practices and publication processes. To support students in distinguishing rhetorical moves in research articles, we systematically used modeling, one component of the cognitive apprenticeship principle (Collins, Brown, & Holum, 1991). The course lecturers illustrated how they identified rhetorical moves by sharing multiple examples from authentic research articles. Two researchers discussed and practiced the use of SAM with both lecturers during the course development. The two course lecturers implemented SAM the way that we, the researchers, envisioned. Students received three individual reading assignments with comprehension questions about the biology content and assignments to identify the rhetorical moves (Gillen, 2006), for instance, to identify the motive of the research study. They also received an information sheet about rhetorical moves (Appendix B). Next, the research articles and the associated assignments were discussed among students and the course lecturers.

After the reading tasks (at the end of the first week) students wrote a brief literature review (750-1000 words) in English in which two articles (A: Koyano et al., 2014; B: Fiesel et al., 2015) are compared, evaluated, and synthesized to answer a central question (see the writing task in Appendix E). In agreement with Spivey (1997), we defined a synthesis as a text in which students select, organize, and connect content from multiple sources, here the two articles. We provided a central question to guide the students' reading and writing. The two articles fitted well together because they present different perspectives on the activation of a Parkinson-related protein (parkin). Article A showed that in parkin activation the protein ubiquitin is phosphorylated by another protein (PINK1) suggesting a two-step model. Article B confirmed the presence of phosphorylated ubiquitin in human patient samples and its dependence on PINK1 activity. Both articles indicated that parkin activation has both a direct and indirect mechanism, whereas article A investigated the molecular mechanism, while article B approached the topic from a pathophysiological perspective. Prior to writing, students answered comprehension questions and mapped the rhetorical moves of both articles. Students gave each other peer feedback on their draft reviews, as

¹⁷ The Flesch Reading Ease Score (Flesch, 1948) is a measure for text readability on a scale between 0 (very difficult to read) and 100 (very easy to read).

peer review may improve students' writing (Nelson, Range, & Burck Ross, 2012), and received additional feedback from the course lecturers. The students and course lecturers used the following feedback criteria: biology content, line of reasoning, critical evaluation, text structure, and English language use. These criteria were different from our analysis criteria (see below). For the line of reasoning criterion the course lecturers were guided by the question: "Did the student clearly state the authors' reasoning in both articles and give a justified answer to the question addressed in the review?". However, in their feedback to students the course lecturers mostly neglected this aspect. The feedback was more focused on the other aspects (e.g., scientific content), aspects that are beyond the scope of our research, and did not influence the students' writing much in terms of synthesis writing.

Participants

A total of 21 students participated in the course (no drop-outs). The students were Dutch biology majors between 18 and 21 years old. All students had some experience with reading research articles prior to the course, ranging from one to six articles ($n = 15$) or more ($n = 6$). Eleven students had never written any kind of scientific text (e.g., research report) prior to the course. All students provided their written consent to participate in the study. Two lecturers taught the course, but they were not involved in data collection and analysis. David (pseudonym) was a professor in Molecular Microbiology and Alex (pseudonym) was a professor in Cell Biochemistry. Both had six years of teaching experience at the time this study was conducted.

Data Collection and Analysis

Students' reviews

All reviews ($n = 21$, final text) were collected through an online submission system, they were anonymized, and they were assigned an identification code. We used a genre analytic perspective to analyze the reviews (Biber, Connor, & Upton, 2007), as it is an appropriate way to segment a text in various components to identify genre characteristics. We developed an analytical framework to identify the components of the review: aim, rhetorical moves from both articles, comparison between the two articles, evaluation of the articles, and a final conclusion (Appendix F). The main rhetorical moves of both research articles that constitute their main lines of reasoning were identified and validated by one of the course lecturers (an expert in the research field of Parkinson Disease). The analysis followed three steps: selection, organization and connecting content, which are required when writing a review (synthesis task). Figure 4.2 provides an overview of the analysis steps alongside an example. The first step in the analysis was to divide the student's text into text units and categorize their main (rhetorical) function corresponding to one of the components in the analytical framework using linguistic, content, and/or organizational features of the text units. Text units were defined at sentence level, sometimes combined sentences when

these evidently belong together. It also happened that a phrase within a sentence was taken as a unit. Text units that contained background information about theory, methodology or prior research were called information moves, and were also included in the framework (Dudley-Evans, 1994, see Figure 4.2, unit 1). In order to explore whether and to what extent the students evaluated the articles' content, we categorized text units with an evaluative statement. Following Gillen (2006), we explored how the students judged the strengths (positive evaluation) or weaknesses (negative evaluation) of one or both articles. Evaluative statements that were neither positive or negative, or statements that were neutralized by another statement, were coded as neutral. In Table 4.2 we illustrate students' evaluative statements. The first step enabled us to examine what content the students included in their text, and specifically what content (rhetorical moves/information moves) they selected from the two articles. After having categorized all text units, in the second step we noted the order and organization of the text units (i.e., what was the overall text structure?). In the third step (not shown in Figure 4.2), we examined whether the student connected the two articles by assessing whether the final conclusion provided by the students answered the central question given the review's content. Next, we analyzed how the students made use of qualifiers in their final conclusions, because qualifiers (i.e., hedges or boosters) are an important linguistic characteristic of scientific writing and could provide us with clues about the strength or weakness a student assigned to a conclusion in light of their interpretation and evaluation of the research articles' content (Hyland, 2015). We marked these words in the student's text using a priori codes. Grammar, spelling, and other linguistic features were not analyzed, since these are not genre characteristics.

Figure 4.2. Analysis steps with an excerpt of the data analysis of student 8's review. In parentheses text units are indicated. The underlined word in the student's review is coded as a hedge.

In order to establish trustworthiness, the author of the present PhD thesis and a second researcher discussed the analysis steps prior to the analysis and collaboratively analyzed one sample text. Then these researchers discussed a randomly selected part of the total sample ($n = 5$), showing much agreement. Cases of disagreement were discussed until consensus was reached. Next, the author of this PhD thesis analyzed all texts ($n = 21$) using an adapted version of the analysis steps and framework.

Students' and lecturers' perceptions about using SAM

For the purpose of examining students' perceptions about their engagement in SAM we carried out semi-structured interviews with them. The author of this thesis interviewed nine randomly selected students individually at the end of the course (see Appendix G for the interview questions). We carried out pilot interviews with students during the first course implementation to validate the questions. The interviews (lasting ± 30 minutes) were audio-recorded and transcribed verbatim. We marked fragments in the transcripts related to the students' experiences about using SAM during their reading and writing. These interviews were supplemented by a questionnaire that was filled out by 20 students after the last course meeting (see Appendix H). We performed a pilot test of the questionnaire during the first implementation testing the comprehensibility of the items. The students had to indicate how much they agreed (on a five-point Likert scale) with four statements about the usefulness of SAM in reading. We calculated median scores for each statement. In addition, the students were asked to answer three open-ended questions about the difficulties they might have experienced during move identification, reading research articles, and writing the review. Their answers were categorized according to the type of difficulty.

To examine the course lecturers' viewpoints, the author of the present thesis interviewed them individually after the course to identify their perceived experiences with the course and the students' use of SAM (see Appendix I for the interview questions, pilot tested in the first course implementation). The interviews (± 45 minutes) followed a semi-structured format and were audio-recorded. Audio fragments were analyzed and summarized. The summaries were sent to the course lecturers for verification, after which small adjustments were made.

FINDINGS

Students' Reviews

Content selection

The students included most rhetorical moves from the original articles in their texts, particularly the objectives, supports and main conclusions as shown in Table

4.1. Article A's motive was mentioned more often than article B's motive, maybe because article A's motive and objective are more directly linked with the aim of the review. The counterargument in article B was included more often than the one in article A, because it was probably easier to recognize since it was stated in the discussion section, a typical place for counterarguments. Refutations and implications were included by less than half of the students. Apart from the findings on counterarguments and refutations, the findings suggest that the students identified most components of the authors' arguments.

Table 4.1. Number of student texts (*n* = 21) containing rhetorical moves. Article A: Koyano et al. (2014). Article B: Fiesel et al. (2015).

Article	M	O	S	CA	R	MC	I
A	12	15	21 (students mentioned 3 to 9 supports, total 9)	1	0	18	3 (students mentioned 1 out of 2 implications)
B	2	12	21 (students mentioned 2 to 6 supports, total 6)	12	3	12	6 (students mentioned 1 out of 3 implications)

Note. M: Motive, O: Objective, S: Support, CA: Counterargument, R: Refutation, MC: Main Conclusion, I: Implication.

Seventeen students compared the two articles with respect to their objectives, methods, results, and/or conclusions. Nineteen students evaluated both articles, often on multiple aspects, mostly on text structure/line of reasoning and the methods used (see Table 4.2). Overall, positive evaluations had the upper hand. Article B was criticized more often than article A (42 vs. 34 instances, not shown in Table 4.2). In most cases the evaluations were neither further explained nor supported. Sometimes it was simply stated that it impacted the results, or that a method, like using patient samples, was more reliable than another method without explanation.

Content organization

Three types of structures in the students' reviews emerged, which we described as summary-based, topic-based, and evaluation-based, as explained in Figure 4.3. In most texts (*n* = 12) a topic-based structure was evident, like the review by student 8. In the interview he explained: "[the authors from both articles] are actually proving the same thing only using different methods. I have bundled that together in different sub headings" (18). The summary-based structure and the evaluation-based structure were found to a lesser extent.

Table 4.2. Topics of evaluation in students' reviews. Indicated is the frequency of positive (+), negative (-), or neutral (±) evaluation statements.

Topic of evaluation	Nature (frequency)	Examples
Text structure / line of reasoning	+ (15) - (5)	"Koyano et al. found more substantial data than Fiesel et al. and their line of reasoning was clear and well explained." (+, student 1, unit 31)
Methods	+ (19) - (4)	"In my opinion they are not wrong to draw that conclusion but I would like to see more tests to prove that pS65-UB is specific to only mitochondrial damage and occurs in all cell types." (-, student 21, unit 16)
Data / results	+ (4) - (2)	"In contrast, Fiesel et al, have a main support based on experiments solely with their own antibodies, which weakens their statements." (-, student 7, unit 22)
Counterarguments	+ (1) - (8) ± (2)	"Furthermore, the experiments where described in detail and there seemed to be no hard counterarguments." (±, student 11, unit 21)
Conclusions	+ (1) - (2)	"Even though Fiesel et al. ² experiments and supports weren't as clear as Koyano et al ¹ , they might have provided evidence that can be used for therapeutic purposes, which in my opinion is more a far-reaching finding." (+, student 13, unit 18)
Relevance of information	+ (7) ± (1)	"However, the in vivo part of their study was quite interesting, but not relevant for this review." (±, student 17, unit 19)

Summary-based (<i>n</i> = 6)	Topic-based (<i>n</i> = 12)	Evaluation-based (<i>n</i> = 3)
<ul style="list-style-type: none">• Introduction (background information, aim)• Summary article A• Summary article B• Comparison and/or evaluation articles• Final conclusion	<ul style="list-style-type: none">• Introduction (background information, aim)• Main text<ul style="list-style-type: none">◦ Topic 1◦ Topic ...• Comparison and/or evaluation articles• Final conclusion	<ul style="list-style-type: none">• Introduction (background information, aim)• Main text<ul style="list-style-type: none">◦ Discussion article(s) + Evaluation and/or comparison• Final conclusion

Figure 4.3. Organization of sections in three types of review structures.

Content connection

We analyzed whether the students connected the content of both articles in answering the central question. Seventeen texts contained both an aim (i.e., the (paraphrased) central question) and a final conclusion. In most of these texts we observed a connection of the content of the two articles, however in varying ways. The degree of connection was irrespective of the text’s structure. In eight of these texts, the articles were fully connected: information from the two articles was used to answer the aim correctly. A few of those students weighed the relevance of the two articles for their answer, as student 6 did:

It was clear that the article by Koyano et al. was more relevant for my main conclusion than that of Fiesel et al., because Fiesel et al. mainly described physiological events of phosphorylated ubiquitin. Therefore, most information revealed by Fiesel et al. was not of importance for my review. (student 6, unit 25)

Below we share an example of a student connecting the two articles in an explicit manner:

In Koyano et al. [1] they found that PINK1 was responsible for UB phosphorylation. In the article of Fiesel et al. [2] the [sic] confirmed these findings with similar results. The authors of Koyano et al. [1] also showed that although PINK1 phosphorylates Parkin, it remains inactive without interaction with pS65-UB. Given the results of both articles I conclude that PINK1 activates Parkin both directly and indirectly upon (simulated) mitochondrial damage (...). (student 16, units 20-22)

These texts came closest to a full synthesis, as the students formulated a new conclusion based on the preceding statements. In six other texts there was a constrained connection of both articles. In these texts the conclusion was correct with respect to the stated aim, but was mainly based on one article. Or the text lacked important information, resulting in an insufficient justification final conclusion. In another three texts the final conclusion did not answer the aim correctly and/or did not follow completely from the preceding information, resulting in an incorrect argument. We also observed that students did not incorporate their evaluative statements in their final conclusions, as illustrated by the following fragment:

In contrast, Fiesel et al. have a main support based on experiments solely with their own antibodies, *which weakens their statements* [emphasis added]. Also disregarding the fact that their antibodies recognized both parkin and ubiquitin phosphorylated versions in simply fixing their error margin, *weakens their conclusions* [emphasis added]. All in all, *Koyano et al. and Fiesel et al. have given enough support* [emphasis added] to show that ubiquitin is phosphorylated by PINK1 and is a co-factor in activating parkin. (student 7, units 21-24)

Although most students did compare and evaluate the articles’ content on various aspects, this information was little or not visible in their (formulation of the) final conclusion. Our analysis of the use of qualifiers in their final conclusions ($n = 19$) showed that four students used a booster (“have given enough support”, “support the already convincing”, “show”, “obvious”) and four students included a hedge (“suggest”, “it could be concluded”, “indicate”, “implies”). While article A drew conclusions with some caution, this was not always visible in students’ final conclusions.

Students’ Perceptions about SAM

The questionnaires showed that all 20 students overall agreed about the usefulness of identifying rhetorical moves for understanding research articles, during the course, but also in the future (Table 4.3).

Table 4.3. Median scores about the students’ perceptions about SAM ($n = 20$). A five-point Likert scale was used (1: *strongly disagree* to 5: *strongly agree*).

Statements	Median score (span)
The illustration of the different elements (e.g., motive) by the lecturers was helpful to understand the different elements in research articles.	4.0 (1-5)
The article discussions were helpful to understand the research articles.	4.0 (1-5)
It is useful to identify different elements (e.g., motive) to understand a research article.	4.0 (2-5)
In future, I will look for the different elements to understand a research article when reading one.	4.0 (3-5)

From both the interviews and questionnaire, we observed that identifying moves (esp. motive, objective, supports, counterarguments, and refutations) was difficult for students, but that practice helped. The students mentioned difficulties with distinguishing between motive and objective, with determining the importance of supports, and with the identification of counterarguments and refutations. The students indicated in the questionnaire that the articles were sufficiently comprehensible, but they found reading often difficult caused by a lack of background knowledge and knowledge of scientific language. Yet, lectures and discussions during the meetings helped the students in reading: “With the SAM, understanding the main reasoning from the articles was a lot easier. After the lectures the experiments were clear” (Q5).

Sixteen students indicated in the questionnaire that they encountered difficulties in writing the reviews. Most students had difficulty with the selection of information and with the format of a review. In the interviews, the nine students mentioned most frequently difficulties with content selection, critical evaluation, expectations of a review’s format, and using scientific language. Seven of the nine interviewed

students found the focus on SAM in the research articles during the course helpful for writing the review. Main reasons were that it helped in understanding the articles and organizing the important content. Summing up the above, the analysis of the data shows that the students perceived SAM as a useful tool in understanding the research articles, while experiencing sometimes reading and move identification difficulties. Writing the review was considered as a difficult task by most of the students, particularly content selection. Still the interview findings suggest that SAM was of use in writing the review, mainly in terms of organizing and understanding the content.

Lecturers' Perceptions about SAM

According to Alex most of the students learned to extract the most important information from a research article in a reasonably simple and fast way. He observed that students read an article faster at the end of the course compared to the start, which had probably to do with their increased subject knowledge, but also with their new reading strategies. David believed that, after the course, the students know that they can read a research article by themselves, and that they have a more comprehensive view of how science works. Both course lecturers perceived that the students' reading ability was at a good level at the end of the course. David indicated that generally the students understood the main message in the articles and were able to identify the important content. Both lecturers said that the majority of the students did not understand the articles' methods in detail. The lecturers agreed on the usefulness of SAM for students in reading research articles, mainly in selecting the most important information. SAM was helpful for David when he discussed the articles with the students: "It prevents to getting lost into details". Both lecturers indicated that the supports are difficult to find in research articles, because the texts have a high information density. Alex thought it is better to look for the more general, preliminary conclusions (a generalization of a finding). David believed that the students saw the relevance of SAM, but that it is difficult to identify each rhetorical move in an article: "that is difficult, we, as lecturers also have discussion about that". He experienced that students often think in terms of "right" or "wrong" when searching for rhetorical moves in articles, while their reasoning in identifying a particular text fragment is more important.

Both lecturers were satisfied with the level of the students' reviews. In particular, the text structure was excellent, said Alex. Both noticed that some students had difficulty in making a synthesis in their texts, which is in accordance with our text analysis findings. Alex mentioned that some students found it difficult to combine the results of the articles and draw a final conclusion. David added that some students were clearly better in making a synthesis compared with other students. Lastly, many students did well in critically evaluating the articles, said Alex, although students formulated their evaluation as a personal opinion (e.g., "I think this article was not

very good, because of..."). David emphasized the difficulty students had in their evaluation. Both lecturers thought that SAM was useful in helping students to write the review. Rhetorical moves from both articles appeared in the students' reviews, they explained. Alex mentioned that SAM helped students mainly in organizing their text. Summing up, the findings show that the course lecturers perceived SAM as useful for supporting students in reading research articles in terms of selecting the most important information of the text, as well as bringing structure in a text when writing the review.

DISCUSSION AND CONCLUSIONS

In carrying out this study, we departed from the assumption that a reading-based writing task (from a reading-writing perspective) and explicit instruction in the genre characteristics of research articles (following a genre-based writing instruction) can help students in scientific writing. We hypothesized that SAM would be used as a heuristic helping students to understand the main argument put forward in a research article by explicitly developing their rhetorical consciousness needed for writing a science text. Based on these assumptions we implemented a teaching strategy for science writing in an undergraduate biology course. We aimed at exploring which genre characteristics (i.e., rhetorical moves and qualifiers) first-year biology students used in writing a literature review, a form of synthesis writing, of two complementary articles. In what follows, we discuss the findings of the study as response to our main research question: *To what extent do first-year biology students make a synthesis of two articles in a written review following their engagement in SAM?* We expected that the reviews required selection, organization, and connection of information from both articles, leading to a synthesis. Based on our findings, we conclude that most students did make a synthesis of the two articles and suggest that SAM could be used as a first step in understanding and grasping an article's content, selecting and organizing important moves when writing a review. SAM might prepare students for writing a review in terms of selecting and organizing content of the source texts. Van Ockenburg, Van Weijen, and Rijlaarsdam (2019) showed that a similar activity, in which students answer questions on the main ideas of a text, is effective in selecting and organizing content in synthesis writing.

The findings showed that the students distilled and selected most rhetorical moves from both articles for their text, especially the objective, supports and main conclusion. The findings about the students and course lecturers' perceptions about using SAM showed that they perceived SAM as useful for reading and understanding research articles, mainly in getting an overview of a research article and selecting important information. The students found some move identifications difficult, especially the main supports and counterarguments. These findings correspond with

those by Van Lacum et al. (2014). Our findings suggest that the students identified and probably grasped the authors' arguments, although the students did not fully comprehend the articles' details. It is well-documented in literature that students' scientific argumentation depends on their familiarity with scientific content (Von Aufschnaiter, Erduran, Osborne, & Simon, 2008). We must be aware that our students are novice readers and incidental audiences for research articles (Yore, Bisanz, & Hand, 2003). Studies have indicated the difficulty of reading research articles for novices, due to the high information density, technical vocabulary, and abstract language (Fang, 2005; Gillen, 2006). Some students noted their unfamiliarity with the use of scientific English, however, studies have indicated that Dutch students have a very high English proficiency (Education First, 2019), and therefore we maintain that this had no impact on their comprehension. While SAM appears to be supportive for understanding the rhetorical structure of a research article, it does not guarantee a full comprehension of the content. Although we invested a lot in explaining the content of the research articles, additional instruction in combination with SAM might stimulate students' rhetorical consciousness.

The students' reviews were organized according to three text structures (summary-, topic-, and evaluation-based), which did not correlate with the extent to which the students connected the two articles. Spivey (1997) indicated that writers often follow or repeat a source text in synthesis writing. This was evident in the students' texts with a summary-based structure in which the two articles were summarized consecutively. The students' task representation could have been of influence, as students might conceive a synthesis task as summarizing source texts (Mateos & Solé, 2009). Future studies could improve our understanding of the way students synthesize research articles in review tasks. In the other two structures the students combined and organized the content less consecutively, which reflects the variability in synthesis writing. Most students and the course lecturers perceived SAM as useful in structuring and organizing important information for the review.

The findings of the study illustrate that the majority of the students' reviews contained an evaluation. The students evaluated the articles mainly on the line of reasoning, as was asked for in the writing task, and on the methods. The evaluative statements by the students were often not elaborated nor did they sound in the final conclusions. This finding concurs with the literature indicating that novices' critical evaluation skills and content knowledge restrict them in evaluating an article's argument (Gillen, 2006; Yore et al., 2003). Although this has been discussed in the lectures only a small number of students ($n = 8$) used a qualifier in their final conclusion. And if students used qualifiers, they did not always chose the ones corresponding to their evaluation of the articles. These findings suggest that students had problems with the rhetorical meaning of qualifiers in science texts.

The students and course lecturers indicated difficulties with writing, such as content selection. Studies have shown that undergraduate students experience difficulties with writing from sources (Mateos & Solé, 2009; Zhang, 2013), but that they develop certain strategies to deal with these complex processes (Cumming et al., 2016). We note that there was no extensive instruction or practice in synthesis writing during the course. To better support students in connecting and justifying content, we should address synthesis writing more explicitly in the course by including effective learning activities (Van Ockenburg et al., 2019), practice and feedback.

Some characteristics of our teaching design could have affected our conclusions. The small sample size means that we should be careful in drawing conclusions. The selected research articles were complex and we should be cautious with our interpretations about students' text comprehension reflected in their writing. Using a review as a writing task has also a shortcoming in this respect, because novice writers tend to paraphrase, and even copy text from textual sources: a phenomenon often observed in writing from sources tasks (Keck, 2006). This could have influenced the way in which students' texts were phrased, and could have hide, for instance, an incomplete text understanding and their recognition of the text's rhetorical structure.

From our analysis of students' texts, we got indications that SAM is a useful heuristic with regard to the structural elements in comprehending and setting up a science text. We also found that the students and the course lecturers perceived SAM as a useful heuristic for reading and understanding research articles and for selecting and structuring the content when writing a review. This is exactly what we intended with our course, which was developed from a genre-based approach and the perspective of Swales' (1990) construct of rhetorical consciousness: the recognition of a genre's rhetorical structure. As other researchers have found, students' understanding and recognition of this structure can help them in reading and writing (Grabe, 2001; 2003; Grabe & Zhang, 2016). Our findings suggest that SAM is helpful in explicitly drawing students' attention towards the rhetorical structure of research articles when reading and writing a literature review. It would be promising to investigate whether students could apply SAM when writing other science texts, like a laboratory research report. Based on the findings of this study, we recommend a larger follow-up study to measure students' reading and writing abilities after having followed a course in which SAM is used, and to examine the potential effectiveness of SAM on students' scientific reading and writing skills. Another possible future study would be an examination of the role of the course lecturers in implementing SAM and giving feedback to students' texts to provide important input for the design of professional development programs and university writing courses.

CHAPTER 5

Scientific Epistemologies: A Relation with
Undergraduate Biology Students' Evaluation
of and Writing about Research Articles?

ABSTRACT

Prior research gives an inconclusive picture about the possible relationship between students' writing and their epistemological beliefs, here referred to as scientific epistemologies. Therefore, the purpose of the present study is to examine undergraduate biology students' writing in relation to their scientific epistemologies. We focused on the way students used and evaluated content from research articles when writing a brief literature review and how this relate to their scientific epistemologies. The study was conducted in a first-year biology course in which 21 students used the Scientific Argumentation Model as a heuristic for reading of and writing about research articles. Data were collected through students' written reviews and a questionnaire exploring their scientific epistemologies. The analysis of the questionnaire data showed that the students' responses reflected a diversity of contemporary and traditional views regarding scientific knowledge and its construction with a majority of the students selecting mainly contemporary viewpoints. The analysis of students' reviews showed that most students connected the research articles' content and evaluated the articles largely positively, indicating the strengths of an article. In contrast with what we expected, we could not attribute students' scientific epistemologies' responses to their writing. The students with mainly contemporary views did evaluate the articles slightly more often. We conclude that our study did not point to a conclusive and clear relation between the students' scientific epistemologies and their evaluation of and writing about research articles. In future studies we recommend to complement the text analysis with student interviews to gain deeper insight into students' knowledge construction during writing and the role of their scientific epistemologies therein.

INTRODUCTION

Scientific writing is a professional activity that is an essential part of scientists' daily practice (Erduran & Dagher, 2014; Yore, Bisanz, & Hand, 2003). Scientists write and publish research articles in which they try to convince the scientific community about the validity of the asserted claims (Penrose & Katz, 2004). In this sense, scientific writing has an argumentative and persuasive character and reflects the rhetorical nature of science (Locke, 1992; Yore et al., 2003). In research universities, where future scientists are trained, it is important to support students in developing their scientific writing skills in order to enculturate them as member of the scientific community. In addition, research has shown that scientific writing promotes students' scientific literacy (Jiménez-Aleixandre & Erduran, 2008; Norris & Phillips, 2003; Treacy & Kosinski-Collins, 2011), science concept learning (Choi, Hand, & Greenbowe, 2013), and academic and professional success (Breeze, 2012; Newell et al., 2011).

Research has shown that writing texts is a complex and demanding task for students (Kellogg, 2008; Rijlaarsdam et al., 2012) and that students face difficulties, like constructing an argument: the justification of a claim by data (Daems & van der Westen, 2008; Galbraith & Rijlaarsdam, 1999; Kelly, Regev, & Prothero, 2008; Sampson & Clark, 2008). Research has been carried out on the introduction of scientific writing in undergraduate and graduate programs and how to support university students' writing development and learning (Cronje, Murray, Rohlinger, & Wellnitz, 2013; Gamberi & Hall, 2019; Reynolds, Thaiss, Katkin, & Thompson Jr., 2012). Structural integrated writing instruction in research universities is often limited in Europe, especially in the Netherlands, the context of the present study, despite a growing amount of initiatives (Björk, Bräuer, Rienecker, & Stray Jørgensen, 2003; Daems & van der Westen, 2008; Herelixa & Verhulst, 2014; Raad voor de Nederlandse Taal en Letteren, 2015). As an example, in our previous research presented in Chapters 3 and 4, we integrated writing instruction in undergraduate physics and biology courses aiming at supporting students' genre knowledge. We found that the Scientific Argumentation Model (SAM), a heuristic to read and analyze research articles, is useful for students in understanding, selecting, and organizing research articles' content when summarizing research articles or writing a review based on research articles (Lammers & Goedhart, 2017; Lammers, Goedhart, & Avraamidou, 2019).

However, besides genre knowledge other factors play a role in learning to write and students' writing strategies, like student's interest, prior knowledge, goals, reading ability, self-efficacy, and epistemological beliefs (Alexander, 2005; Alexander & Jetton, 2000; Fox, 2009; Hayes, 1996; Lavelle & Zuercher, 2001; Tanyer, 2015). To continue our research, in the present study we focus on students' epistemological beliefs, since research suggests a correlation between students' writing and their epistemological beliefs (cf. Baytelman, Iordanou, & Constantinou, 2015; Kuhn, 1991). Epistemological

beliefs refer to the beliefs someone holds about knowledge and knowing (Hofer & Pintrich, 1997). In the science education research it is common to refer to nature of science beliefs or scientific epistemologies when discussing beliefs about scientific knowledge. Still, research had not yet revealed clearly to what extent students' scientific epistemologies influence their writing and vice versa (Khishfe, 2012; Neely, 2014; Sandoval, 2005; Yarden, Norris, & Phillips, 2015). Therefore, we aimed at examining students' written texts in relation to their scientific epistemologies, which could provide useful insights how to instruct students in scientific writing, and more specifically when using SAM in our scientific writing courses.

THEORETICAL BACKGROUNDS

Scientific Epistemologies

Research on nature of science (NOS) has a long tradition since it is a critical component in developing students' scientific literacy (Dagher & Erduran, 2016; Khishfe, 2012; Lederman, 2007; Lederman & Lederman, 2014). Traditionally, NOS refers to professional science as a way of knowing, and to the "characteristics of scientific knowledge that are necessarily derived from how the knowledge is developed" (Lederman et al., 2014, p. 66). There is much debate about what constitutes NOS. The consensus view on NOS for K-12 science is reflected by science education reform documents and is used to measure students' NOS beliefs (Lederman & Lederman, 2014). This consensus view comprises a set of seven tenets that is used as a frame of reference to delineate NOS from science processes and scientific inquiry: scientific knowledge is (a) tentative; (b) empirically based; (c) subjective; (d) involves human inference, imagination, and creativity; and (e) is socially and culturally embedded. Also considered are (f) the distinction between observations and inferences; and (g) functions of and relationships between scientific theories and laws (Abd-El-Khalick, Bell, & Lederman, 1998; Lederman & Lederman, 2014). This list of tenets is often supplemented by the tenet that there is no universal scientific method for doing science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Although the consensus view is still widely used today it is not without criticism (Dagher & Erduran, 2016; Hodson & Wong, 2017). For instance, the declarative character of the tenets does not promote and foster discussion about what science is. Proponents of the consensus view, like Lederman and colleagues, differentiate NOS from scientific inquiry. Scientific inquiry is considered as "the processes of how scientists do their work and how the resulting scientific knowledge is generated and accepted" (Lederman et al., 2014, p. 66), while NOS is about the epistemological characteristics of scientific processes and knowledge. Others dispute this differentiation and state that both constructs are more alike and that scientific inquiry is considered important for NOS, as they are inextricably linked (Erduran & Dagher, 2014).

A comparable point of view towards NOS comes from Sandoval (2005), who coined the term "scientific epistemologies" to refer to students' beliefs about the epistemology of science: "students' ideas about the nature of scientific knowledge and the methods appropriate for generating and evaluating such knowledge" (p. 638). Sandoval's perspective considers the role students' scientific inquiry might play in students' understanding of scientific knowledge and vice versa, as opposite to the proponents of the consensus view. Sandoval brings forward four inter-related epistemological ideas students should understand when involved in scientific inquiry. First, scientific knowledge is constructed by scientists and is not discovered. Knowledge is thus socially mediated. Human creativity plays a major role in its development. Consequently, scientific knowledge is accepted by persuading others of the credibility of the claims. This is in contrast with a traditional conception that scientific knowledge is accepted because it is true. Second, there is a diversity of scientific methods within and between science disciplines, more than just controlled experimentation for hypothesis testing that is often advanced as the method of doing science. Scientists rely on standards to evaluate methods. This evaluation will in turn affect the degree of certainty assigned to the derived knowledge claims. Third, there are various forms of scientific knowledge that differ in their scope and purpose (i.e., laws, theories, models, or arguments). And fourth, scientific knowledge varies in certainty. That is to say, some claims are more subject to change than other ones. In some areas scientific knowledge is likely to change in light of new research findings, while in other areas research findings are more robust.

Alternative proposals for conceptualizing NOS have placed less emphasis on the epistemological components, but propose a more comprehensive view of the scientific enterprise that includes other facets as well. Irzik and Nola (2014), two philosophers of science, proposed the Family Resemblance Approach (FRA) to NOS. Dagher and Erduran (2016) elaborated and extended the FRA in order to develop a more comprehensive and holistic understanding of the nature of science: "The FRA acknowledges both shared and unique features that make various domains scientific" (p. 151). It is a framework at a higher level of abstraction and could be used to organize and develop science curricula and instruction (Erduran, Dagher, & McDonald, 2019). The framework views science as a cognitive-epistemic system (consisting of, for example, scientific practices and scientific knowledge) and a social-institutional system (e.g., professional activities, scientific ethos). Erduran and Dagher (2014) extended the FRA with three additional components to provide a fuller account of the social context of NOS: social organizations and interactions, political power structures, and financial systems.

In sum, nowadays NOS could be conceived as a broader construct consisting of multiple components next to the epistemological component. In the present study we focus on epistemological factors (e.g., what is the status and scope of

knowledge claims) in students' argumentative writing (e.g., analyzing data, drawing, and communicating conclusions, see Sandoval, 2005). We use the term "scientific epistemologies", following Sandoval, to refer to the epistemological understandings of students when engaged in writing, rather than using the term NOS to avoid conflation with the other conceptualizations.

Measuring scientific epistemologies

Research instruments to measure students' NOS beliefs (or scientific epistemologies) are abundant (Suzuri-Hernandez, 2010). The measurement of NOS beliefs requires a clarification of the NOS construct. It is common practice to view NOS beliefs as a cognitive outcome and not displayed through someone's behavior or attitude. Therefore, observation of student actions during scientific inquiry is not sufficient to assess students' NOS beliefs. Typical methods of measurement range from forced-choice (questionnaire with closed items or Likert scale items) to open-ended instruments (open-response surveys or interviews) (see an overview of instruments in Abd-El-Khalick, 2014; or Lederman et al., 2014). Forced-choice instruments are appropriate for administering to large groups, but are criticized on validity (often measuring other aspects, like attitude towards science), biased construction, and usefulness (Lederman, 2007). In most of these instruments the questionnaire items are developed reflecting the developers' philosophical stance and interpretations (Abd-El-Khalick, 2014), with the exception of the empirically-driven VOSTS questionnaire (Aikenhead & Ryan, 1992). Open-ended instruments are often favored, because the use of these instruments can result in a finer and richer understanding of a person's NOS beliefs and respondents get the opportunity to formulate thoughts in their own words. However, a discrepancy could exist between the interpretations of students' written responses and interpretations from interviews (Lederman, 2007).

Common for all these instruments is that they refer to what Sandoval (2005) called formal epistemologies, defined as a student's beliefs about scientific knowledge and its production in professional science (Sandoval, 2005). Decades of research has produced consistent findings that high school and university students' understandings of science often appear to be inadequate (Lederman, 2007; Lederman & Lederman, 2014). Abd-El-Khalick (2006) showed, for example, that 153 undergraduate and graduate science majors had inaccurate understandings of science, like about the tentativeness and theory-ladenness of scientific knowledge. In a study by Liu and Tsai (2008) undergraduate science students seemed to have less sophisticated beliefs regarding the theory-ladenness and cultural embeddedness of science compared to non-science students. In another study, a similar trend was found: undergraduate and graduate science students considered scientific knowledge as more certain compared to students from social science and arts/humanities (Jehng, Johnson, & Anderson, 1993). These studies suggest that university science students could have inaccurate understandings of scientific knowledge.

Students' Writing and Scientific Epistemologies

Prior research suggests a correlation between undergraduate students' written arguments and their epistemological beliefs (Kuhn, 1991). When undergraduate students' epistemological beliefs were more informed, students constructed stronger written arguments, meaning that their arguments were better supported by the use of different evidence (Baytelman et al., 2015; Nussbaum, Sinatra, & Poliquin, 2008). Khishfe (2012) showed a relationship between students' NOS understandings (aged 16-17) regarding the tentative, subjective, and empirical characteristics of scientific knowledge, and their written argumentations (conceptualized as the justification of a claim: giving arguments, counterarguments and refutations) in the context of socioscientific issues. Students' use of counterarguments had the highest significant correlation with the three NOS components, meaning that students with more informed NOS views constructed stronger counterarguments. However, other studies did not find a significant correlation between undergraduate students' epistemological beliefs and an argumentative writing task (Mateos et al., 2011; Neely, 2014). Other studies suggest that university students' and adults' ability to read and evaluate science texts more critically may be influenced by their scientific epistemologies (Feinkohl, Flemming, Cress, & Kimmerle, 2016; Kendeou, Muis, & Fulton, 2011). Therefore, in the present study, we focused both on students' evaluation and writing of science texts in combination with students' scientific epistemologies. Our research is a response to the inconclusive findings of the relationship between students' understanding of the nature of scientific knowledge and their writing.

RESEARCH AIM AND QUESTION

Continuing our line of research about undergraduate students' writing (Lammers et al., 2019), we aimed at examining students' texts to understand the way their scientific epistemologies manifest in their writing about research articles. We focused on the way students used and evaluated content from research articles in writing a brief literature review. It was not our intention to determine their formal scientific epistemologies in terms of categorizing students in different philosophical viewpoints. Instead we use their responses to items about the epistemological aspects of science to interpret their writing and get a more nuanced view of students' understanding of particular components. We anticipated that students who favored contemporary views about the nature of scientific knowledge would evaluate the research articles more critically. Additionally, we expected they would give a justified and appropriate formulation of a final conclusion in their writing. The context of the study was defined by an undergraduate biology course that aimed at supporting students' reading and writing of scientific texts. We formulated the following research question:

How do first-year biology students' evaluation of and writing about two research articles in a brief literature review relate to their scientific epistemologies?

METHODS

We used a mixed methods case study approach that allowed for an exploration of the students' writing in combination with their scientific epistemologies using different kinds of data (Denscombe, 2014). The case was defined as the group of 21 first-year biology students participating in the course. We did not intend to generalize our findings to a larger population, but we aimed at an analytic generalization: meaning that the study's findings can be generalized to theoretical propositions. The findings may be transferable to other comparable university contexts (Denscombe, 2014). We used a student questionnaire and students' written texts as data sources to answer our research question.

Educational Setting

The context of the study was the undergraduate biology degree program of a large public research university in the Netherlands. We collected data from the general molecular biology first-year course Biomolecular Research in 2016 that lasted three weeks ($\pm$ 51 contact hours). The course aimed at supporting students in developing skills and understandings about basic molecular biology laboratory techniques and practicing with reading and writing scientific texts about Parkinson Disease research. We designed the course in collaboration with the two course lecturers, who were responsible for the teaching and grading. The language of instruction was Dutch, but learning materials and assignments were provided in English.

Teaching strategy

In the course we implemented a teaching strategy that was developed to support the students in reading and writing scientific texts (course meetings: $\pm$ 19 hours). Its core consists of explicit instruction and analysis tasks about the research article's genre characteristics following genre-based writing instruction principles (Hyland, 2003; 2007; Swales, 1990). Genre-based writing instruction is concerned with teaching explicitly rhetorical, textual, and linguistic features of a specific text genre that are appropriate to its purpose, taking the genre's social context, here scientific discourse, at its account. The instruction aims at supporting students' genre knowledge that will help them in learning how to write a genre (Hyland, 2003; 2007; Swales, 1990). The students were introduced to a research article's rhetorical structure¹⁸ using the

18 Rhetorical structure is the specific arrangement of rhetorical moves in a text. Rhetorical moves are defined as text fragments fulfilling a specific communicative function, present in the different sections playing an important role in the argumentation (Connor, Upton, & Kanoksilapatham, 2007; Swales, 1990; Van Lacum et al., 2016).

heuristic Scientific Argumentation Model (SAM) developed by Van Lacum, Koeneman, Ossevoort, and Goedhart (2016). This heuristic was originally developed to help science undergraduates read and understand the argument in research articles, focusing explicitly on their structural and rhetorical features. SAM consists of a set of seven rhetorical moves comprising an article's line of reasoning (e.g., a study's objective and main conclusion) and a scheme depicting the relationships between the moves, see Figure 5.1 (Van Lacum, Ossevoort, & Goedhart, 2014).

We used modeling, one component of the cognitive apprenticeship principle (Collins, Brown, & Holum, 1991), as instructional pedagogy. The lecturers illustrated how they identified rhetorical moves in research articles by showing multiple examples from recent research articles.

Figure 5.1. Scientific Argumentation Model (adapted from Van Lacum et al., 2016).

Students read and analyzed individually three research articles about Parkinson Disease. The course lecturers selected recent articles from their own research field. The Flesch Reading Ease Score (FRES)¹⁹ of the articles had an average of 29.8 indicating that the articles were very difficult to read. Optional (review) articles were

19 The Flesch Reading Ease Score (Flesch, 1948) is a measure for text readability on a scale between 0 (very difficult to read) and 100 (very easy to read).

available to students for more information and an information sheet about rhetorical moves (Appendix B). They were asked to answer questions about the biology content of the article (comprehension questions) and identify its rhetorical moves and its rhetorical structure (Gillen, 2006). These analysis tasks were discussed in small-group meetings (duration of ± 90 minutes) between the lecturer and students. They also discussed the nature of scientific writing practices and the publication process. In addition, different topics about molecular biology and Parkinson Disease were discussed and explained addressing the subject knowledge students need to read and understand the research articles. There was no explicit instruction in nature of science components.

Next, students read and analyzed two new research articles that formed the basis of writing a review in English. We defined a review as a brief literature review (750-1000 words) in which the two articles are compared, evaluated, and synthesized to answer a central question (see Appendix E for the writing assignment). A synthesis was defined as a task in which students select, organize, and connect (research articles') content (Spivey, 1997). The two articles for the review writing task fit well together. Both articles presented different perspectives on the identification and the role of ubiquitin phosphorylation of the PINK1 protein. Article A (Koyano et al., 2014) showed that the protein ubiquitin is phosphorylated by PINK1 to activate parkin. The authors also provided a model for parkin activation, suggesting two steps in this process (a direct and indirect pathway), as they formulated: "To gain further insight into the mechanism we used computational modeling to generate two structural models that support binding of phosphorylated ubiquitin or phosphorylated UBL domain facilitates accessibility to Cys 431 (...)" (Koyano et al., 2014, p. 166). Article B (Fiesel et al., 2015) studied and confirmed the presence of phosphorylated ubiquitin in human patient samples and its dependence on PINK1 activity. Both articles indicated that parkin activation has both a direct and indirect mechanism, whereas article A investigated the molecular mechanism, while article B approached the topic from a pathophysiological perspective. Prior to writing, students answered comprehension questions and mapped the rhetorical moves of both articles. Students gave each other peer feedback on their draft reviews, as peer review may improve students' writing (Nelson, Range, & Burck Ross, 2012), and received additional feedback from the course lecturers (criteria: biology content, line of reasoning, critical evaluation, text structure, and English language use). Students used this feedback from peers and lecturers to write a final version of their review.

Participants

A total of 21 first year biology majors between 18 and 21 years old participated in the course (no drop-outs). The students had some prior experience in reading research articles prior to the course, ranging from one to six articles ($n = 15$) or more ($n = 6$). Eleven students did not write any scientific text, like a research report, prior to the

course. They all gave their written consent to participate in the study. Two lecturers taught the course, but they were not involved in data collection and analysis. Lecturer A was a professor in Molecular Microbiology and lecturer B was a professor in Cell Biochemistry. Both had six years of teaching experience at the time that this study was conducted.

Data Collection and Analysis

Students' scientific epistemologies

To explore the students' scientific epistemologies, we administered a questionnaire near the end of the course. We chose to use a selection of items from the Views on Science-Technology-Society (VOSTS) questionnaire developed by Aikenhead and colleagues for Canadian high school students (age 16-18) (Aikenhead & Ryan, 1992; Aikenhead, Ryan, & Fleming, 1989). The VOSTS consists of a pool of 114 empirically-driven multiple-choice items in English. Depending on the purpose and target group, items from this pool are selected to compose a questionnaire. The items are organized in eight themes surrounding a broad scope of science, technology, and society issues, for example the nature of scientific knowledge (Aikenhead & Ryan, 1992). Each item consists of a statement regarding one of the themes and multiple responses (generally eight to 10). We used the VOSTS questionnaire, because of its specificity and concrete formulation of the items, and the fact that multiple item themes were directed to epistemological aspects of science, the focus in this study. VOSTS has also a high degree of validity, as determined by Ryan & Aikenhead (1992). While respondents are forced to choose a response for each item, they can also choose 'neutral' responses (e.g., "I don't understand"). The VOSTS items have been successfully used with university students (Fleming, 1988) and are still in use today (Abd-El-Khalick, 2014). A disadvantage is that the questionnaire items do not present contexts, like scientific areas and disciplines, for example biology or physics. However, Abd-El-Khalick (2014) declared: "While the VOSTS items are of the forced-choice type, its empirically driven development process renders it unique and affords it a measure of validity that could not be claimed in the case of theoretically driven forced-choice instruments" (p. 631).

We selected 12 VOSTS items based on the following criteria: (a) appropriate topics for the course context in relation to the participants' undergraduate degree program; (b) comprehensibility and recognition of the items in terms of content and language for the participants; and (c) related to epistemological aspects of science (i.e. about scientific knowledge and its development, methods of inquiry). We used the original student instruction, language, and design of the questionnaire. The questionnaire items are included in Appendix J. All 21 students completed the questionnaire by hand after the last group meeting. The original VOSTS does not use a scoring scheme, but has a diagnostic function, unveiling student viewpoints, rather than a normative function (Suzuri-Hernandez, 2010). In later research, a scoring key has been developed

to employ statistical analyses (cf. Vázquez-Alonso, Manassero-Mas, & Acevedo-Díaz, 2006). In our analysis, we determined the frequency of students’ responses for each item (just like Ryan & Aikenhead, 1992). Next, we grouped the items in five overarching categories about the scientific approach to investigations and social construction and nature of scientific knowledge (see Table 5.1 for a description of each category). We based our categories and descriptions on Aikenhead and Ryan (1992), Erduran and Dagher (2014), Ryan and Aikenhead (1992), Sandoval (2005), Yore et al. (2003), and Yore, Florence, Pearson, and Weaver (2006). To interpret students’ answers, we distinguished the item responses in traditional and contemporary views²⁰ on science (Table 5.1 and Appendix J). From a traditional perspective scientific knowledge is developed through observations and measurements in the natural world, and is established by reasoning and not affected by a scientist’s personal background or beliefs, neglecting science as a social practice. In contrast, a contemporary perspective views science as a search to describe or explain reality with increasing accurateness. Multiple interpretations of observations or evidence by different scientists could co-exist. The resulting claims need to be evaluated critically and agreed on by the public and scientific community. Scientific knowledge is temporary and is subject to change, yet some knowledge is well-established and therefore durable (Yore et al., 2003; Yore et al., 2006). Next, we determined the number of traditional and contemporary responses selected by the students, which formed the basis to interpret our text analysis findings (see Appendix J and K).

Table 5.1. Categorization of items. The responses are distinguished in traditional and contemporary viewpoints with the corresponding VOSTS item responses.

Category	VOSTS responses
1. Social construction of scientific knowledge	
<i>Traditional:</i> science is seen as a discipline which yields ‘true’ results, based on observation and measurement, and progresses through objective, conclusive evidence, independent from the personal views and opinions of the researcher. Scientists might work from different theoretical perspectives though.	Item 1: A, C Item 2: A, B Item 3: A, B, E, F Item 4: B Item 5: C
<i>Contemporary:</i> scientific knowledge is constructed by scientists and personal perspectives (views and opinions) affect their findings. Scientific knowledge is established by reaching consensus to be agreed on in a community.	Item 1: D, E Item 2: C, D Item 3: C Item 4: C, D, E, F Item 5: A, B

20 It is common in literature to use terms as “naïve” or “uninformed” in opposite to “sophisticated” or “informed” to indicate students’ views. We rather prefer to use less judgmental labels for the students, and, from this point, we differentiate the students’ responses in traditional and contemporary. It was not our intention to classify the students according to a specific philosophical standpoint, but for clarity and readability purposes we use these terms in the remaining text to distinguish between the students.

Table 5.1. Continued.

Category	VOSTS responses
2. Nature of scientific knowledge	
<i>Traditional:</i> scientific models and classification schemes are considered as reflecting reality, i.e., scientific knowledge reflects reality.	Item 6: C, D Item 7: B
<i>Contemporary:</i> scientific models and classification schemes are a tool to explain nature (instrumentalism), i.e., scientific knowledge is socially constructed.	Item 6: E, F, G Item 7: C, D, E, F
3. Tentativeness of scientific knowledge	
<i>Traditional:</i> as time progresses we gain new knowledge, e.g. by improved methods and instruments. Older knowledge does not change, but is interpreted differently rebutting older facts (falsification), or because new facts are added (a cumulative view).	Item 8: A, C, D
<i>Contemporary:</i> scientific knowledge (facts, theories, etc.) can change, through reinterpretation of existing knowledge in light of new findings. Some knowledge is well-established and is unlikely to change.	Item 8: B
4. Scientific approach to investigations	
<i>Traditional:</i> all scientific work follows well-defined step-wise procedures (e.g., the scientific method), leaving no room for personal interpretation, creativity, imagination, and accidental discoveries.	Item 9: A, C, E, F Item 10: A, B Item 11: B, E, F
<i>Contemporary:</i> there is not one scientific method (i.e., the myth of scientific method). There is a diversity of approaches within and between disciplines. Scientific knowledge is partly a product of human creativity.	Item 9: G, I, J Item 10: C Item 11: A, D
5. Epistemological status of scientific knowledge	
<i>Traditional:</i> scientific knowledge is telling us what is really out there in nature, only to be discovered by scientists.	Item 12: A, B, C, D
<i>Contemporary:</i> scientific knowledge is a creation of the mind, i.e., scientists invent and construct knowledge.	Item 12: E, F

Students’ reviews

All reviews ($n = 21$, final texts) were collected by online submission, were anonymized, and were provided with an identification code. Our aim was to get insight into the students’ evaluations of and writing about the two research articles, and the justification they give when answering the central question in the review. We used a genre-analytic perspective to analyze the reviews (Biber, Connor, & Upton, 2007), as it is an appropriate way to segment a text genre in various components and to identify genre characteristics such as rhetorical moves. We developed an analytical framework to identify and describe the review components: aim, rhetorical moves from both articles, comparison between the two articles, evaluation of the articles, and a final conclusion (see Appendix F). The main rhetorical moves of both research articles that constitute their main lines of reasoning were identified and validated by one of the course lecturers (an expert in the research field of Parkinson Disease).

The first step in the analysis was to divide the students' text into text units and categorize their main (rhetorical) function corresponding to one of the components in the analytical framework using linguistic, content, and/or organizational features of the text units (see Figure 5.2). Text units were defined at sentence level, often combined sentences when these evidently belong together. It also happened that a phrase within a sentence was taken as a text unit. This first step enabled us to examine what content the students included in their text. Secondly (not shown in Figure 5.2), we examined whether the student connected the two articles by assessing whether the final conclusion was justified and answered the central question. Further, we examined whether, and how, the students wrote about the model presented by article A, as it is an important element of answering the central question. Moreover, it could give insight in their understanding of the use of scientific models. Thirdly, we analyzed how the students formulated their final conclusion by noting whether students made use of qualifiers²¹, because it can provide clues about the synthesis of the two articles and may reflect students' epistemological ideas about the scope and degree of certainty assigned to knowledge claims. We marked these words in the student's text using a priori codes. Finally, we explored whether and to what extent the students evaluated the articles' content. The text units categorized as evaluative statements about one or both articles (analysis step 1) were divided according to their evaluative nature (positive, negative, or neutral). We defined evaluation here as the students' own judgement of the strengths and weaknesses of the articles (Gillen, 2006), more specifically the justification of the main conclusions in the articles. Students' statements about the articles were noted as positive when a strength of an article was addressed (e.g., "Koyano et al. found more substantial data than Fiesel et al. and their line of reasoning was clear and well explained." – student 1, unit 31). Negative statements indicated a weakness of the article (e.g., "Fiesel et al. mention they could not exclude some cross reactivity of their antibodies with pS65-parkin, making their experiment a little less reliable than the results of Koyano et al." – student 5, unit 23). Evaluative statements that could not clearly been categorized as either positive or negative, or positive/negative evaluative statements that were neutralized by another statement, were coded as neutral (e.g., "However, the in vivo part of their study was quite interesting, but not relevant for this review" – student 17, unit 19).

Prior to the analysis, the author of the present PhD thesis and a second researcher analyzed collaboratively one sample text in order to establish trustworthiness. Then, we discussed a randomly selected part of the total sample ($n = 5$), showing much

21 Qualifiers are used to express the degree of certainty assigned to a statement and are distinguished in hedges and boosters. Hedges express tentativeness of a statement, while boosters express certainty in statements. Examples of hedges are "suggest", "indicate", "probably", "may", "could", "possible", "might", "perhaps", "imply". Examples of boosters are "clearly", "obviously", "demonstrate", "prove", "show" (Hyland, 2005; Penrose & Katz, 2004).

agreement. Differences were discussed until agreement was reached. Next, the author of this PhD thesis analyzed all texts ($n = 21$).

Introduction		
[Text unit 1: Mutations in pink1 and parkin, proteins related to mitochondrial damage control, have been shown to be responsible for recessive early onset Parkinson's disease. ¹ This is due to the sensitivity of dopaminergic neurons to mitochondrial damage. Pink1 and parkin proteins are involved in a pathway that induces mitophagy. Where pink1, which becomes stable after depolarization of the mitochondrial membrane, acts as a kinase upstream of parkin. Activated parkin subsequently ubiquitinates certain substrates, leading to mitophagy ² .] [Text unit 2: Recently two papers have been published, Koyano et al. (2014) ³ and Fiesel et al. (2015) ⁴ , proposing that pink1 phosphorylates not only parkin but ubiquitin as well. This phosphorylated ubiquitin (also called pS65-Ub) supposedly plays an important role in activating parkin.][Text unit 3: This review will compare these two publications and discuss their content and argumentation.](...)		
Analytical framework (first part shown)		Text unit
Aim of the review		Question in the assignment: Does (and how does it do this?) PINK1 activate parkin directly, indirectly, or both?
Article A	Motive	It is poorly understood how the E3 activity of parkin is accelerated by damaged mitochondria.
	Objective	What is the genuine substrate of PINK1 responsible for parkin activation?
	Main conclusion	Ubiquitin is phosphorylated by PINK1 to activate parkin.
	Implication 1	A complete understanding of the molecular mechanism underlying parkin activation is expected to clarify pathogenesis of hereditary and sporadic forms of PD.

Figure 5.2. Example of the text analysis showing an excerpt of student 8's review and a part of the analytical framework describing the review aim and some of article A's rhetorical moves. Text unit 1 was categorized as information move about the articles' topic, which is not considered in the present study.

FINDINGS

Students' Scientific Epistemologies

We found that the 21 students chose very different answers to the VOSTS items. Since students did not often select neutral responses, we assumed that a majority of the students did understand the statements in the questionnaire and recognized their viewpoint in the provided statements. Only student 5 selected multiple responses for four items. We considered these responses as "None of these choices fits my basic viewpoint". In Appendix J the items and the frequencies of students' responses are shared. In the Supplementary data we present an overview of the individual student responses. Below, we discuss the students' responses using the five categories from Table 5.1.

Social construction of scientific knowledge

Approximately half of the whole group of students selected responses assuming that facts play a major role in the acceptance of scientific knowledge, while the other half of the students also recognized the role of personal opinions and subjective feelings herein (items 1 and 2). Most students ($n = 18$) indicated that a researcher's personal background has an influence on the content of a theory (item 4). In contrast, 12 students favored a response that observations made by different scientists will be similar, in other words, that there is less or no influence of the scientists' interpretation based on differences in theoretical frameworks (item 5). This suggests that some students have inconsistent views. Eight students selected a response that highlighted the importance of convincing other scientists to make a theory more accurate, reflecting a contemporary view (item 3). However a majority of the students did not exactly understand or recognize the role of consensus in science.

Nature of scientific knowledge

A majority of the students ($n = 13$) responded to item 6 that scientific models are copies of reality. Seven students answered that models are helpful for learning, change with time or are educated guesses, which reflects a more contemporary view towards this subject. Most of the students ($n = 18$) favored a response that there are many ways to classify nature against a few students ($n = 3$) who selected the position that classification schemes match the way nature really is (item 7).

Tentativeness of scientific knowledge

Regarding the tentativeness of scientific knowledge (item 8), all students responded that scientific knowledge is subject to change. Seven students selected the contemporary view that old scientific knowledge changes when reinterpreted in light of new research findings. The other students selected more traditional interpretations of the tentativeness of scientific knowledge that new knowledge replaces or accumulates on existing knowledge.

Scientific approach to investigations

Only student 13 did select the response that there is no uniform scientific method, reflecting the most contemporary view (item 9). The most selected response by nine students was that the scientific method consists of "questioning, hypothesizing, collecting data and concluding", another contemporary view that reflects the typical general activities during scientific research in the students' degree program. Twelve students favored a response that indicated that scientists use originality and creativity in their work (item 10), acknowledging that doing science is more than strictly following a step-wise procedure. In addition, most students ($n = 11$) selected responses that the actual work by scientists is often less logical than the work presented in research articles (item 11), a contemporary view reflecting scientific practice.

Epistemological status of scientific knowledge

Ten students selected a position that a scientific theory is invented, in opposition to four students who think that a theory is discovered (item 12). Five students selected the response that scientific theories sometimes are discovered and sometimes invented with the already gathered facts.

Taken together, the responses by the students reflect a diversity of contemporary and traditional viewpoints. Examining the responses by the individual students for all twelve items together, we observed a group of six students showing more traditional responses (7 or more from 12 items) and a second group of 10 students having more contemporary views (7 or more) (see Supplementary data). From our group of 21 students, five did not fall in any of the above groups, because their responses showed a high diversity of traditional, contemporary, and/or neutral responses.

Students' Written Reviews

Justification and formulation final conclusion

Four student reviews out of 21 (19%) did not contain a synthesis due to the lack of an aim and/or final conclusion. The other 17 student reviews contained both an aim (i.e., the (paraphrased) central question) and a final conclusion related to that aim. In these texts the students used and connected the content of the two articles, however a synthesis was achieved in varying degrees. In eight texts (38%) students came closest to a full synthesis, as the students formulated a new conclusion based on the content from both articles. In six other texts (29%), there was a constrained connection of both articles. In these texts the conclusion was correct with respect to the stated aim, but was mainly based on one article or the text lacked important information, resulting in an insufficient justification of the final conclusion. In three other texts (14%), with the least synthesis, the final conclusion did not answer the aim correctly and/or did not follow completely from the preceding information, resulting in an incorrect justification. The differences in justification and connection of the two articles could not be attributed to the students' VOSTS responses. In other words, students from both the traditional and contemporary group wrote texts with varying degrees of justification.

A majority of the students included in their reviews a description of the model presented by article A (see Table 5.2 for examples), which is an important element in answering the central question. All six students with the traditional VOSTS views described the model. Two of these students explicitly stated that it is about a model (students 6 and 11). One of them mentioned it as a visualization of the authors' findings (student 7). Student 7's traditional response to the VOSTS item about the nature of scientific models (scientific models come close to being copies of reality) was not consistent with her model description, which refers to it as a useful tool to

visualize research findings. From the contemporary group of 10 students, eight of them included a description of the model, of which six explicitly mentioned that it is a model. Two of these students included uncertainty in their formulation about the status of the model, like:

With this information and the knowledge that the catalytic cysteine is repressed by the RING0 domain (5) they used computational modelling to generate two structural models. With all this they *speculate* [emphasis added] that pS65-UB activates parkin (only when the UBL domain is also phosphorylated) by unlocking the repression of the RING0 domain.(3). (student 21, unit 20)

While another student formulated the model as rather certain: “Koyano et al.’s main conclusion is their proposed model as seen in fig. 1, showing the *exact* [emphasis added] workings of the mechanism, (...)” (student 8, unit 26).

Examining the students’ VOSTS responses, we found relative differences between the students in their formulation of the scientific model: two out of six students (33%) from the traditional group mentioned the reaction pathway explicitly a model, against six out of 10 students (60%) from the contemporary group. It seems that the contemporary group mentioned the model nature of the proposed mechanism more often.

In Table 5.2 we present a selection of the students’ final conclusions for both groups. Our analysis of the use of qualifiers in the students’ final conclusions (19 students presented a final conclusion) showed that four students used a booster (“have given enough support”, “support the already convincing”, “show”, “obvious”) and four students included a hedge (“suggest”, “it could be concluded”, “indicate”, “implies”). Most students from the traditional group (four out of six) formulated their final conclusions without a qualifier. Only student 7 used a booster (“have given enough support to show”). Student 20 uses “we now know”, which is not characterized as a typical booster, but yet suggests a higher degree of agreement with the concluding statement. Relatively, the students from the contemporary group used more often a qualifier in their final conclusion: four students out of 10 used a qualifier in their final conclusion (one booster: “show”, and three hedges: “implies”, “suggest”, “indicate”) (40%) and two of the six students from the traditional group (33%). However, this is a very small difference, which should be interpreted with great caution.

Summing up these findings, we did not find substantial differences in the way the students justified their conclusions when taking into account their VOSTS responses. For the model description and use of qualifiers in their final conclusion we observed relative (small) differences between the students in terms of their VOSTS responses.

Table 5.2. Students’ text fragments about the scientific model description, final conclusions, and evaluative statements. Student 10, 11 and 20 belong to the traditional student group. Student 8, 9 and 17 belong to the contemporary group.

Student	Description model	Final conclusion	Evaluation
10	“Together, these data show that ubiquitin is phosphorylated by PINK1 to activate parkin. This proceeds following ubiquitin phosphorylation by PINK1. This happens following a unique two-step phosphorylation dependent manner. The first step is the phosphorylation of the UBL domain of parkin. Koyano et al (2014) state that the second step is the phosphorylation of ubiquitin.” (unit 12-13)	“Both studies present valuable insight in the function and physiological relevance of the phosphorylation of ubiquitin. Parkin is indirectly activated by phosphorylated ubiquitin which is dependent on PINK1 (...)” (unit 28)	“In my opinion Koyano et al.(2015) present the best constructed argument. The authors clearly demonstrate each step in their research and convincingly show results. On the other hand Fiesel et al. (2015) use a mouse model and PD human brain tissue to investigate if pS65-Ub-positive mitophagy granules accumulate with age and time, linking it directly to the pathogenesis of PD.” (unit 23, positive evaluation)
11	“Taken all the arguments together, a model has been made, based on the findings of their experiments. [figure1]” (unit 14)	“With the arguments of Koyano et al. and Fiesel et al: PINK1 directly phosphorylates Parkin and indirectly by phosphorylating (sic) ubiquitin. Thus, phosphorylated ubiquitin and PINK1 both activate Parkin: PINK1 activates Parkin directly as well as indirectly.” (unit 23)	“However, there were only 16 sections done in this experiment, perhaps not enough section to make this statement.” (unit 20, negative evaluation)
20	“First they showed that Ubiquitin is needed to activate Parkin, this they did by using a phosphorylation-deficient ubiquitin. This resulted in a delay of CCCP-triggered Parkin activation. This implies that phosphorylated ubiquitin is needed for activation of Parkin (figure 1), but leaves a possibility for activation without the use of phosphorylated ubiquitin. Another way Koyano et al. suggested that activation of Parkin is done by ubiquitin was by phosphomimetics, because if ubiquitin was a PINK1 substrate phosphomimetic ubiquitin should still activate parkin with a PINK1-deficiency (...) Thus Phosphorylated ubiquitin activates Parkin.” (unit 13)	“Through their results we now know that PINK1 phosphorylates Parkin and ubiquitin and after that phosphorylated ubiquitin activates phosphorylated Parkin, which makes mitophagy a 2 step process.” (unit 19)	“Fiesel et al. did have a problem with their antibody specificity, because phosphorylation of Parkin and ubiquitin both happened on a serine. This makes their results a bit questionable, but since Koyano et al. used radioactive phosphot tagging and low-molecular-weights scans and came to the same conclusion we can accept the results.” (unit 10, neutral evaluation)

Table 5.2. Continued.

Student	Description model	Final conclusion	Evaluation
8	"With all these supports taken together, Koyano et al. came to the model found below. This model shows a mechanism where pink phosphorylates both ubiquitin and parkin, and the phosphorylated parkin allows phosphorylated ubiquitin to fully activate parkin." (text unit 20) + "Koyano et al.'s main conclusion is their proposed model as seen in fig. 1, showing the exact workings of the mechanism, (...)." (unit 26)	n.a.	"Although this weakens Fiesel et al.'s conclusion somewhat, since some cross contamination was present, their found data are strong enough to come to a relevant and viable conclusion." (unit 28, negative evaluation)
9	"Research into the mechanism of parkin activation revealed that parkin's E3 ligation activity is usually repressed by autoinhibition. This autoinhibition can be released following (1) the binding of a Ub molecule (phosphorylated by PINK1) to parkin's RING0 domain and (2) the phosphorylation of parkin's UBL domain by PINK1. These phosphorylation events free the catalytic Cys 431 residue and allow it to conjugate ubiquitin molecules to other proteins. This was uncovered by the Koyano study, and is further supported by the Fiesel research which provides a range of additional evidence that the Koyano findings are physiologically relevant to PD." (unit 17)	"The results of these studies suggest therefore that PINK1 activates parkin both directly (on UBL) and indirectly (via pUb)." (unit 18)	"These experiments used whole cells, and the same findings were produced by multiple different methods. This increases the reliability of their findings, as whole cells more closely resemble the conditions surrounding PD than cell extracts do. By using multiple different methods to show the same thing, the influence of factors such as experimental error is reduced, and the findings become more reliable." (unit 7, positive evaluation)
17	"A model for parkin activation Koyano et al used data from this study to run a computer model to generate two models of parkin activation (fig. 1). Both Ub and UBL have to be phosphorylated, so both states can be an intermediate. Phosphorylating of both Ub and the UBL domain unlocks the repression and activates parkin." (unit 12)	"Briefly, PINK1 activates parkin both directly and indirectly. Two steps are necessary for parkin activation: phosphorylation of ubiquitin and phosphorylation of the UBL domain of parkin. Both steps are done by PINK1. If UBL is phosphorylated and a phosphorylated ubiquitin is present, parkin folds open and exposes Cys431, its catalytic domain. The repression is unlocked and parkin is in the active state." (unit 15)	"This information doesn't look really useful for the molecular function for parkin, but it can be useful for understanding the physiological pathways of Parkinson's disease." (unit 14, neutral evaluation)

Note. Qualifier indicated in bold. N.a.: not present.

Article evaluation

Nineteen students included evaluative statements (total 71) in their reviews concerning one or multiple aspects drawn from the article(s) (see Table 5.3). Article B was evaluated more often than article A (42 vs. 34 instances). In most cases the evaluations were neither further explained nor supported. Sometimes it was simply stated that a method, like the use of patient samples, was more reliable than another method without giving further explanation. We observed that the students evaluated the articles mostly on their line of reasoning and the methods used (see Table 5.2 and 5.3 for some examples).

Table 5.3. Topics of evaluation in students' reviews. Indicated is the frequency of positive (+), negative (-), or neutral (±) evaluative statements.

Topic of evaluation	Nature (frequency)	Examples
Text structure / line of reasoning	+ (15) - (5)	"Koyano et al. found more substantial data than Fiesel et al. and their line of reasoning was clear and well explained." (+, student 1, unit 31)
Methods	+ (19) - (4)	"In my opinion they are not wrong to draw that conclusion but I would like to see more tests to prove that pS65-UB is specific to only mitochondrial damage and occurs in all cell types." (-, student 21, unit 16)
Data / results	+ (4) - (2)	"In contrast, Fiesel et al, have a main support based on experiments solely with their own antibodies, which weakens their statements." (-, student 7, unit 22)
Counterarguments	+ (1) - (8) ± (2)	"Furthermore, the experiments where described in detail and there seemed to be no hard counter-arguments." (±, student 11, unit 21)
Conclusions	+ (1) - (2)	"Even though Fiesel et al. ² experiments and supports weren't as clear as Koyano et al ¹ , they might have provided evidence that can be used for therapeutic purposes, which in my opinion is more a far-reaching finding." (+, student 13, unit 18)
Relevance of information	+ (7) ± (1)	"However, the in vivo part of their study was quite interesting, but not relevant for this review." (±, student 17, unit 19)

Note. Students could have given more than one evaluative statement in their review.

Eleven students referred to a counterargument they located in the articles (mostly for article B). These evaluative statements citing an article's counterargument were mainly of a negative or neutral nature, which is not surprising according to the typical nature of counterarguments in research articles. The students mentioned in their texts that the counterargument (i.e., errors in the method or anomalies in the results) could have weakened the articles' conclusions or made the results less reliable. We did not find any significant differences in the topics that were evaluated between the students from the traditional group and those having mostly contemporary responses.

More in detail, the six students from the traditional group had an average of three evaluative statements about the articles with mostly positive evaluative statements (11 positive, six negative, and one neutral). Among the contemporary group of 10 students, we found a similar pattern: more positive evaluative statements (29 positive, 10 negative, and one neutral). This group had an average of four statements per student, and, on average, more positive statements compared to the traditional group. These findings suggest that the contemporary group had, on average, more evaluative statements than the traditional group, but with a same ratio of positive, negative, and neutral statements.

We observed a discrepancy in two cases between students' texts and their VOSTS responses. For instance, in student 4's evaluation: "The fact that both studies also used multiple methods of testing results and still finding [sic] that the research they conducted was good shows that these studies' results are close to true" (student 4, unit 11). Here the phrasing "these studies' results are close to true" made us assume that this student hold some traditional perspective towards science, where scientific knowledge could be considered as absolute. His VOSTS responses suggest otherwise (contemporary), but while specifically looking at item 9 about the scientific method, he favored the response that it is about "testing and retesting – proving something true or false in a valid way". This is more in line with his evaluative statement shown above. We observed a similar instance in the following text fragment by a student reporting about article A's support based on tests in yeast cells, who selected an almost even amount of traditional and contemporary VOSTS responses:

Koyano et al. also showed, using GFP-tagged forms of Parkin and varying levels of PINK1 presence (knock-out, endogenous), that pS65-Ub is essential for Parkin activation in living yeast cells to argue that their proposed pathway *is true in real life* [emphasis added] (Koyano et al., 2014). (student 14, unit 20)

DISCUSSION AND CONCLUSIONS

In the present study we aimed to explore first-year biology students' evaluation of and writing about research articles taking their scientific epistemologies into account. The students participated in a course with genre-based writing instruction, emphasizing the rhetorical structure of the research article genre. After using the heuristic Scientific Argumentation Model (SAM) for reading and analyzing research articles the students were assigned to write a brief literature review based on two different research articles with complementary findings. We evaluated their writing and their responses to items about the epistemology of science to understand the way their scientific epistemologies manifest in their writing about research articles. We discuss the findings answering our research question: *How do first-year biology students'*

evaluation of and writing about two research articles in a brief literature review relate to their scientific epistemologies? Our analysis of the students' responses to the VOSTS items showed that students selected a diversity of contemporary and traditional views regarding scientific knowledge and its construction. A majority of the students (about 50%) selected mainly contemporary viewpoints. A minority of the students (about 25%) mainly selected traditional viewpoints indicating that these students hold inaccurate views on science. A third group (about 25%) showed mixed answers to the VOSTS items. These findings partially concur with other studies that showed that undergraduate students often still hold uninformed views on science (Abd-El-Khalick, 2006; Lederman & Lederman, 2014; Liu & Tsai, 2008; Ryan & Aikenhead, 1992). Further, our findings show that the students' scientific epistemologies as their responses to the VOSTS items did not manifest clearly and conclusively in the students' texts and in their evaluation of both articles. In what follows, we discuss the findings about the students' writing and evaluations in the context of their scientific epistemologies.

The analysis of the reviews showed that most of the reviews contained a connection of the articles' content, but their degree of synthesis differed: 38% of the texts came closest to a full synthesis and 29% of the text had a constrained synthesis. The other student reviews missed an aim and/or final conclusion (19%), or had a weak justification for the final conclusion (14%). The way students justified their final conclusions did, however, not differ between the students from the traditional and contemporary groups. The students did not use qualifiers in their final conclusions very often. A small difference between the two groups of students was noted in the students' use of qualifiers in the final conclusions. The students with mainly traditional VOSTS responses used qualifiers less frequently (33%) compared to students with contemporary views (40%), but due to the small sample size this is not significant. We also examined a relation between students' scientific epistemologies and their formulation of the conclusion in their reviews. A few instances showed that a formulation in a student's text suggested a traditional perspective ("these results are close to true"), but this did not correspond to the student's contemporary VOSTS responses. In describing the mechanism from article A eight students explicitly identified this as a model of which only a few indicated the scope or nature of this particular finding. We saw that the contemporary group relatively described the model nature of the mechanism more explicitly than the traditional group. Students may think of scientific models in a common everyday sense: as physical replicas of some aspect of the world, rather than conceptual systems for explaining phenomena (Grosslight, Unger, Jay, & Smith, 1991). From our data, however, we did not get a detailed view on students' conceptions of a scientific model to draw such conclusions.

The findings showed that article evaluations occurred frequently in the students' texts and that positive evaluations were made more frequently than negative evaluations.

The students from the contemporary group did evaluate the articles' content slightly more often than the students who had selected more traditional viewpoints. They did not differ much in the topic of their evaluations. The limited number of critical, negative evaluations could be explained by the students' (limited) prior knowledge in the research field of Parkinson Disease and the students being novices in evaluating research articles critically (Allchin, 2001; Gillen, 2006; Yore et al., 2003). One needs an understanding of the discipline-specific standards to critically evaluate an article's relevance to the field, the reliability of methods, the accuracy of data, and validity of conclusions. The students' answers to the comprehension questions accompanying the writing task were overall adequate. The lecturers stated in their course evaluation (data not shown in this article, see Chapter 4) that the students understood the articles. However, many students perceived the task of critically evaluating the research articles as a difficult one (see Chapter 4), probably because of a lack of detailed knowledge of the methods and procedures used in the research field.

In sum, our findings did not point to a conclusive and clear relation of the students' scientific epistemologies and their evaluation of and writing about research articles. Until now, literature gives a varied picture of the role of students' epistemologies on their argumentative writing. The study by Neely (2014), for instance, did not find a significant correlation, where other studies did find a relationship (e.g., Baytelman et al., 2015; Khishfe, 2012; Nussbaum et al., 2008). These studies focused on the amount and strength of students' arguments and used other instruments to determine students' scientific epistemologies, which makes comparison with our study difficult. Our findings suggest that the students' texts did not relate directly to or at least did not immediately reflect their (formal) scientific epistemologies. In addition, as the finding showed, the views of the students were not always consistent. Sandoval (2005) indicated that it seems likely that students' epistemological beliefs, or here scientific epistemologies, are contextualized rather than coherent frameworks. The contextual nature of students' epistemologies are not covered by the VOSTS items, which consider views about general science. This could mean that the VOSTS items do not give a coherent image of students' views and point to a methodological limitation of this study. Maybe, the nature of the questionnaire as a diagnostic tool and our selection of items did not reveal one clear image of students' scientific epistemologies. We should therefore be cautious with interpreting the VOSTS items and categorization of traditional and contemporary responses used in this study. Therefore the questionnaire findings were restricted in getting a full understanding of students' scientific epistemologies. This also suggests that the students' writing and their (epistemic) choices herein are contextualized and are not necessarily guided by their views about the nature of formal science. Another factor that could have influenced our findings has to do with paraphrasing. Novice writers tend to paraphrase, and even copy text from textual sources: a phenomenon often observed in writing from sources tasks (Keck, 2006). This could have influenced the way in which students'

texts were phrased, and hides their own scientific sense making of the articles' content. The students' formulation of findings and conclusions was sometimes very similar to the articles' texts (data not shown). Therefore, we recommend in future studies to complement the text analysis with student interviews to examine the students' choices in constructing and evaluating scientific knowledge from research articles. By interviewing students, we could make a more accurate inference about their intentions during writing and gain more knowledge about their own knowledge production. A follow-up interview with the students could also have provided more insights in their way of thinking about models and their writing about it; something we did not do in the present study for practical reasons. Another recommendation for future researchers is to examine the discourse students have during their writing tasks, together with their fellow students and with their supervisors, to aim for a deeper understanding of their scientific epistemologies at stake. Such future studies could shed light on students' scientific epistemologies when evaluating and writing about research articles, and their possible mutual relationship.

Some contextual factors limit the validity of our conclusions. First of all, we used a small and specific sample of first-year biology undergraduates. Students' expectations, attitudes, prior knowledge, and writing experiences affect the quality of their writing (Fox, 2009) and our conclusions. Another factor that has possibly influenced the findings is the selection of articles. The articles did not contain major flaws, which made it difficult for students to take a critical stance. In addition, the two research articles were complementary, but were not contradictory in terms of the findings. Research articles with non-concurring findings could probably foster more critical reflection.

In conclusion, the findings of our study suggest no direct relation between the students' writing and their scientific epistemologies, which is partly in accordance with prior research. We recommend to further investigate students' scientific epistemologies in the context of specific science topics addressed in research articles and in the context of their writing based on literature sources or their own research.

CHAPTER 6

General Discussion

The main incentives for conducting the research presented in this thesis were the students' difficulties in writing that are reported in literature and the shortage of structural writing instruction in undergraduate science curricula in the Netherlands, more specifically at the University of Groningen. Therefore, we were primarily interested in how we could contribute to efforts supporting science undergraduates' scientific writing using discipline-specific writing instruction embedded in science curricula. In this final chapter, we first discuss the main findings of the research studies that addressed student writing practices, a teaching strategy we developed that aimed at promoting undergraduates' written argument construction, and students' scientific epistemologies in relation to their writing. Next, we evaluate our research studies. We end the chapter with recommendations for future research and educational practice.

MAIN FINDINGS

Study 1: Student Writing Practices

We started our research with exploring students' writing practices at the science faculty of the University of Groningen in the Netherlands (Chapter 2). For this purpose, we purposefully selected and interviewed 16 faculty members with teaching responsibilities from four undergraduate science programs (astronomy, biology, chemistry, and physics) to distil their experiences with and beliefs about writing instruction as well as students' writing skills. The analysis of the interviews showed that the interviewees recognized the importance of teaching writing skills in their undergraduate curricula. They mainly believed students needed to develop writing competences for their (science-related) career as a graduate student. They also expressed their expectations about students' writing level at the end of the bachelor programs, which reflected a range of skills needed to be able to write a variety of text genres. With the above conclusions in mind, the findings about the current teaching writing practices and the minimal attention to writing instruction in the curricula were notable. At the time of the study, the interviewees said that their students engage in writing various text types, particularly in laboratory courses, but frequencies differ between individual students and degree programs. It follows from the interviews that there is little integrated, consistent, and explicit writing instruction in the four science curricula. This seems to be in accordance with the tendency in Dutch higher education institutions (both university of applied sciences and research universities) to give less attention to academic writing instruction in science programs compared to content learning (Björk, Bräuer, Rienecker, & Stray Jörgensen, 2003; Daems & van der Westen, 2008; Herelixa & Verhulst 2014; Raad voor de Nederlandse Taal en Letteren, 2015). The findings did not indicate the existence of a consistent writing curriculum or the use of specific writing pedagogies by the interviewees, such as writing-to-learn activities (e.g., the use of writing prompts to promote science learning, see Choi, Hand, & Greenbowe, 2013).

Furthermore, the analysis of the interviews showed that there is a lack of formal and consistent curriculum guidelines for supervision and instruction in writing in the context of this study. The interviewees stated that they use their own strategies when supporting student writing (e.g., providing feedback or assigning pre-writing activities). Eight of the interviewees suggested integrating writing instruction with content learning, for example, in the context of research projects. In their evaluation of student texts the faculty members also differed in their expectations and mentioned a variety of important criteria to take into account, which may lead to inconsistent assessments during a degree program. This is in agreement with existing research findings that show that faculty members often have their personal preferences in giving feedback. These preferences are influenced by the specific disciplinary community they belong to (Hyland, 2013). Lea and Street (1998) noted that what counts as a 'good text' is often not explicated to students, neither by lecturers nor in learning materials. These preferences in giving feedback and implicit requirements for texts can often result in different and opposite interpretations and expectations by students and their lecturers.

The findings showed that the interviewees do not have sufficient understandings on how to organize writing instruction in their teaching due to limited resources or their priority to teach subject content. In addition, the interviewees wondered whether writing instruction should be done by subject experts or language experts. Some of the interviewees mentioned the role of secondary education for supporting students in developing their scientific writing skills. Six interviewees thought writing instruction is beyond their teaching tasks. These teacher beliefs are in line with beliefs and ideas seen in other (inter)national educational contexts, as for example, in the United Kingdom where traditionally students were expected to be capable in writing before starting university (cf. Coil, Wenderoth, Cunningham, & Dirks, 2010; Raad voor de Nederlandse Taal en Letteren, 2015; Russell, Lea, Parker, Street, & Donahue, 2009; Wingate & Tribble, 2012). Subject lecturers might be reluctant to teach writing as they feel a lack of time, or they find themselves not competent to teach writing because they have the feeling they lack pedagogical skills (Boice, 1990; Herelixka & Verhulst, 2014; Wingate, 2011; Wingate & Tribble, 2012). Given that the faculty members are trained as scientists, they might not have the knowledge and skills needed to support their students. Next to that, the faculty members' own prior education and experiences in scientific writing could impact their ideas about teaching writing to their students. Then, these ideas act as a barrier or, at best, as a driver in implementing writing instruction. They probably are not used to explicate their (tacit) views on writing (instruction), which also restrict their writing support to students and create obstacles in providing a consistent writing curriculum.

The analysis of the interviews also showed that, according to the interviewees' experiences, undergraduate students' writing abilities are very diverse and in some

cases they are not at a satisfactory level. The number of texts students write during a degree program, varied between individual students and depended on the degree programs. The faculty members recognized some of students' writing problems (e.g., constructing an argument, structuring a text, or using language). These problems are in line with studies reporting about undergraduate students' writing difficulties (Galbraith & Rijlaarsdam, 1999; Herelixka & Verhulst, 2014; Kelly, Regev, & Prothero, 2008; Sampson & Clark, 2008).

To gain more detailed information on undergraduate students' written texts, particularly their argument construction, we analyzed 10 bachelor theses (biology and physics), which we selected by systematic sampling with an at random start. The argument analysis revealed that the main argument in the bachelor theses consisted of different components, like research questions, evidence, and claims. Rebuttals and qualifiers were used and elaborated by the students to a lesser extent. In half of the theses, the justifications of the claims were scored as a novice level (using an adapted rubric criterion developed by Crotwell Timmerman, Strickland, Johnson, and Payne, 2011), suggesting that the students had difficulty in constructing an argument. The claims lacked in some instances sufficient justification, especially in the biology theses. This provided evidence that some students did not include all available findings (from literature) in their formulation of the claim. We also observed that most of the physics theses contained redundant information about experiments and supplementary data that did not directly relate to the main argument, distracting the reader from the main argument in the text. In conclusion, the students' theses contained an argument, but were limited in offering a strong justification or presenting the gist without abundant and unnecessary information.

As described above, there is a lack of explicit and consistent writing instruction in the four undergraduate science programs and writing is a challenge for undergraduates. The exploratory study highlights the importance of paying attention to undergraduates' writing abilities in science curricula and integrating writing instruction more structurally and consistently in the programs to develop students' scientific writing abilities.

Studies 2 and 3: Students' Written Argument (Re)Construction

As a next step in our research we developed and examined a research-based teaching strategy in a physics course and a biology course to support science undergraduates' written argument construction (Chapters 3 and 4). This teaching strategy was based on a presupposition drawn from ideas from genre-based writing instruction and research on reading-writing connections.

We assumed that the scientific research article genre with a focus on argumentation and rhetorical genre characteristics could serve as a model for undergraduate science

students to construct a written argument. For this reason, we used explicit instruction in the genre characteristics of research articles adhering to genre-based writing instruction principles. The main genre characteristic was the rhetorical structure of research articles: a set of rhetorical moves²² that together form the line of reasoning. We used the Scientific Argumentation Model (SAM), a tool with which we developed and elaborated a genre approach, to introduce students to the rhetorical structure of research articles. SAM consists of a set of seven rhetorical moves (motive, objective, supports, counterarguments, refutations, main conclusion, and implications)²³.

By combining reading and writing activities in the teaching strategy we drew parallels between reading and writing abilities. The teaching strategy consisted of a repeating cycle of learning activities and tasks to support students' written argument construction. First, the students were taught gradually about the genre characteristics of research articles using authentic (non-adapted and not translated) research articles and SAM. The course lecturers used modeling as instructional strategy. Second, the students individually read and analyzed research articles using SAM. With text analysis tasks we familiarized students with the genre characteristics that they used thereafter as a model for their writing. Third, the students collaboratively discussed the research article and the task with the course lecturer and their fellow students. Subsequently, the students received a reading-based writing task: reconstructing a research article's argument in a summary (physics course) and constructing an argument in a literature review of two research articles (biology course).

We formulated the following main research question that guided our research:

How does a teaching strategy using genre-based writing instruction and reading of research articles support science undergraduates' written argument construction?

In what follows, we discuss our main research findings by claiming four assertions.

Assertion 1: The students had a general understanding of the research articles' content, but additional support was essential for students' reading and writing

We found that the students generally understood the research articles. The teaching activities (lectures and group discussions) in which the students had the opportunity to discuss and practice with the research articles' content and adjacent topics certainly helped the students during the text analysis tasks and writing tasks. This is supported by the self-reported data from the student interviews and questionnaires.

²² Rhetorical moves are text fragments that fulfill a specific communicative function in the text.

²³ In SAM the following moves together represent an argument: objective, supports, counterarguments, refutations, and main conclusion.

The lecturers from the biology course reported that they thought that students' reading improved during the course and that students read faster near the end of the course. The biology lecturers also mentioned during the interviews that the students learned to extract the most important information from the research articles. This finding was also supported by the analysis of the physics' written summaries, which we further discuss in the fourth assertion.

However, we also noticed that reading, evaluating, and writing about research articles was not an easy task for most of the participating students due to their limited domain knowledge and knowledge of scientific language. For instance, we noted some inaccuracies in their written texts. This is in accordance with prior research showing university students' difficulties with the high information density, register (abstract and technical language), and their unfamiliarity with scientific content (Fang, 2005, Gillen, 2006; Von Aufschnaiter, Erduran, Osborne, & Simon, 2008). The difficulties they have could be explained because students are not the intended audiences of the research article genre (Yarden, Norris, & Phillips, 2015). The text analyses demonstrated, for instance, that the physics students had another understanding of essential information when reading and summarizing the research articles than the course lecturers had. We also found that students presented extensive but non-essential information in their written summaries. This is in accordance with novice reading and writing strategies, like a copy-delete strategy in which each statement is considered on its own without taking the other information into account (Brown, Day, & Jones, 1983; Scardamalia & Bereiter, 1991).

Assertion 2: SAM served as a heuristic for understanding, selecting, and organizing research articles' content

Together, the findings from Chapters 3 and 4 indicated that SAM was useful for supporting students in understanding, selecting, and organizing research articles' content when summarizing research articles or writing a review based on research articles. SAM offered a schematic version of an article's line of reasoning and helped students to identify components of a research article's argument and therefore promoted mining, a reading strategy in reading-based writing tasks: extracting information from a text for a specific goal (Plakans, 2009). Similar activities, like schematizing source content, which promote identifying main ideas, have been shown effective in synthesis writing (Van Ockenburg, Van Weijen, & Rijlaarsdam, 2019). The use of SAM also appeared to have value for assisting the course lecturers. It gave guidance in reading instruction, in discussing the research articles with their students, and in assessing student texts. It appeared that using SAM, and especially making a SAM scheme, required a good understanding of the text, as was shown by the student interview findings after the physics course. Therefore, additional explanation of subject content is necessary, like the way the course lecturers did in the courses.

Assertion 3: Students identified and presented most rhetorical moves that are part of an article's argument in their texts, had difficulty finding supports, counterarguments, and refutations, and were sometimes not aware of moves' rhetorical meaning

To examine students' reconstruction of a research article's argument we invited the physics students to summarize a research article before and after the teaching strategy (Chapter 3). In Chapter 4 we examined whether the biology students construct an argument based on two research articles in a literature review. We asked them to synthesize the articles, where synthesis was defined as a task in which students select, organize, and connect research articles' content. The analyses of the students' texts were performed using a genre analytic perspective by examining the presence of rhetorical moves.

In both studies the findings of the text analyses showed that the students identified and used most rhetorical moves from the research articles in their texts, and deemed a selection of those important enough to use for their reconstruction (summary task) and construction of an argument (synthesis task). Overall, most students included the objective, nearly all supports, and the main conclusions in their texts, thus reflecting the articles' main arguments. In both studies the interview and questionnaire findings pointed to the difficulty students had with identifying some supports. Supports are often hard to localize in the articles because of the high information density, for instance in a typical article published in the journal *Nature*. Articles' counterarguments and refutations were often not present in the students' texts. These two rhetorical moves are often harder to identify because of their hidden nature and it requires a good understanding of the content. Another explanation is that the students did not consider these moves as relevant for inclusion in their texts. The students confirmed in the interviews and questionnaires that these two moves were difficult to identify. Similar results were revealed by Van Lacum, Ossevoort, and Goedhart (2014), where first-year life science students used SAM for reading research articles and experienced difficulties in finding counterarguments. In some cases, the rhetorical meaning of a move in the students' texts was not in line with its original rhetorical function in the research article, for example, an implication in a research article presented as an objective in a student's summary. Hence, in some cases the students were probably not aware of the moves' exact rhetorical meaning in research articles.

Assertion 4: Students used rhetorical genre characteristics in their written argument (re)constructions, but students did not frequently use metadiscourse

The detailed analysis of the students' summaries showed that the students reconstructed the articles' arguments almost completely and correctly. Our text analysis combined with the interview findings showed that the students used, and had actually the intention to use, the rhetorical moves important for the article's

line of reasoning in their text. In the interviews, the students reported that they were more aware of the rhetorical moves in research articles after the course. It is noteworthy that the students almost fully reconstructed the pre-test article's argument at the start of the course making an improvement less likely. In the post-test summaries the reconstruction was less complete in terms of some missing supports, counterarguments, and refutations. This finding suggested that there is no change in students' summary writing and argument reconstruction. Possibly, we observed a ceiling effect: the students already recognized the gist of an article's study at the start of the course. Other explanations are the short time span of the intervention, specific features of the articles used in the pre- and post-tests, or the difference in difficulty level of the articles. So, we need to consider the above findings with some prudence. In the second implementation of the teaching strategy in the biology course, the analysis of students' literature reviews showed that most of the moves important for the articles' arguments appeared in the students' texts, suggesting a translation from their reading to their writing. The analysis of the student literature reviews showed that the majority of the students connected the content of the two research articles, used articles' moves, and achieved a synthesis in varying degrees of completeness. From the interviews with students and course lecturers it appeared that the synthesis of the research articles was a difficult task for students though.

In our evaluation of students' texts, we also examined the students' use of metadiscourse; a rhetorical strategy in which the use of linguistic devices helps a writer in constructing an argument. Metadiscourse helps to organize and connect statements, to engage the readership through a text by the use of transition markers and reporting verbs, and helps to express a stance in a main conclusion using qualifiers. A cautious conclusion about the metadiscourse findings is that the students did use metadiscourse, but did not use much or adequate metadiscourse in their texts. The summaries showed a lack of internal coherence due to limited use of transition markers or contained reporting verbs with a connotation different from the intention in the original articles. The findings about the students' use of qualifiers suggested that the physics students may be more aware of using adequate qualifiers in their texts after following the course. On the other hand, the biology students had difficulty in using adequate qualifiers in their literature reviews. This raises the question whether the students were aware of the subtle meaning of specific linguistic features and how metadiscourse helps them to construct an argument. During the courses, the focus lied primarily on the rhetorical structure and on the use of qualifiers. There was no explicit instruction in the use of transition markers and reporting verbs. These linguistic means should have more attention in the teaching strategy.

In conclusion, the above research findings showed a proof of principle of the practicality of the teaching strategy and supports its underlying presupposition in two

undergraduate science courses. The findings of our studies showed that the students generally understood the articles. However, the findings also pointed to the necessity of additional support for students' reading and writing processes (assertion 1 and 2). With the benefits of using SAM (assertion 2) the teaching strategy based on a genre approach has proven beneficial for students in recognizing and understanding the important rhetorical components of an authentic research article, and in organizing scientific texts. The students identified most moves (assertion 3) and the focus on argumentation and rhetorical genre characteristics, especially the rhetorical structure, has the potential to be beneficial for supporting students' reading of and writing about research articles (assertion 4). This means that to some extent reading worked as a model for the students' writing. With these studies, we demonstrated that genre-based writing instruction could be elaborated in science courses to promote students' written argument construction.

Study 4: Students' Scientific Epistemologies in Relation to their Writing

In a final study (Chapter 5) we examined how students represented and evaluated research articles' content in relation to their scientific epistemologies – students' beliefs about the nature of scientific knowledge and its construction. While prior research suggests a correlation between students' writing and evaluation of scientific texts and their epistemological beliefs, it is still unclear how scientific epistemologies and writing affect each other (Baytelman, Iordanou, & Constantinou, 2015; Feinkohl, Flemming, Cress, & Kimmerle, 2016; Khishfe, 2012; Kuhn, 1991; Neely, 2014; Sandoval, 2005; Yarden et al., 2015). More insight in the students' beliefs on the nature of scientific knowledge could inform our teaching strategy, for instance in teaching about how to formulate main conclusions according to scientific standards. In order to gain more insights we examined whether the students' written texts (literature reviews), collected in the molecular biology course, relate to their scientific epistemologies. Based on literature, we made a distinction between students' contemporary views and traditional views. A contemporary view assumes that scientific knowledge is often temporary, socially constructed, and influenced by multiple interpretations and scientists' backgrounds, which allows for a critical stance and weighing evidence in argument construction. In contrast, a traditional view approaches science as a body of knowledge, which is primarily established without any influences of scientists' beliefs and often has an absolute character (e.g., Erduran & Dagher, 2014). Therefore, we expected that students with contemporary views about the nature of scientific knowledge and its construction would be more critical in their evaluation, and/or give an appropriate and justified conclusion in their literature review.

We used a selection of 12 items about epistemological aspects of science from the VOSTS questionnaire (Aikenhead & Ryan, 1992; Aikenhead, Ryan, & Fleming, 1989) to elucidate students' views on scientific knowledge and its construction. These items were selected based on their appropriateness in terms of content and language

for first-year biology students, their correspondence to the course topic, and their relation to the epistemology of science. The analysis of the questionnaire data showed that the students' responses to the VOSTS items reflected a diversity of contemporary and traditional views regarding scientific knowledge and its construction. Most students (about 50%) selected mainly contemporary viewpoints (the contemporary group) against a minority of about 25% of the students classified in the traditional group with predominantly traditional responses. Another quarter of the students had mixed responses of contemporary and traditional viewpoints. These findings were partly in accordance with prior research, which revealed that a substantial proportion of undergraduate students still holds uninformed views about science (cf. Lederman & Lederman, 2014).

In contrast with what we expected, we could not relate students' constructed arguments to their scientific epistemologies. The analysis of students' reviews showed that most students connected the content of the two research articles, but with different degrees of synthesis. The differences between reviews did not clearly relate to their VOSTS responses, neither for the justification of the final conclusion nor for the critical evaluation of the articles. Yet, we noticed minor differences between the contemporary and traditional student groups. The contemporary group described the model, presented in one article, more explicitly and they used qualifiers more often than the traditional group. They also evaluated the conclusions of the two articles more often, but with the same ratio of positive, negative, and neutral statements as the students of the traditional group. All students mainly pointed to the strengths of an article instead of giving critical negative evaluations. This can be related to the students' limited subject knowledge on the topic and the students being novices in reading these highly specialized articles, which makes it difficult to indicate weaknesses in the studies (Allchin, 2001; Gillen, 2006; Yore, Bisanz, & Prain, 2003). Another explanation could be that the students had a belief in authority when reading articles, especially from *Nature*, which is considered a credible source. We concluded that our study did not point to a relation between the students' scientific epistemologies and their evaluation of and writing about research articles. This is in accordance with some previous research publications (cf. Baytelman et al., 2015; Neely, 2014). This means that our findings added to the existing varied picture and tended to indicate that there is no direct relation. Nevertheless, the finding that some students hold inadequate views on the nature of scientific knowledge informs course lecturers about the needs to discuss the research articles' outcomes and their presentation in research articles.

In Figure 6.1 we summarize the main findings of the four research studies.

Figure 6.1. Overview of the main findings.

REFLECTIONS ON THE RESEARCH

In this section, we evaluate the four research studies by indicating and discussing limitations of the selection of research samples, data sources, and analysis methods. We also offer suggestions for further research.

Exploratory Study

Interviews faculty members

An important issue to take into account when interpreting the interview findings in the exploratory study (Chapter 2) is whether the faculty members gave an accurate image of their writing instruction. The findings were based on self-reported data, which is limited in showing the actual teaching practice and tacit knowledge about writing. To get a full understanding and a more comprehensive overview of their instructional practices and views, we recommend a follow-up study to investigate the actual teaching practice by using observations or stimulated recall interviews to reflect on teachers' practices (Kane, Sandretto, & Heath, 2002; Pajares, 1992). Another suggestion is to examine current writing instruction from a students' perspective. For instance, we could interview students of a science degree program to get a more detailed view on students' writing competencies, their writing processes, their existing writing difficulties, and their current and desired amount of writing instruction.

Argument analysis

There are a number of factors that may have influenced the argument analysis of the students' bachelor theses. One is the amount and quality of supervision students received during their thesis writing. Some supervisors ask for revisions until the final product is of sufficient quality according to their personal standards. And even, as our interview findings showed, supervisors sometimes revise parts of the students' texts themselves. Further, expectations about the requirements of a thesis vary across supervisors and disciplines (Paltridge, 2002). We should be aware that our samples are biased: the theses were selected from publicly available repositories, which do not contain all student theses. Theses under embargo are excluded, for example. Also, students decide about uploading their thesis themselves. Therefore, we suppose that these sets of available theses mainly contain the 'better' examples of student theses. We realize that the above factors and our small sample size can limit our understandings about the quality of argument construction of undergraduate biology and physics students. We cannot extrapolate our conclusions to the whole set of bachelor theses written by physics and biology students of the faculty. By increasing the number of theses and collecting theses from multiple science areas we could obtain a more representative and nuanced image of students' writing abilities, accounting for different influences like the lecturers' text preferences (Rijlaarsdam et al., 2012). It will also be useful to conduct a longitudinal study to follow students'

progress in writing performances during their degree program and how this relates with writing instruction. Herewith, we can gain more information on the impact of writing instruction on students' writing proficiency.

Teaching Strategy in Physics and Biology Courses

The role of lecturers

The development and implementation of the teaching strategy embedded in the two science courses was done in close collaboration with the course lecturers. It allowed for using a discipline-specific writing instruction and carrying out the research in a natural setting matching with the lecturers' usual teaching practice. The course lecturers were experienced scientists in the fields of biophysics and molecular biology, and these lecturers can be considered expert readers and writers. We implemented the teaching strategy twice in each course with the first edition serving as a pilot study. These pilots led to refinements of the course and the teaching strategy, mainly in organizational issues (timing), shift in focus (e.g., discriminate between data supports and methodological supports, and selection of the most relevant supports), and adjustments to the reading and writing tasks (reformulations). Here, the cyclic character of design research is evident. In addition, at the time of the courses and afterwards, we discussed issues together with the lecturers, and, when necessary, solved problems, such as the timing of assignments. Regarding the use of SAM, we discussed and practiced its use with the course lecturers prior to the course. We observed and video-recorded all course meetings and noticed that the teaching strategy generally was implemented the way we envisioned (data not reported in this thesis). However, it appeared that the course lecturers spent little time on modeling their identification of rhetorical moves in research articles. More emphasis could have been laid on the identification of the counterarguments, for instance, thus offering more support to students in their identification of counterarguments and associated refutations.

Choice of research articles

The lecturers of both courses selected recent research articles from their own research fields. The selected articles probably influenced the way the students read and write. The articles came from different journals and had different formats, but were comparable in their presence and amount of the different rhetorical moves. When selecting the articles, we did not account for the presence of multiple lines of reasoning. As a result, one of the articles used for the summary task in the physics course became probably more difficult to read and summarize because of the presence of two main lines of reasoning, which made comparison between the summaries more difficult. Also, the articles about Parkinson Disease used in the biology course were complicated with the high information density and specialized methodological issues and procedures. The two articles for the literature review were

complementary in their findings, which facilitated comprehension of the content. Probably, the students' critical evaluation could have been enhanced if we had selected articles with contrasting findings.

Participants

For the purpose of our research, we examined the whole group of students who participated in the physics and biology courses. These students were physics and biology majors, respectively. The students from both groups shared similar characteristics. The students finished their first semester and their prior reading and writing frequencies were comparable. Most of the participants were L2 writers with English as their second language, apart from a few international physics students from English-speaking countries. Overall, in the Netherlands, Dutch students have a very high English proficiency in reading and listening skills (Education First, 2019). The students' texts contained little incorrect English usage as the text assessments by the course lecturers showed (data not reported in this thesis). Therefore, we believe that the findings of the studies were not much influenced by the students' English proficiency.

Writing tasks

The choice of a summary and a literature review as writing tasks in the research studies, addressed in Chapters 3, 4, and 5, has both advantages and shortcomings. These reading-based writing tasks as data sources allowed us to have insight in students' article comprehension, their content selection, and presentation. It also enabled us to examine their move identification and their (re)construction of an (article's) argument since they need to interpret and paraphrase statements from the original texts. Using these tasks as data sources has some limitations. The students' formulation of the information derived from the articles was sometimes very similar to the articles' texts. In reading-based writing tasks novice writers tend to repeat the original text structure (as was shown in some of the students' literature reviews), and even copy text fragments in their texts (Keck, 2006; Mateos & Solé, 2009; Spivey, 1997). Another phenomenon is patchwriting, which is thought as being part of a transition phase towards developing paraphrasing skills. This activity causes writers to transform original statements in their own text with minimal changes in words, using synonyms, and changing grammatical structures of sentences (Howard, Serviss, & Rodrigue, 2010). Therefore, students' tendency to copy or to patchwrite could have covered the students' incomplete text understanding and recognition of the text's rhetorical structure. It could also hide the students' own scientific sense making of the articles' content, which makes it harder to examine how, and possibly whether, scientific epistemologies have an effect (see Chapter 5). Another issue we want to highlight is that our identification of moves in student texts does not guarantee that students use and represent these in a correct way. This was shown in the findings about the dissimilarities between students' SAM schemes (including quoted

statements for moves) and the representation of moves in the summaries written in their own words (Chapter 3). In addition, the writing tasks served for the students as exercises. The tasks did not reflect authentic activities because of the students' purpose for writing (i.e., fulfilling the assignment and achieving learning goals) and their audience (i.e., course lecturers and fellow students).

Analyzing students' writing

The analyses of the students' texts were performed using a genre analytic perspective, which means that we divided a text in different smaller text units, each having a defined communicative function (e.g., a sentence stating the main conclusion). We categorized these text fragments on their rhetorical function using linguistic, organizational and content features, and on the analytical frameworks, validated by the course lecturers (experts in their research fields). Our analysis of rhetorical moves in student arguments did not give a complete assessment of the quality of their writing. We did not look at the students' basic linguistic skills (e.g., use of appropriate grammar), use of literature, structure (at least not for the physics summaries) and other components of writing that are needed to express ideas. This points indirectly to a problem of writing research that many factors influence the evaluation of writing quality. We are dealing here with the complexity of both the source texts (research articles) and the students' texts. Using these authentic tasks and zooming in on rhetorical characteristics is partly a consequence of genre-based instruction. Alternative methods to study student writing have their disadvantages. For instance, the use of think-aloud interviews where students write a text at the moment of data collection and report about their thoughts and actions, affects students' reading and writing processes (Hyland, 2016). Therefore, this think-aloud method has its limitations in providing a complete picture of a writer's cognitive activities and the resulting written texts.

We analyzed the students' writing from a rhetoric viewpoint: their written texts. This meant that the emphasis was less on the social processes during their writing. Did they, and how did they, interact with fellow students? How did they use (peer) feedback? What was the role of discussion and the nature of interaction about the research articles during the group meetings? Although the interviews revealed information about the students' writing process (their perceived difficulties and their considerations), we strongly recommend in future studies to include a social stance as well, since a text is socially mediated. We could, for instance, analyze the discourse among students and between students and lecturers to investigate how genre conventions are communicated and developed in classrooms. This information is useful for fine-tuning the writing support, for instance, by offering extra time for discussing text conventions, and for gaining insight in the influences of fellow students' viewpoints and feedback on students' writing development.

Interviews

To gain a deeper understanding of students' processes and experiences we used interviews as data source, which were pilot-tested in the first course editions on comprehensibility of interview questions and validity of our interpretations. We used retrospective interviews in both courses following a stimulated recall design. Our purpose was to get more insight into the students' processes and experiences during writing their texts and reading of research articles. However, we saw that both the physics students and the biology students had difficulties in explaining their choices. Although the period between the writing and the interviews might be an explanation, it was obvious that students had problems with reflecting on their writing. Although stimulated recall interviews are used frequently in writing research (Gass & Mackey, 2000), we noted some inconsistencies in students' explanations and therefore the interview findings were restricted in getting a full understanding of students' considerations in their writing.

Scientific Epistemologies

We used a selection of 12 empirically-driven items derived from the VOSTS questionnaire (Aikenhead & Ryan, 1992; Aikenhead et al., 1989) to examine students' scientific epistemologies that suited our research purpose and the educational context. It was our intention to arrive at a nuanced view of students' viewpoints on the epistemology of science without classifying students in strictly defined philosophical viewpoints (e.g., an absolutist view of science). In retrospect, the resulting variety in students' responses showed a nuanced and diversified view, but the VOSTS items did not always give a coherent image of students' scientific epistemologies. There may be several reasons for this. First, this may be due to the way we used the questionnaire. We combined students' answers to the items to characterize their views as contemporary or traditional, but this is different from what the authors of the instrument originally intended. The VOSTS items should be considered as singular and have a more diagnostic function. Second, the items considered topics about science in a broader sense (formal science), not in a specific context, like molecular biology. The student views are probably contextualized (Sandoval, 2005), and do not reflect a coherent framework. This also means that the students' texts about research articles' content and their (epistemic) choices herein are contextualized and are not necessarily guided by their views about the nature of formal science. Maybe, the task of reading and synthesizing research articles was challenging in such a way that their beliefs did not influence their decisions. Therefore, we suggest to use follow-up interviews to gain deeper insight into students' knowledge construction during writing, their meaning making of articles' content, and the role of their scientific epistemologies in argument construction.

RECOMMENDATIONS FOR FUTURE RESEARCH

With our research we did not measure the potential effectiveness of the teaching strategy in improving students' writing proficiency (on the long term). We focused on the implementation of a teaching strategy for supporting students' written argument construction. Since it concerned a two-shot study, we recommend a larger follow-up study to measure students' writing abilities after having followed the teaching strategy in terms of increasing the number of students and using multiple writing tasks (e.g., extend to writing a laboratory research report using student's own collected data) in different contexts or courses. We also recommend conducting a longitudinal study to examine how students' competences evolve as they move through their program. For instance, by collecting written texts of a selected group of students in different years to gain insight in their writing abilities and conducting periodic interviews to examine their experiences (cf. Delcambre & Donahue, 2012).

Another recommendation for future research grows from previous research that suggests that writing can promote subject content learning. By interacting between the content and the rhetorical requirements of writing a text a writer's understanding of the subject content could be enhanced (Hyland, 2016; Rijlaarsdam et al., 2012; Scardamalia & Bereiter, 1991). Does genre-based reading instruction turn students into better readers of research articles and does this affect their content learning? Does reading research articles using SAM and writing about it have an effect on students' content knowledge? Do they develop adequate views about the nature of scientific knowledge and its construction? These questions could stimulate further research.

In Chapter 2 we reported that faculty members were not always aware or confident how to instruct and support students in their writing. We cannot conclude however, based on the findings of the exploratory study, that the faculty members actually lack the knowledge and skills to support students in their writing. Faculty members' pedagogical knowledge, skills, and efficacy in teaching writing is nevertheless an interesting field to explore further. What competencies are required to fulfill their role as supervisor of student writing? How could we anticipate on their needs? How do we best involve faculty administrators? In addition, we recommend conducting studies on the role of course lecturers in implementing genre-based teaching strategies for reading and writing and the application of SAM. More knowledge about the role of the lecturer seems worth examining to provide important input for the design of a professional development program when subject experts need to implement writing instruction. We used modeling as instructional strategy in which the course lecturers modeled and illustrated how they identified rhetorical moves in research articles, but we did not examine its application and effectiveness. For such a purpose, we can observe lecturers how they use modeling behavior and examine its effects on student

writing. A related and promising strategy that can be applied is observational learning. Students observe videos showing peers who carry out a writing task and think aloud about their processes. Studies using this strategy with undergraduates have shown that it promotes students' writing of literature reviews and improves the quality of their texts (cf. Raedts, Rijlaarsdam, Van Waes, & Daems, 2007). It is worthwhile to investigate the role of this strategy in genre-based writing instruction.

RECOMMENDATIONS FOR EDUCATIONAL PRACTICE

In Appendix L we included an example of the course manual we used in this thesis. This manual can easily be adapted to other courses. Based on our research, we offer course lecturers and administrators additional guidelines to adopt the teaching strategy as a starting point to integrate reading and writing in undergraduate science courses that emphasize the disciplinary character of writing:

- *Select authentic research articles based on the following criteria:* (a) articles should connect to the course topic and students' prior knowledge; (b) the text of the articles should present clear identification markers for rhetorical moves (e.g., to recognize counterarguments); (c) articles should contain, preferably, a single main line of reasoning to avoid complexity; (d) reading classes should offer a wide range of formats of research articles from different journals; and (e) select articles with contrasting findings to stimulate more critical reflection.
- *Use the Scientific Argumentation Model (SAM):* SAM makes students aware of the main line of reasoning in research articles. Its benefits lie in offering a view of an article's rhetorical structure. It is particularly helpful in finding main supports and preliminary conclusions in research articles, and in using supports in argument construction in writing. SAM should be used alongside writing instruction that addresses other aspects of writing as well, like using an academic style and addressing a readership, and developing writing strategies (e.g., revision strategies).
- *Pay attention to multiple lines of reasoning and metadiscourse in research articles:* Authentic research articles, like the ones used in the courses, sometimes contain multiple lines of reasoning. We suggest to start using SAM with articles having one line of reasoning. Later on, articles with a greater complexity can be used. Then it is necessary to discuss the multiple lines of reasoning in an article and reflect on the most important argument that is presented. Information sheets about the rhetorical moves could be complemented with an overview of linguistic devices, herewith we can support the use of metadiscourse in students' texts.
- *Encourage a dialogue between students:* when discussing rhetorical moves with students it is important to realise that it is not about identifying exactly each single move and grouping this in the right category. Most important is to discuss

in small groups students' reasons for choosing a text fragment as a specific move and give them enough opportunity to exchange their views. A discussion about text variability can help students to reflect on genres and also promotes a critical stance towards rules and conventions in scientific writing and formulating their own texts. For this purpose, lecturers could use a tool (e.g., diagnostic function of specific VOSTS items, see Chapter 5) to stimulate discussion with students about the nature of the main conclusions in research articles and how one should or could write about it (a strict or nuanced formulation?). In addition, stimulate discussions about the (dis)similarities between research articles and the use of metadiscourse to acquaint students with the variety of rhetorical cues in the research articles genre. Introduce students also to new developments in research articles, such as the use of an online visual summary, and the meaning of writing in scientific discourse.

- *Combine reading-writing instruction with teaching subject knowledge:* Use lectures and group meetings to explain essential science concepts and methodological procedures and techniques. Start exploring with students the basics of reading and interpreting graphs and tables, and practice with interpreting visual data representations to see how data is used to justify a main conclusion. Visual data representations were discussed with the students during the two courses as it plays a major role in identifying supports. A promising learning tool is the template Figure Facts with which students focus on each figure in a research article, interpret the presented data, and draw a corresponding conclusion (Round & Campbell, 2013).
- *Combine writing and reading activities:* Use reading-based writing tasks, like we did in the physics and biology courses. When combining reading and writing activities, we recommend to include practice in summarizing and synthesizing (multiple) text sources and to discuss paraphrasing. Realize that it is possible that novices might have another understanding of essential issues about the content of a research article when reading and summarizing research articles compared to experts. For instance, students can value methodological issues more often, as was shown by our study in the physics course. Therefore, assignments need explicit requirements about what elements and content a text should contain.

In addition to these specific guidelines, we propose to design more extensive curriculum guidelines for a varied approach of teaching and assessing writing across an undergraduate science degree program. We argue to introduce text genres with an increased level of writing complexity during a degree program. A possible sequence could be: summary, review article, poster, literature review, essay, research report, research article/bachelor thesis. Most of these genres share much resemblance with a research article's structure, for which the core of the teaching strategy presented in this thesis could be used. As an intermediate step, working towards writing a research report, we could offer students research data from experiments and ask

them to write a results and discussion section presenting supports to justify the main conclusion. Students could compose a portfolio with a selection of texts written over the years (research reports, essays, literature reviews, posters), including drafts, feedback and peer review outcomes (Rijlaarsdam et al., 2012). Herewith, we could get more insight in students' writing proficiency and its progress. Another suggestion is to introduce writing tasks that could test students' content knowledge instead of traditional written exams, for instance, brief popular science texts. We should keep in mind that our teaching strategy focuses on argument construction, and that students need to develop other knowledge (e.g., about data representation) and skills (e.g., revision strategies) as well for developing scientific writing proficiency. Also, we should broaden student writing by including exercises in writing popular scientific texts, which nowadays gains more attention in university science curricula (e.g., Mercer-Mapstone & Kuchel, 2016). To make activities more authentic one could use tasks that reflect scientific practices, for instance, tasks with team-based writing, which is characteristic for the scientific writing process (Penrose & Katz, 2004; Yore, Hand, & Prain, 2002). Translated to educational practice, we could use, for example, an online platform where students collaboratively compose and revise a text with the course lecturer acting as the project leader.

In the research reported in this thesis, subject experts were engaged in the teaching of writing, and they integrated reading and writing tasks in their content courses. We therefore believe it is ideal to stimulate subject experts to collaborate closely with language experts. It is important to strive for a widespread support among faculty teaching staff and administrators to embed writing in the curriculum. Faculty members could be offered a platform to articulate and share their (tacit) knowledge and views about writing instruction. What text features do they find important? How to design and enact explicit writing instruction? Through sharing practices we may promote a collaborative approach to support and assess student writing (Blake & Pates, 2010). This means that professional development should be tailored to the role of the scientists in writing instruction. All in all, with these recommendations and insights derived from the research studies, we believe that together with faculty members we can work towards undergraduate science curricula giving scientific writing the attention it deserves as it intrinsically belongs to becoming a scientifically trained academic.

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APPENDICES

OVERVIEW

- A. Interview questions faculty members (Chapter 2)
- B. Information sheet students (Chapters 3, 4, and 5)
- C. Summary task (Chapter 3)
- D. Analytical framework (Chapter 3)
- E. Review task (Chapters 4 and 5)
- F. Analytical framework review (Chapters 4 and 5)
- G. Interview questions students (Chapter 4)
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- I. Interview questions course lecturers (Chapter 4)
- J. VOSTS questionnaire (Chapter 5)
- K. Supplementary data VOSTS items (Chapter 5)
- L. Course manual – example

APPENDIX A

Interview questions faculty members (Chapter 2)

- 1. What is the importance of scientific writing in the undergraduate program?
What are important characteristics of scientific writing to be taught to students (e.g., conventions, language, writing style, ethics, argumentation)?
- 2. How should scientific writing be taught in the undergraduate curriculum?
- 3. Could you tell something about the way particular conventions should be taught to undergraduate students (like IMRD, use of literature references)?
- 4. Which text genre(s) do you consider relevant for undergraduate students?
Is there a particular order of genres you should wish for?
Which types of writing assignments do you think are important (writing collaboratively or individually, different reader audiences)?
- 5. What level do you expect from students at the end of the undergraduate program (e.g., quality of the final draft of their thesis)?
- 6. Are you involved in the undergraduate program of your discipline?
In what teaching are you involved? Which course(s)?
Do you address scientific writing in your course(s)? If so, how?
Do you supervise students in writing their bachelor theses?
What are your experiences with teaching/supporting students' scientific writing?
Do you have good practices?
- 7. Which text genres do students write in your courses?
- 8. How do you support your students in writing?
What strategies do you use?
- 9. How do you assess students' writing? Which criteria do you use?
Do you give feedback to your students? What kind of feedback do you give?
How do you give feedback to students (individually, interim, written)?
- 10. Do you experience any writing difficulties or problems with students?
If there are any difficulties or problems in writing, how do you support your students?

APPENDIX B

Information sheet students (Chapters 3, 4, and 5).

<p>MOTIVE</p> <p>Can usually be found in: Introduction section.</p> <ul style="list-style-type: none">• Why is the research important according to the authors?• The motive is a statement indicating why the research was done.• The motive leads to the objective.• Possible motives:<ul style="list-style-type: none">o There is something unknown; a gap of knowledge.o There are conflicting results.o There is a specific problem that needs a solution.
<p>OBJECTIVE</p> <p>Can usually be found in: Introduction section.</p> <ul style="list-style-type: none">• What do the authors want to know?• Indicates the function of the research. Possible functions: giving a description of a phenomenon, comparing, determining if something falls into a certain category, evaluating a theory or design, finding an explanation for a certain phenomenon, et cetera.• May be formulated as a:<ul style="list-style-type: none">o Research aimo Research questiono Hypothesiso Design aim
<p>MAIN CONCLUSION</p> <p>Can usually be found in: Conclusion/Discussion section.</p> <ul style="list-style-type: none">• The main conclusion is a statement about the main outcome of the research and relates to the objective of the study: the authors answer the research question, they state to what extent the research aim was met, they decide if the hypothesis was correct or not, or they determine if the design has the desired characteristics.• The main conclusion is often recognizable by signal words: “we conclude”, “our results show”, et cetera.• Authors often indicate how certain they are of their main conclusion. This is done with words like: “might”, “suggest”, “prove”, “may”, “indicate”, et cetera.• Sometimes authors give additional conclusions. These are not <u>directly</u> related to the study's objective, but these are other conclusions the authors draw from their results.• The main conclusion will usually lead to an implication.
<p>IMPLICATION</p> <p>Can usually be found in: Conclusion/Discussion section.</p> <ul style="list-style-type: none">• What is the meaning or consequence of the main conclusion in the study's context?• Possible implications:<ul style="list-style-type: none">o Recommendation.o Statement about the applicability of the results in the scientific community or society.o Suggestions for future research.

Information sheet students (Chapters 3, 4, and 5) continued.

SUPPORTS

Can be found in: Results & Discussion section.

- All the elements that the authors use to justify their main conclusion.
- Possible supports:
 - o Own results (data, data interpretations).
 - o Methodological supports to test their techniques used for measurements.
 - o Control experiments.
 - o Statements from literature (references to other research).
- Supports may occur in so-called support chains: bits of supports leading to a preliminary(sub) conclusion, forming a chain.
- A main conclusion is often supported by multiple support chains.

Support chain example (schematic):

COUNTERARGUMENT & REFUTATION

Can usually be found in: Results/Discussion section.

- Counterarguments are statements that weaken or discredit the main conclusion OR supports.
- Possible counterarguments:
 - o Potential errors.
 - o Anomalous data (conflicting results).
 - o Problems with the methodology.
 - o The main conclusion or supports are contradicting other previous research.
 - o Limitations of the main conclusion; situations in which the main conclusion is not valid.
- Counterarguments are sometimes called “limits” or “limitations”.
- Authors almost always try to refute or weaken counterarguments. They do this with refutations (statements why the counterargument is not valid).

APPENDIX C

Summary task (Chapter 3)

Write an extensive summary of the article you read. The goal behind this writing task is that it helps you to look at the content of the article and to become familiar with the research article genre. Additionally, practice in summarizing research articles helps you with writing a literature review (part of the bachelor thesis).

Guidelines

- The length of the summary should be between 500 and 750 words.
- Make clear how the authors drew the conclusion: what is their line of reasoning?
- Write the summary from an outsiders perspective. Instead of using “we measured...” use “the authors measured...”.
- Take your fellow physics students who did not read the article as your reader audience.
- You can use your SAM scheme as a support to write your summary (*only post-test*).
- Keep in mind the criteria of the peer review form (*only post-test*).

APPENDIX D

Analytical framework (Chapter 3)

Analytical framework of the pre-test article (Noji et al., 1997)	
Research object	1. F ₁ -ATPase, 2. consists of a γ-subunit that turns in an α ₃ β ₃ -subunit.
Method	1. A fluorescently labelled actin filament was attached to the γ-subunit. 2. Use of an epifluorescence microscope. 3. Observation of the motion of multiple actin-tagged α ₃ β ₃ γ subcomplexes.
Main line of reasoning	
Motive	1. There is only one rotary motor (bacterial flagellum) investigated in detail (indirect described in research article) (direct: investigate F ₁ -ATPase). 2. It has been suggested that γ-subunit of F ₁ -ATPase rotates within the α ₃ β ₃ -subunit.
Objective	1. To observe the motion of the γ-subunit of F ₁ -ATPase directly.
Main conclusion	1. F ₁ -ATPase acts as a rotary motor.
Implication	1. Further research on the rotary motor F ₁ -ATPase is planned.
Support	1. Rotating actin filaments were observed. 2. Most rotating actin filaments had a rotation axis at one filament end and some had a rotation axis in the middle, and with the arrangement of the method in mind, it shows the γ-subunit rotates in the centre of the α ₃ β ₃ -subunit. 3. All observed rotating actin filaments rotated in an anticlockwise direction. 4. By absence of ATP and by adding Azide (NaN ₃) in presence of ATP no rotary motion was observed. 5. Actin filaments made more turns in the ATP presence condition (following from a new test).
Counter-argument	1. There were fluctuations in the motion measurements (rotary speed not constant and small momentary reversals).
Refutation	1. The fluctuation should in part be of Brownian motion, 2. but also an angle-dependence was noticeable, which could be explained by obstruction by nearby proteins and intrinsic properties of the rotary motor.
Additional line of reasoning	
Support	1. The observed rotary rate was lower than a predicted rotary rate; 2. the torque is quite large, >45 pN nm and >23 pN nm for two observed rotating actin filaments.
Additional conclusion	1. The rotary torque produced by the rotating actin filaments on the γ-subunit reached more than 40 pN nm under high load.
Implication	1. It remains to be investigated whether there is a loose or tight coupling between ATP hydrolysis and the rotation in F ₁ -ATPase.

APPENDIX E

Review task (Chapters 4 and 5)

Write a review based on the articles by Koyano et al. (2014) and Fiesel et al. (2015) in which you give an answer to the following question:

Does (and how does it do this?) PINK1 activate parkin directly, indirectly, or both?

The review should contain:

- A description of the content and the argumentation of both articles. Include how the authors came to their main conclusion(s) (what is their line of reasoning?).
- A critical evaluation about the way the authors of both articles justified their main conclusion(s). Do you agree with the main conclusion(s) based on the given supports? Why do you (not) agree?
- A comparison of both articles with reference to the question addressed above.

Guidelines

- The length of the review should be between 750 and 1000 words.
- You could use your tables with elements of both articles as a support to write your review.
- Take your fellow biology students who did not read the articles as your reader audience.
- Keep in mind the criteria of the peer review form.

APPENDIX F
Analytical framework review (Chapter 4 and 5)

Components of review		Text unit	Remarks
Aim			Question in the assignment: Does (and how does it do this?) PINK1 activate parking directly, indirectly, or both? It is poorly understood how the E3 activity of parkin is accelerated by damaged mitochondria. What is the genuine substrate of PINK1 responsible for parkin activation? Ubiquitin is phosphorylated by PINK1 to activate parkin. A complete understanding of the molecular mechanism underlying parkin activation is expected to clarify pathogenesis of hereditary and sporadic forms of PD. This article shows for the first time ubiquitin phosphorylation and its significance. Ubiquitin is phosphorylated by PINK1. the phosphorylation site on ubiquitin is <u>Ser65</u> . <u>PINK1 is required</u> for ubiquitin phosphorylation. (about the role of phosphorylated ubiquitin): parkin conjugates both unphosphorylated and phosphorylated ubiquitin to substrates. phosphorylated ubiquitin <u>activated parkin</u> . <u>ubiquitin phosphorylation at Ser65 is essential</u> for parkin activation (experiment in <u>yeast system</u>). Activation of parkin is <u>allosteric</u> (the molecular mechanism by which phosphorylated ubiquitin activates parkin). phosphorylated ubiquitin <u>interacts physically</u> with parkin. The presented model in Figure 4j. (is a speculation, use of computational modeling) The absolute level of endogenous ubiquitin was very low, but it might be a significant pool due to the pleiotropic functions of ubiquitin.
Article Koyano et al. (2014)	M		
	O		
	MC		
	I 1		
	I 2		
	S 1		
	S 2		
	S 3		
	S 4		
	S 5		
	S 6		
	S 7		
	S 8		
	S 9		
	CA + R		

Analytical framework review (Chapter 4 and 5) continued.

Components of review (continued)		Text unit	Remarks
Article Fiesel et al. (2015)	M		The (patho-)physiological <u>significance</u> (in neurons and brain) of ubiquitin phosphorylation is unknown. Generate novel antibodies and assess <u>pS65-Ub signals <i>in vitro</i></u> and in cells (demonstrate the (patho-)physiological relevance). 1. The authors confirmed the presence of pS65-Ub in stressed primary neurons and <i>in vivo</i> in human postmortem brains. 2. The two pS65-Ub antibodies can be used as a tool to monitor mitochondrial damage in cell models and brain tissue. Additional studies are needed to further investigate <u>pS65-Ub functions</u> and <u>explore its potentials for biomarker/therapeutic development</u> . The nature and composition of pS65-Ub-positive structures must be exactly determined from <u>larger case studies</u> . <u>pS65-Ub</u> should be further analyzed in <u>different genetic or environmental animal models of PD</u> . two pS65-Ub antibodies were validated <u>in vitro</u> . cellular pS65-Ub signal is induced by stress and amplified by functional Parkin. pS65-Ub is specific to mitochondrial damage in <u>all cells</u> . pS65-Ub depends on PINK1 kinase activity and is <u>reversible</u> . pS65-Ub in human patient's fibroblast-derived and primary mouse neurons. pS65-Ub in human postmortem brain. + <u>pS65-Ub positive mitophagy granules accumulate with age and disease in human brains</u> Results suggested a much greater cellular abundance of pS65-Ub over pS65-Parkin. Though it was not noticeable in the staining pattern, they could not formally exclude some minor contribution of <u>pS65-Parkin cross-signal</u> to the staining obtained with pS65-Ub#2. Ubiquitin and Parkin are both PINK1 substrates and <u>jointly act as important regulators of the mitochondrial quality control pathway</u> .
Comparison of articles Evaluation of articles Final conclusion Other components (e.g., information moves)			

Note: M: Motive, O: Objective, S: Support, CA: Counterargument, R: Refutation, MC: Main Conclusion, I: Implication.

APPENDIX G

Interview questions students (Chapter 4)

Introduction interview

- 1. Do you give your consent to record the interview on audio?
- 2. The data will be treated confidentially and anonymously.
- 3. The research aim is to gain more knowledge about the way first-year students learn to write scientifically. The aim of the interview is to reflect on your approach for writing the review and to evaluate the course. During the interview we will not assess your review or writing skills.
- 4. The interview will last for a maximum of half an hour.
- 5. Please ask for clarification of the questions or raise other questions.

Questions

Please try to recall and remember the moment you were writing the review.

- 6. Did you have any difficulties in understanding the studies presented in the two articles (the method and the results)? If yes, what difficulties did you experience?
- 7. Did you recognize the line of reasoning in the two articles? (if needed, refer to the different rhetorical moves)
- 8. Did you have any difficulties in writing the review? If yes, what difficulties?
- 9. Did you have any difficulties with English language use?
- 10. Do you think that the focus on structure and key elements (i.e. SAM) in research articles helped you in writing the review? Why or why not?
- 11. What is your experience with identifying key elements in research articles? Was it useful? Was it difficult? Were some key elements more difficult to identify than others? If so, which and why?
- 12. Do you have any questions, additions, or remarks?

APPENDIX H

Student questionnaire (Chapter 4)

- 1. Please indicate how much you agree with the following statements. The numbers have the following meaning (Put your answer behind each statement):

1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree

- A. The illustration of the different elements (e.g., motive) by the lecturers was helpful to understand the different elements in research articles.
- B. The article discussions were helpful to understand the research articles.
- C. It is useful to identify different elements (e.g. motive) to understand a research article.
- D. In future, I will look for the different elements to understand a research article when reading one.

- 2. In general, which of the seven elements did you find hard to identify in the research articles? (Highlight your answer(s))

none motives objectives supports counterarguments
refutations main conclusions implications

If you find one or more elements hard to identify, please shortly explain why:

- 3. Did you have any difficulties in reading the research articles? Yes / No
If yes, please explain which difficulties you had:
- 4. Did you have any difficulties in writing the review? Yes / No
If yes, please explain which difficulties you had:

APPENDIX I

Interview questions course lecturers (Chapter 4)

Introduction interview

- 1. Do you give your consent to record the interview on audio?
- 2. The data will be treated confidentially and anonymously.
- 3. The aim of the interview is to reflect on the course and your use of SAM.
- 4. The interview will last for a maximum of 45 minutes.
- 5. Please ask for clarification of the questions or raise other questions.

Questions

- 6. How did you experience the first part of the course (related to the use of SAM)?
- 7. What went well in the course and what needs improvement?
- 8. Do you think the research articles were appropriate for the course?
- 9. Do you think that the students understood the research articles' content?
- 10. To what extent did the students achieve the learning goals?
- 11. What did the students learn from the course? What are bottlenecks?
- 12. How did you experience working with SAM?
- 13. How did the students experience using SAM, according to you?
- 14. Could they work well with SAM?
- 15. Do you think using SAM helped the students with reading research articles? Why or why not?
- 16. Do you think using SAM helped the students with identifying the line of reasoning in research articles? Why or why not?
- 17. Do you think using SAM helped the students with writing the review? Why or why not?
- 18. What is your impression of the students' reading abilities after the course? Why?
- 19. What is your impression of the students' writing abilities after the course? Why?
- 20. What was the writing quality of the *first* drafts of the review? Why? And more specifically, what was the quality of the line of reasoning in the reviews?
- 21. What was the writing quality of the *final* drafts of the review? Why? And more specifically, what was the quality of the line of reasoning in the reviews?
- 22. Do you have any questions, additions or remarks?

APPENDIX J

VOSTS questionnaire²⁴ (Chapter 5)

Questionnaire science viewpoints BMO1 (2016)

Please write your name here:

Instructions

Each question begins with a statement about a science topic. Most of these statements express an extreme view on the topic. You may happen to agree strongly with this view; you may happen to disagree vigorously; or your own position may be in between the two. Next, there is a list of positions (or viewpoints) on the issue. These usually go from one extreme to the other. You are asked to choose one of these positions, BUT ONLY THE ONE that comes closest to your personal view or belief.

To summarize:

- Read the statement carefully.
- Think to yourself whether you agree or disagree with the statement, or can't make up your mind.
- Then read the list of different positions on the topic.
- Pick the one that comes closest to your own position and circle your choice.

Every page ends with the same three positions. Here is how you can use them if you wish:

- "I don't understand." This choice is included in case there is a key word or phrase that you just don't understand.
- "I don't know enough about this subject to make a choice."
- "None of these choices fit my basic viewpoint." This choice can be used when none of the other positions comes close to your own belief, or when you want to combine two or more choices into one position.

There are no "right" answers; this is not a test. We simply want to understand what your position is on a number of science issues.

Thank you for completing the questionnaire!

24 The items were selected from the VOSTS questionnaire (Aikenhead et al., 1989).

SCIENTIFIC DECISIONS
Item 1

When scientists disagree on an issue (for example, whether or not low-level radiation is harmful), they disagree mostly because they do not have all the facts. Such scientific opinion has NOTHING to do with moral values (right or wrong conduct) or with personal motives (personal recognition, pleasing employers, or pleasing funding agencies). Disagreements among scientists can occur:

Student positions	Frequency
A. because not all the facts have been discovered. Scientific opinion is based entirely on observable facts and scientific understanding.*	2
B. because different scientists are aware of different facts. Scientific opinion is based entirely on a scientist's awareness of the facts.	-
C. when different scientists interpret the facts differently (or interpret the significance of the facts differently). This happens because of different scientific theories, NOT because of moral values or personal motives.*	7
D. mostly because of different or incomplete facts, but partly because of scientists' different personal opinions, moral values, or personal motives.**	6
E. for a number of reasons — any combination of the following: lack of facts, misinformation, different theories, personal opinions, moral values, public recognition, and pressure from companies or governments.**	6
F. when different scientists interpret the facts differently (or interpret the significance of the facts differently). This happens mostly because of personal opinions, moral values, personal priorities, or politics. (Often the disagreement is over possible risks and benefits to society.)	-
G. because they have been influenced by companies or governments.	-
H. I don't understand.	-
I. I don't know enough about this subject to make a choice.	-
J. None of these choices fits my basic viewpoint.	-

Note. The frequency of students' responses is given for each item. We categorized the responses selected by the students in traditional* and contemporary** responses. Traditional responses are indicated in grey.

SCIENTIFIC DECISIONS
Item 2

When a new scientific theory is proposed, scientists must decide whether to accept it or not. Their decision is based objectively on the facts that support the theory. Their decision is *not* influenced by their subjective feelings or by personal motives.

Student positions	Frequency
A. Scientists' decisions are based solely on the facts, otherwise the theory would not be properly supported and the theory could be inaccurate, useless or even harmful.*	2
B. Scientists' decisions are based on more than just the facts. Decisions are based on whether the theory has been successfully tested many times, on how logical the theory is compared with other theories, and on how simply the theory explains all the facts.*	9
C. It depends on the individual scientist. Some scientists will be influenced by personal feelings, while others will live up to their duty to make decisions based only on the facts.**	5
D. Because scientists are only human, their decisions are, to some extent , influenced by inner feelings, by the personal way a scientist views a theory, or by personal gains such as fame, job security or money.**	5
E. Scientists' decisions are based less upon the facts and more upon inner feelings, upon the personal way a scientist views a theory, or upon personal gains such as fame, job security or money.	-
F. I don't understand.	-
G. I don't know enough about this subject to make a choice.	-
H. None of these choices fits my basic viewpoint.	-

SCIENTIFIC DECISIONS
Item 3

When a new scientific theory is proposed, scientists must decide whether to accept it or not. Scientists make this decision by consensus; that is, proposers of the theory must convince a large majority of fellow scientists to believe the new theory.

Student positions	Frequency
<i>Scientists who propose a theory must convince other scientists:</i>	
A. by showing them conclusive evidence that proves the theory true.*	6
B. because a theory is useful to science only when most scientists believe the theory.*	3
C. because when a number of scientists discuss a theory and its new ideas, scientists will likely revise or update the theory. In short, by reaching a consensus, scientists make the theory more accurate.**	8
<i>Scientists who propose a theory do not have to convince other scientists:</i>	
D. because the supporting evidence speaks for itself.	-
E. because individual scientists will decide for themselves whether to use a theory or not.*	1
F. because an individual scientist can apply a theory as long as the theory explains results and is useful, no matter what other scientists believe.*	1
G. I don't understand.	-
H. I don't know enough about this subject to make a choice.	-
I. None of these choices fits my basic viewpoint.	2

INDIVIDUAL'S INFLUENCE ON SCIENTIFIC KNOWLEDGE
Item 4

With the same background knowledge, two scientists can develop the same theory independently of each other. The scientist's individuality does NOT influence the content of a theory.

Student positions	Frequency
<i>The scientist's individuality will NOT influence the content of a theory:</i>	
A. because this content is based on facts and the scientific method, which are not influenced by the individual.	-
B. because this content is based on facts. Facts are not influenced by the individual. However, the way a scientist conducts an experiment will be influenced by his or her individuality.*	3
C. because this content is based on facts. The way a scientist interprets the facts will, however, be influenced by his or her individuality.**	3
<i>A scientist's individuality WILL influence the content of a theory:</i>	
D. because different scientists conduct research differently (for example, probe deeper or ask slightly different questions). Therefore they will obtain different results. These results then influence the content of a theory.**	4
E. because different scientists will think differently and will have slightly different ideas or viewpoints.**	8
F. because a theory's content may be influenced by what a scientist wants to believe. Bias has an influence.**	3
G. I don't understand.	-
H. I don't know enough about this subject to make a choice.	-
I. None of these choices fits my basic viewpoint.	-

NATURE OF OBSERVATIONS
Item 5

Scientific observations made by competent scientists will usually be different if the scientists believe different theories.

Student positions	Frequency
A. Yes, because scientists will experiment in different ways and will notice different things.**	3
B. Yes, because scientists will think differently and this will alter their observations .**	5
C. Scientific observations will not differ very much even though scientists believe different theories. If the scientists are indeed competent their observations will be similar.*	12
D. No, because observations are as exact as possible. This is how science has been able to advance.	-
E. No, observations are exactly what we see and nothing more; they are the facts.	-
F. I don't understand.	-
G. I don't know enough about this subject to make a choice.	-
H. None of these choices fits my basic viewpoint.	1

NATURE OF SCIENTIFIC MODELS
Item 6

Many scientific models used in research laboratories (such as the model of heat, the neuron, DNA, or the atom) are copies of reality.

Student positions	Frequency
<i>Scientific models ARE copies of reality:</i>	
A. because scientists say they are true, so they must be true.	-
B. because much scientific evidence has proven them true.	-
C. because they are true to life. Their purpose is to show us reality or teach us something about it.*	1
D. Scientific models come close to being copies of reality, because they are based on scientific observations and research.*	12
<i>Scientific models are NOT copies of reality:</i>	
E. because they are simply helpful for learning and explaining, within their limitations.**	4
F. because they change with time and with the state of our knowledge, like theories do.**	2
G. because these models must be ideas or educated guesses, since you can't actually see the real thing.**	1
H. I don't understand.	-
I. I don't know enough about this subject to make a choice.	-
J. None of these choices fits my basic viewpoint.	1

NATURE OF CLASSIFICATION SCHEMES
Item 7

When scientists classify something (for example, a plant according to its species, an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to *the way nature really is*; any other way would simply be wrong.

Student positions	Frequency
A. Classifications match the way nature really is, since scientists have proven them over many years of work.	-
B. Classifications match the way nature really is, since scientists use observable characteristics when they classify.*	3
C. Scientists classify nature in the most simple and logical way, but their way isn't necessarily the only way.**	1
D. There are many ways to classify nature, but agreeing on one universal system allows scientists to avoid confusion in their work.**	10
E. There could be other correct ways to classify nature, because science is liable to change and new discoveries may lead to different classifications.**	3
F. Nobody knows the way nature really is. Scientists classify nature according to their perceptions or theories. Science is never exact, and nature is so diverse. Thus, scientists could correctly use more than one classification scheme.**	4
G. I don't understand.	-
H. I don't know enough about this subject to make a choice.	-
I. None of these choices fits my basic viewpoint.	-

TENTATIVENESS OF SCIENTIFIC KNOWLEDGE
Item 8

Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future.

Scientific knowledge changes:

Student positions	Frequency
A. because new scientists disprove the theories or discoveries of old scientists. Scientists do this by using new techniques or improved instruments, by finding new factors overlooked before, or by detecting errors in the original "correct" investigation.*	11
B. because the old knowledge is reinterpreted in light of new discoveries. Scientific facts can change.**	7
C. Scientific knowledge APPEARS to change because the interpretation or the application of the old facts can change. Correctly done experiments yield unchangeable facts.*	1
D. Scientific knowledge APPEARS to change because new knowledge is added on to old knowledge; the old knowledge doesn't change.*	1
E. I don't understand.	-
F. I don't know enough about this subject to make a choice.	-
G. None of these choices fits my basic viewpoint.	1

SCIENTIFIC APPROACH TO INVESTIGATIONS**Item 9**

When scientists investigate, it is said that they follow the scientific method. The scientific method is:

Student positions	Frequency
A. the lab procedures or techniques; often written in a book or journal, and usually by a scientist.*	2
B. recording your results carefully.	-
C. controlling experimental variables carefully, leaving no room for interpretation.*	2
D. getting facts, theories or hypotheses efficiently.	-
E. testing and retesting — proving something true or false in a valid way.*	2
F. postulating a theory then creating an experiment to prove it.*	1
G. questioning, hypothesizing, collecting data and concluding.**	9
H. a logical and widely accepted approach to problem solving.	-
I. an attitude that guides scientists in their work.**	2
J. considering what scientists actually do, there really is no such thing as the scientific method.**	1
K. I don't understand.	-
L. I don't know enough about this subject to make a choice.	-
M. None of these choices fits my basic viewpoint.	2

SCIENTIFIC APPROACH TO INVESTIGATIONS**Item 10**

The best scientists are those who follow the steps of the scientific method.

Student positions	Frequency
A. The scientific method ensures valid, clear, logical and accurate results. Thus, most scientists will follow the steps of the scientific method.*	4
B. The scientific method should work well for most scientists; based on what we learned in school.*	1
C. The scientific method is useful in many instances, but it does not ensure results. Thus, the best scientists will also use originality and creativity.**	12
D. The best scientists are those who use any method that might get favourable results (including the method of imagination and creativity).	-
E. Many scientific discoveries were made by accident, and not by sticking to the scientific method.	-
F. I don't understand.	-
G. I don't know enough about this subject to make a choice.	-
H. None of these choices fits my basic viewpoint.	4

SCIENTIFIC APPROACH TO INVESTIGATIONS
Item 11

Scientists publish the results of their work in scientific journals. When scientists write an article for a journal, they organize their report in a very logical orderly way. However, scientists actually do the work in a much less logical way.

Student positions	Frequency
<i>Articles are written in a more logical way than the actual work:</i>	
A. because scientists can think and work without following a set plan. Consequently, if you read the actual order of their thoughts and procedures, it would be confusing. Therefore, scientists write logically so other scientists will understand the results.**	8
B. because scientific hypotheses are personal views or guesses and thus are not logical. Scientists, therefore, write logically so other scientists will understand the results.*	1
C. Scientists usually don't want to give away "the recipe" but they do want to tell the world about their results. So they write it up logically but in a way that does not reveal how it was actually done.	-
D. It depends. Sometimes scientific discoveries happen by accident. But other times discoveries happen in a logical orderly way, just like the articles are written.**	3
<i>Articles are written in a logical way showing how the actual work was done:</i>	
E. because a scientist's work is conducted logically; otherwise, it would not be useful to science and technology.*	3
F. because scientists do work in a logical way so that their published report will be easier to write in a logical way.*	1
G. Articles are not necessarily written in a logical way. They're written the way the work was done. This can be complicated or straightforward.	-
H. I don't understand.	-
I. I don't know enough about this subject to make a choice.	2
J. None of these choices fits my basic viewpoint.	3

EPISTEMOLOGICAL STATUS OF SCIENTIFIC KNOWLEDGE
Item 12

For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific THEORIES. Others think that scientists *invent* them. What do you think?

Student positions	Frequency
<i>Scientists discover a theory:</i>	
A. because the idea was there all the time to be uncovered.*	1
B. because it is based on experimental facts .*	1
C. but scientists invent the methods to find the theories.*	2
D. Some scientists may stumble onto a theory by chance, thus discovering it. But other scientists may invent the theory from facts they already know.*	5
<i>Scientists invent a theory:</i>	
E. because a theory is an interpretation of experimental facts which scientists have discovered.**	8
F. because inventions (theories) come from the mind — we create them.**	2
G. I don't understand.	-
H. I don't know enough about this topic to make a choice.	-
I. None of these choices fits my basic viewpoint.	2

Note. Extra clarification by student 9: Response position E: "'Science' is a way to explain the world around us. Experiments may have certain results but it is up to the scientists to formulate a theory or model that explains why the results are so. It also depends on the field. I believe mathematics is invented but biology leans more towards being discovered. I had to write essays about this kind of stuff in high school, it was fun."

APPENDIX K

Supplementary data VOSTS items (Chapter 5)

Overview of students' responses to 12 VOSTS items and the total of traditional responses for each student.

Category 1. Social construction of scientific knowledge				Category 2. Nature of scientific knowledge		Category 3. Tentativeness of scientific knowledge		Category 4. Scientific approach to investigations		Category 5. Epistemo- logical status of scientific knowledge		Total of traditional responses	
Student	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Item 12	
1	D	C	B*	D	C*	C*	D	A*	G	C	D	E	4
2	E	B*	C	E	A	D*	D	A*	E*	C	A	E	4
3	E	C	I ^a	E	C*	F	D	B	G	C	I ^b	C*	2
4	C*	B*	I ^a	E	B	G	D	B	E*	C	I ^b	F	3
5	D	B*	C	D	H ^a	D*	E	B	M ^a	H ^a	J ^a	E	2
6	A*	A*	C	B*	C*	E	D	A*	G	B*	A	B*	7
7	C*	B*	A*	E	C*	D*	E	A*	G	C	J ^a	C*	7
8	E	C	C	F	A	D*	D	B	M ^a	C	A	I ^a	1
9	D	D	F*	F	B	J ^a	F	B	I	H ^a	F*	E	1
10	E	A*	A*	B*	C*	D*	D	A*	A*	A*	A	D*	9
11	A*	B*	E*	C	C*	E	B*	A*	G	A*	B*	I ^a	8
12	D	D	C	E	C*	D*	F	A*	C*	C	E*	D*	6
13	C*	B*	C	D	A	D*	C	A*	J	C	A	F	4
14	C*	D	B*	E	B	E	D	A*	F*	H ^a	E*	A*	6
15	D	D	A*	C	C*	D*	F	A*	C*	C	E*	E	6
16	E	B*	A*	B*	B	D*	B*	C*	I	A*	A	E	7
17	D	C	C	F	B	D*	D	B	G	C	D	D*	2
18	C*	B*	A*	C	C*	F	F	B	G	C	J ^a	E	4
19	C*	C	A*	D	C*	D*	E	A*	G	C	D	D*	6
20	C*	B*	B*	E	C*	E	B*	D*	A*	A*	A	E	8
21	E	D	C	E	C*	D*	D	G ^a	G	H ^a	A	D*	3

Note. Traditional responses are indicated with an *. ^a response: “None of these choices fits my basic viewpoint”, ^b response: “I don’t know enough about this subject to make a choice”. Light grey highlight: students with the highest amount of traditional responses. Dark grey highlight: students with a mix of responses, which do not fall in either the traditional or contemporary group.

APPENDIX L

Course manual – example

This manual was used in the physics course (Chapter 3).

PHYSICS OF LIFE

Course details

Period: semester IIa (week 6-15, 2015)

Language of instruction: English

Credits (ECTS): 5

Target audience

First-year students (Applied) Physics / Astronomy

Learning objectives

Biophysics:

- The student is able to apply fundamental physical principles to describe and explain biological phenomena.
- The student is able to use basic principles from statistical physics, thermodynamics, classical mechanics, polymer physics, and optics to describe processes such as molecular diffusion, the behavior of biopolymers such as protein and DNA, and the functioning of motor proteins.
- Further, the student is able to use these physical concepts to explain how modern biomedical methods work such as clinical imaging, fluorescence microscopy, and DNA sequencing.

Reading/writing/presenting:

- The student is able to describe the content of a research article, describe and represent the argument of a research article, and critically reflect on the article.
- Finally, the student is able to present a research article (written and oral).

Course outline

Each week meetings with the students are planned (week 1-8). Each meeting lasts 1.5 hours (mandatory attendance!). In the ninth week students have a study week. The final assignment (a presentation) is done in the tenth week (see Course overview and schedule online). During lectures and tutorials students are instructed in various biophysical topics and academic skills. Besides providing an introduction to biophysical principles and techniques, the course is organized around three skills: scientific reading, writing, and presenting.

In week 1-4 students practice with the reading of research articles. Student are instructed how to read a research article. Each week they are assigned to read a research article and make the associated assignment. At a subsequent meeting, the research article, with reference to the assignment, is discussed with the students.

In week 4-8 scientific writing is the main theme. Students have to read a research article, make a scheme of it and finally write a summary. During tutorials an instruction in scientific writing is given. Students have to review a summary of a fellow student. This review will be discussed in a tutorial. Thereafter, students will rewrite their summary, which will be graded by the lecturer. Additionally, they will write a short critical reflection about the research article they have read.

In week 7 students receive instruction in presentation skills. They are assigned to choose a research article for their final assignment: an oral presentation about a research article to their fellow students and lecturers.

The lectures on the various biophysical topics give students the necessary background information to understand the research articles.

Course content

See the course schedule on Nestor for the course outline and the topics of the lectures and tutorials. The following research articles are used during the course:

- Example paper: Noji et al. (1997)
- Assignment 1-3: Blainey et al. (2006), Smith et al. (2001), Hammar et al. (2012)
- Assignment 4: Yildiz et al. (2003), Yildiz et al. (2004)
- Final presentations: Eid et al. (2009), Rothberg et al. (2011), Wang et al. (2006), Lee et al. (2006), Betzig et al. (2006)

All these articles can be found on the course Nestor page.

Assessment

Students will be assessed on three elements; an active participation during the course and submission of the homework assignments (1/3), the writing assignment (second version) (1/3) and the final assignment (presentation) (1/3). The grade is determined by the average of the three individual grades. The assessment forms for the writing assignment and the presentation are included in the manual.

Reading task 1

Read paper 1 Blainey et al., (2006) and answer the questions below. Upload your answers onto Nestor **before Monday February 9th, 9:00**. Indicate your answers with the corresponding question numbers.

1. What is “facilitated diffusion” and describe what cellular problem it solves in the context of the enormous amount of DNA in a cell’s nucleus.
2. The authors visualize individual hOgg1 DNA-repair proteins moving on the DNA using fluorescent labels. Explain why a single-molecule approach is useful compared to an ‘ensemble-averaging’ method. Also explain what type of constraints a single-molecule imaging experiment places on the concentration of labeled protein.
3. How do the authors make sure the proteins they see are actually located on the DNA?
4. Explain why the mean square of the protein motion is linear with time.
5. What is the theoretical net displacement of a particle obeying a perfect random walk? Why might you expect a different outcome in this particular experiment?
6. Explain why the ‘hopping’ and ‘sliding’ models give different predictions for the dependence of the diffusion coefficient on the salt concentration. Explain why the dependence of the binding lifetime of the protein on the salt concentration should be the same for the two models.
7. Explain what the Arrhenius relation is and how the authors use this to relate the ‘roughness’ of the free energy landscape of DNA binding to the speed of movement along the DNA.
8. The authors describe that a random walk of the protein along the DNA would result in a situation in which a specific location will be visited a large number of times. How would this be advantageous for the protein’s function?

The following questions relate to the key elements in research papers:

9. Describe the motive(s) of the paper.
 - a. In what text part(s) did you find the motive(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the motive(s) of the paper?
10. Describe the objective(s) of the paper.
 - a. In what text part(s) did you find the objective(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the objective(s) of the paper?

11. Describe the main conclusion(s) of the paper.
 - a. In what text part(s) did you find the main conclusion(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the main conclusion(s) of the paper?
 - c. How certain are the authors of their main conclusion(s)? How did you infer this?
12. Describe the implication(s) of the paper.
 - a. In what text part(s) did you find the implication(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the implication(s) of the paper?
13. There are many references to previous studies in the paper. What is in general the function of these references?

Reading task 2

Read paper 2 Smith et al. (2001) and answer the questions below. Check also the supplementary information belonging to the paper. Upload your answers onto Nestor **before Monday February 16th, 9:00**. Indicate your answers with the corresponding question numbers.

1. Describe what a bacteriophage is and what aspect of it the authors set out to study.
2. Describe the experiment.
3. What is the difference between the 'constant force feedback' mode and the 'no feedback' mode of doing the experiment?
4. Why do you think do the authors use a DNA molecule that is 1.8 times the length of the Phi29 genome?
5. How much DNA fits into the phage capsid?
6. What is the stall force of the packaging motor? What does the concept stall force mean?
7. The DNA packaging rate is force dependent, even at low forces. What does this observation mean?
8. How do the authors determine how much work has been done by the motor in packaging the DNA? And how does this value compare to the expected energy stored in the DNA?

The following questions relate to the key elements in research papers:

9. Describe the motive(s) of the paper.
 - a. In what text part(s) did you find the motive(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the motive(s) of the paper?
10. Describe the objective(s) of the paper.
 - a. In what text part(s) did you find the objective(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the objective(s) of the paper?
11. Describe the main conclusion(s) of the paper.
 - a. In what text part(s) did you find the main conclusion(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the main conclusion(s) of the paper?
 - c. How certain are the authors of their main conclusion(s)? How did you infer this?

12. Describe the implication(s) of the paper.
 - a. In what text part(s) did you find the implication(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the implication(s) of the paper?
13. Describe the most important supports the authors use to justify their main conclusion(s).
 - a. In what text part(s) did you find the most important supports? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose these text part(s) as the most important supports?
14. Are there counterarguments given by the authors? If so, what counterargument(s)?
15. Can you think of a counterargument by yourself that could weaken the authors' main conclusion(s).

Reading task 3

Read paper 3 Hammar et al. (2012) and answer the questions below. Upload your answers onto Nestor **before Monday February 23th, 9:00**. Indicate your answers with the corresponding question numbers.

1. We read an article two weeks ago that discussed the observation of facilitated diffusion of proteins along stretched DNA molecules using purified proteins (Blainey et al., PNAS (2006)). Why is it so important to study similar processes in a live cell?
2. How do the authors distinguish whether a fluorescently labelled protein is bound to the DNA or freely diffusing in the cell?
3. The protein LacI is a 'repressor' and the molecule IPTG an 'inducer'. What do the terms repressor and inducer mean in the context of this work?
4. How do the authors determine the sliding distance of the LacI protein along the DNA?
5. Is the sliding distance the authors measure inside living cells consistent with what researchers have measured in vitro?

The following questions relate to the key elements in research papers:

6. Describe the motive(s) of the paper.
 - a. In what text part(s) did you find the motive(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the motive(s) of the paper?
7. Describe the objective(s) of the paper.
 - a. In what text part(s) did you find the objective(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the objective(s) of the paper?
8. Describe the main conclusion(s) of the paper.
 - a. In what text part(s) did you find the main conclusion(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the main conclusion(s) of the paper?
 - c. How certain are the authors of their main conclusion(s)? How did you infer this?

9. Describe the implication(s) of the paper.
 - a. In what text part(s) did you find the implication(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the implication(s) of the paper?
10. Describe the most important supports the authors use to justify their main conclusion(s).
 - a. In what text part(s) did you find the most important supports? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose these text part(s) as the most important supports?
11. Describe the counterargument(s) of the paper.
 - a. In what text part(s) did you find the counterargument(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the counterargument(s) of the paper?
 - c. Can you think of a counterargument by yourself that could weaken the authors' main conclusion(s).
12. Describe – if mentioned – the corresponding refutation(s) of each counterargument of the paper.
 - a. In what text part(s) did you find the refutation(s)? Quote the text part(s) with the first four and the last four words of the sentence(s) with corresponding page number(s).
 - b. Why did you choose this/these text part(s) as the refutation(s) of the paper?
 - c. Do you think that the authors sufficiently refute their counterarguments? Explain your answer.
13. Do you think the main conclusion(s) are sufficiently justified? Explain your answer.
14. How are the different elements of this paper related to each other? Try to visualize all the elements and their relations in a scheme (digitally or on paper). Use your description of the elements to illustrate the element. Put behind each element a letter that indicates the type of element: (M) motive, (O) objective, (MC) main conclusion, (I) implication, (S) support, (CA) counterargument, and (R) refutation.

Writing assignment 4a

Upload your answers onto Nestor **before March 2nd, 9:00.**

The following people will read paper 4:

Myosin V walks hand-overhand: Single fluorophore imaging with 1.5nm localization.

Science (2003), vol. 300, pp. 2061-2065

The following people will read paper 5:

Kinesin walks hand-overhand.

Science (2004), vol. 303, pp. 676-678

1. Look in the lists where your name is, check whether you read the correct paper and write down the first word in the title of the paper you read. I know, this is an easy question, but it allows us to easily see which paper you've read ☺
2. In both papers, the authors attach a fluorophore to the protein of interest (kinesin or myosin) and excite it with a laser to see the teeny-tiny fluorescence of the labeled protein. How do they ensure that the small fluorescence signal doesn't get overwhelmed by the laser light?
3. In the microscopy lecture on Wednesday February 18th, was explained how the smallest thing you can see using an optical microscope has a size of around half of the wavelength of light (~ 250 nm). How can the authors then visualize steps of only a few tens of nanometers?
4. Why is the accuracy of measuring protein steps dependent on the number of photons detected?
5. If you look at the distribution of step sizes (Figure 3A in the kinesin paper and Figure 3 (inset) in the myosin paper), there is quite a spread in step sizes. How do you reconcile this with the fixed periodicity of the binding sites on the filaments?
6. Take a look at the distributions of the stepping times (Figure 3B for the kinesin paper and Figure 6 for the myosin paper). For a single reaction (like a step taken by a molecular motor), you expect a single-exponential decay for the reaction times. Why do you see distributions instead that first go up and then go down ('rise and decay')?
7. Explain which two models existed on how the protein moves along the filament and how the work described in the paper allows for a discrimination between these two models.

Writing assignment 4b

Make a scheme of the paper you read with all the elements and their relations as was explained in the previous lectures. This assignment is a preparation to write an extensive summary of the paper next week.

Put all the elements in a scheme as was shown during the lecture on Monday February 23th (see slides on Nestor under the 'Week 4' folder).

Use your own descriptions of the elements and indicate in what text part(s) you have find these elements using quotes (write the first four and the last four words of the sentence(s) with corresponding page number(s)).

Note: regarding the supports, look for the most important ones the authors use to justify their main conclusion(s).

Put behind each element a letter that indicates the type of element: (M) motive, (O) objective, (MC) main conclusion, (I) implication, (S) support, (CA) counterargument, and (R) refutation.

Upload your scheme onto Nestor **before March 9th, 9:00**. You may also hand in your scheme on paper next Monday before the start of the tutorial.

Writing assignment 4c

Write an extensive summary of the paper you read (see list above). The goal behind this summary writing is that it helps you to look at the content of the paper and to become familiar with the research article genre. Additionally, this summary writing might help you when you will write a literature review for your bachelor thesis, for example.

Guidelines:

- The length should be between 500 and 750 words.
- Make clear how the authors come to their conclusion; what is their line of reasoning?
- Write the summary from an 'outsiders' perspective. For example: instead of using "we measured...", use "the authors measured..."
- Take your fellow physics students who do not know the paper as the audience for your summary.
- You can use your scheme as a support to write the summary.
- Keep in mind the criteria of the peer review form (see the Week 6 folder on Nestor).

Upload your summary onto Nestor **before Monday March 16th, 9:00**.

Writing assignment 4d

Review the summary of one of your fellow students (see list above) by filling in the peer review form. You can find the form in the Week 6 folder on Nestor. Give for each criterion at least one suggestion to improve the summary. Bring the summary you reviewed (with your feedback) with you to the next meeting.

Select a paper to present from the 5 options in the presentation folder on Nestor.

Upload your completed peer review form and your presentation selection onto Nestor **before Monday March 23th, 9:00**.

Writing assignment 4e

Revise your summary by using your received peer feedback. You can find your peer feedback in the Week 7 folder on Nestor.

Write a short critical reflection with a length between 100 and 150 words of the paper you have summarized. Give in this reflection your own opinion about the way the authors justified their main conclusion(s). Do you agree with the main conclusion(s) based on the given supports? Why do you (not) agree?

Upload your revised summary and critical reflection onto Nestor **before Monday March 30th, 9:00**.

Final assignment

On Tuesday April 7th, 9:00-12:00 (room: X 5116.0116) you will present your selected paper to your fellow students.

Prepare a presentation in which you present the paper. You have a maximum of 10 minutes. Give an overview of the paper and important key points. Keep in mind the criteria of the presentation assessment form (see the 'Week 10' folder on Nestor). After the presentation there is some time for questions and discussion.

Upload your presentation (slides) onto Nestor **before Tuesday April 7th, 9:00**.

Assessment form – writing assignment (summary)

Student name:

Summary of paper: Myosin / Kinesin

Final score (Criteria 1-4 each a weight of 25%):

Criteria

1. Content

Did the student clearly communicate the content of the research article?

Score:
Comments (both strengths and weaknesses):

2. Line of reasoning

Did the student clearly state the authors' reasoning?

Score:
Comments (both strengths and weaknesses):

3. Structure/organization

Did the student present a well-organized summary (with an introduction, a core, and a conclusion)?

Score:
Comments (both strengths and weaknesses):

4. Usage of peer feedback

Did the student use the peer feedback to revise the summary?

Score:
Comments (both strengths and weaknesses):

5. English grammar and word usage

Did the student use proper English?

Score:
Comments (both strengths and weaknesses):

SUMMARY

SAMENVATTING

SUMMARY

Given the importance of writing in scientific practice, undergraduate students starting their science studies, like biology or chemistry, should develop their scientific writing skills. They also need an understanding of the scientific texts genres, of which research articles occupy a prominent position. These articles report on recent research findings to the international scientific community. Characteristic of writing such scientific texts is the construction of an argument. An argument is defined here as the justification of a conclusion by research data. In educational practice, however, writing poses challenges to many science undergraduates. For instance, they have difficulty constructing a written argument and writing lengthy texts, like a bachelor thesis. In addition, research has shown that specific writing instruction in many undergraduate science degree programs is often not common practice in European higher education institutions, including Dutch research universities. Therefore, we initiated the research presented in this thesis. We aimed at examining how undergraduate science students can be supported in their scientific writing skills with a focus on written argument construction. We carried out the research in the context of the science faculty of the University of Groningen. We used design research as our overall research approach since it offers a systematic approach to develop and examine a research-based teaching strategy that supports first-year students' scientific writing.

Student writing practices in four science programs

We first investigated the local research context on current student writing practices. For this purpose, we interviewed 16 faculty members from the undergraduate degree programs of astronomy, biology, chemistry, and physics from the Faculty of Science and Engineering at the University of Groningen. We explored faculty members' experiences with writing instruction and students' writing abilities. We also examined their beliefs about adequate writing instruction and expected students' writing abilities. The findings showed that the faculty members recognized the significance of integrating writing instruction in undergraduate science programs. However, at the moment of the study, there was little structural and consistent writing instruction in courses of the four science curricula, which was in accordance with other comparable (inter)national higher education settings. The findings pointed to little agreements about guidelines for writing support and assessment among faculty members. Based on these findings, we noted that there is little consistency in the way students are supported in their writing throughout their studies. According to the faculty members it is hard to realize writing instruction in their teaching due to curricula that are full of teaching subject content and lack instruction time. Some faculty members thought that language experts in a writing center should have the responsibility for writing instruction. Some others assigned secondary education as the place where students should have learned writing prior to attending university. Our findings showed that the level of undergraduate students' writing is very diverse. There are students with

excellent writing abilities as well as students with unsatisfactory writing abilities. Besides, students' writing frequencies (the number of texts they write) vary between the degree programs and between individual students. Students experience different difficulties in writing, mostly with text structure, scientific language use, and argument construction. Therefore, we analyzed 10 bachelor theses to gain more detailed insight into undergraduate students' written argument construction. The argument analysis showed that the students' theses do contain an argument, but that some did not offer a strong justification or did not present the gist without abundant information. Based on the above findings, we emphasized the importance to pay more attention to undergraduates' writing and integrate writing instruction more structurally and consistently in the four examined science curricula.

Teaching strategy to promote students' written argument construction

The exploratory study was a stimulus to further examine how we can support science undergraduates' writing and faculty in providing writing instruction. Therefore, in the second phase of the research, we developed, implemented, and evaluated a research-based teaching strategy to promote students' written argument construction in two undergraduate science courses. The teaching strategy was developed using ideas from two perspectives: genre-based writing instruction and reading-writing connections.

The first perspective is genre-based writing instruction. This is a form of discipline-specific writing instruction and involves subject lecturers, which could offer support for undergraduate science students in learning to write discipline-specific scientific texts (genres) by focusing on the rhetorical demands. Central for genre-based writing instruction is an explicit instruction in genre characteristics of a text genre, for instance, by using text analysis tasks to explore a genre. In the teaching strategy we chose to focus on the research article genre and its argumentation and rhetorical genre characteristics. We were particularly concerned with the rhetorical structure. The rhetorical structure is defined as the arrangement of specific text fragments that together reflect an article's line of reasoning, which includes the argument. These text fragments, also called rhetorical moves, perform a specific rhetorical function in the text, like an objective, reflecting the researchers' goal. We used the Scientific Argumentation Model (SAM)²⁵ to introduce students to the rhetorical structure of research articles. SAM is a heuristic that was designed to support students' reading and understanding of a research article's argument. SAM consists of a set of seven rhetorical moves in a scheme, which is schematically presented in the next figure.

25 The SAM heuristic was developed by Van Lacum, Koeneman, Ossevoort, and Goedhart (2016).

Schematic presentation of SAM showing the line of reasoning in a research article. The line of reasoning starts with the study's motive (reason of the study) towards the main conclusion with implications, justified with supports and refuted counterarguments.

The second perspective draws from literature on reading-writing connections that suggests the beneficial effects of reading skills on writing skills, and vice versa. Therefore, we assumed that the research article genre with its argumentation and rhetorical genre characteristics could serve as a model to help students to construct a written argument by using SAM in reading and analysis tasks of research articles. Combining both perspectives, we formulated the following presupposition:

Use of authentic research articles with a focus on argumentation and rhetorical genre characteristics combined with reading and writing activities will contribute to students' written argument construction.

We evaluated the presupposition by developing a teaching strategy in which students were introduced to the rhetorical structure of research articles using SAM. Our main research purpose was to examine undergraduate science students' argument (re-)construction when participating in the teaching strategy. We implemented and evaluated the teaching strategy in two educational contexts. First, the teaching strategy was tested in a first-year physics course about biophysics with nine participating students. Next, we examined the teaching strategy in a molecular biology course for 21 first-year students. The teaching strategy in both courses consisted of weekly lectures about research articles' rhetorical structure using SAM and methods and concepts from various research articles. After each lecture students made an individual text analysis task in which they identified moves in authentic, non-adapted research articles. In group meetings the students shared and discussed the tasks and articles together with the course lecturer. In both courses the students were assigned a writing task. The physics students summarized a research article prior to and at the end of the course. In the biology course the students wrote a brief literature review of two research articles near the end of the course. These students' texts served

as an important data source to examine whether the students reconstructed (in a summary) or constructed (in a review) an argument based on the research articles' content. The texts were analyzed from a genre analytic perspective to identify and interpret various text fragments. We also analyzed the texts on the use of specific scientific language (metadiscourse). This language use can be used to construct an argument. For instance, qualifiers are words that indicate the (un)certainly of a claim, like 'suggest' or 'prove'. We interviewed the students and administered a questionnaire to examine their reading and writing experiences and use of SAM. We also interviewed the biology course lecturers to give another perspective on the teaching strategy and its effects on students' reading and writing.

Based on the findings from both studies, we first showed that the students generally understood the research articles' content. Here, the group meetings played an indispensable role. Second, we showed that SAM helped the students to understand, select, and organize research articles' content for writing their texts. SAM was also useful for the course lecturers in discussing research articles with the students and assessing students' texts. Third, from the text analyses it became clear that the students identified and presented most of the rhetorical moves important for the articles' arguments (objective, almost all supports, and the main conclusion) in their texts. Some of the moves were harder to identify for the students. For instance, counterarguments are often hidden in the article's text and require expert knowledge to localize. Fourth, the physics students reconstructed the article's argument almost completely and correctly in their summaries. The interview findings showed that the students were more aware of using moves in their writing of texts. However, we need to be cautious in concluding that the teaching strategy improved students' summary writing. Most students performed well prior to the course in reconstructing an article's argument. This finding could be explained by the occurrence of a ceiling effect or the difference in difficulty level of the used research articles. Although writing a review was a difficult task, most of the biology students made a synthesis in their review by combining content and moves from the articles. The metadiscourse findings suggested that the students from both courses did use this specific language in their texts, but not frequently and sometimes in an inadequate way.

All findings together showed the practicality of the teaching strategy in two different courses to support students' written argument construction and supported our presupposition. Reading and analyzing of research articles helped the students to a certain extent in writing texts based on research articles. SAM served as a reading and writing heuristic in this process.

Relationship between scientific epistemologies and students' writing

In a final follow-up study, we examined more in detail students' writing about research articles in relation to their scientific epistemologies to get more insight into their

writing. Scientific epistemologies are students' views about the nature of scientific knowledge and its construction. A traditional view approaches scientific knowledge as being absolute without any influence of scientists' ideas and opinions. More modern views consider scientific knowledge as a product about which multiple perspectives might coexist and that develops in discourse between scientists. It is assumed that someone with modern views will be more critical in the evaluation of research articles and will probably make a thoughtful consideration of the presented information to draw a conclusion. Prior research so far showed contrasting findings about the effects of students' scientific epistemologies on their writing. Therefore, we investigated biology students' evaluation of and writing about research articles in relation to their scientific epistemologies. We analyzed the students' reviews collected in the biology course on the presence and presentation of moves and on evaluative statements. We used a questionnaire to elucidate students' views on scientific knowledge and its construction. The findings showed that we could distinguish two groups of students. A group of 10 students selected mainly modern views and a group of six students had mainly traditional views. The other five students selected a high diversity of views and could not be distinctly classified in one of the two groups. In contrast with what we expected, the findings did not show a clear relationship between students' scientific epistemologies and their evaluation of research articles and their argument construction. The group of students with modern views made more use of qualifiers in their conclusion to indicate the extent of (un)certainly. They also evaluated the articles more frequently compared to the group of students with the traditional views. However, the students with modern views were not more critical in presenting weaknesses of the articles. Due to these small differences we concluded that there was not a direct relation between students' scientific epistemologies and their reviews.

Working towards a science curriculum with attention to scientific writing

This thesis showed that scientific writing deserves more attention in science undergraduate programs. We integrated a teaching strategy using a genre-based writing instruction combined with reading and writing activities in two existing science courses. We also provided guidelines for faculty members and curriculum developers to apply and develop the teaching strategy and to give writing a prominent position in undergraduate science curricula. We hope that our research will give a boost giving scientific writing a central place in science curricula in order to train students for a science-oriented career.

SAMENVATTING

Schrijven is een onmisbaar onderdeel in de uitoefening van wetenschap. Daarom is het van belang dat bachelorstudenten die starten met een bètaopleiding, zoals biologie of scheikunde, goede schrijfvaardigheden ontwikkelen en een goed begrip krijgen van de verschillende wetenschappelijke tekstgenres. Het belangrijkste tekstgenre binnen de wetenschap is het onderzoeksartikel. Hierin worden de meest recente onderzoeksresultaten gedeeld met de internationale wetenschappelijke gemeenschap. Een belangrijk onderdeel bij het schrijven van een onderzoeksartikel is het construeren van een argumentatie: een onderbouwing van een conclusie met onderzoeksdata. In de onderwijspraktijk blijkt wetenschappelijk schrijven een uitdaging te zijn voor veel bachelorstudenten. Studenten ondervinden moeilijkheden bij het construeren van een argumentatie of bij het schrijven van een uitgebreide tekst, zoals een bachelorscriptie. Structureel schrijfonderwijs blijkt volgens de literatuur geen gemeengoed in veel bachelorprogramma's van bètaopleidingen in Europese hoger onderwijsinstellingen, waaronder Nederlandse universiteiten. Om deze redenen zijn we het onderzoek gestart dat in dit proefschrift wordt gepresenteerd. Het doel van het onderzoek in dit proefschrift is om na te gaan op welke manier we bètastudenten kunnen ondersteunen in de ontwikkeling van hun wetenschappelijke schrijfvaardigheden, specifiek gericht op het construeren van een argumentatie. Het onderzoek werd uitgevoerd binnen de bètafaculteit van de Rijksuniversiteit Groningen. We kozen voor *design research* als overkoepelende onderzoeksaanpak. Deze aanpak stelde ons in staat om systematisch in verschillende fasen toe te werken naar een onderwijsstrategie om het schrijven van wetenschappelijke teksten door eerstejaarsstudenten te bevorderen.

Schrijfpraktijken in vier bètaopleidingen

In een vooronderzoek onderzochten we de huidige stand van zaken rondom schrijfonderwijs en schrijfvaardigheden van studenten in de faculteit *Science and Engineering* van de Rijksuniversiteit Groningen. We interviewden zestien docenten uit vier bachelorprogramma's, namelijk sterrenkunde, biologie, scheikunde en natuurkunde. We verkenden enerzijds de ervaringen van de docenten met het geven van schrijfonderwijs en met schrijfvaardigheden van studenten. Anderzijds onderzochten we hun opvattingen over goed schrijfonderwijs en hun verwachtingen van het te realiseren schrijfniveau van studenten. De resultaten lieten zien dat de docenten de noodzaak erkenden om studenten in de bachelorprogramma's goed schrijfonderwijs aan te bieden. Echter, het bleek ook dat er weinig structureel en samenhangend schrijfonderwijs aanwezig was in de opleidingen. Deze situatie bleek vergelijkbaar met andere (inter)nationale onderwijscontexten. Daarnaast was er weinig onderlinge afstemming tussen docenten over richtlijnen voor schrijfondersteuning en -beoordeling. Op basis van deze resultaten constateerden we dat er weinig samenhang lijkt te zijn in de manier waarop studenten kunnen werken aan hun schrijfvaardigheden

in de bachelorprogramma's. Volgens veel van de docenten is schrijfonderwijs ook lastig te geven in de overvolle curricula met een gebrek aan onderwijstijd. Sommige docenten legden de verantwoordelijkheid voor schrijfonderwijs bij taaldocenten in een schrijfcentrum. Weer anderen vonden dat het voortgezet onderwijs juist de taak heeft om studenten met goede schrijfvaardigheden af te leveren aan de universiteit. Studenten bleken een wisselende taalbagage te hebben. Er zijn studenten met zowel uitstekende als met onvoldoende schrijfvaardigheden. Uit de interviews bleek de hoeveelheid teksten die studenten gedurende hun studie schrijven wisselend te zijn met verschillen tussen de opleidingen en tussen individuele studenten. Volgens de docenten leverden het structureren van teksten, het gebruiken van wetenschappelijke taal en het construeren van een argumentatie de meeste problemen op voor studenten. We hebben daarom tien bachelorscripties geanalyseerd om meer inzicht te verkrijgen in de vaardigheden van studenten biologie en natuurkunde om een argumentatie op te zetten in hun bachelorscripties. Uit deze analyse bleek dat de studenten een argumentatie hadden opgebouwd, maar dat een aantal tekortschoot in het geven van een sterke onderbouwing of de tekst overspoelden met onnodige informatie. Op basis van bovenstaande bevindingen benadrukten we de noodzaak om meer aandacht te besteden aan schrijfvaardigheden van bachelorstudenten in de vier bètaopleidingen en structureel en consistent schrijfonderwijs in te bedden.

Onderwijsstrategie om argumentatie in teksten van studenten te bevorderen

Het vooronderzoek heeft ons verder aangezet om te onderzoeken hoe we studenten kunnen ondersteunen en schrijfonderwijs vorm kunnen geven. In de tweede fase van het onderzoek hebben we daarom een onderwijsstrategie ontwikkeld, geïmplementeerd en geëvalueerd in twee verschillende cursussen uit het natuurkunde- en uit het biologiecurriculum. Deze onderwijsstrategie had als doel om de kwaliteit van de argumentatie van studenten te bevorderen. We gebruikten hiervoor ideeën vanuit twee perspectieven: genredidactiek en de connectie tussen lees- en schrijfvaardigheden.

Het eerste perspectief is genredidactiek, een vorm van schrijfonderwijs die geïntegreerd kan worden binnen een specifieke discipline, waarbij docenten van vakspecifieke cursussen betrokken worden. Genredidactiek legt de nadruk op de retorische eisen die nodig zijn voor het schrijven van een bepaalde vakspecifieke tekst (een genre). Studenten analyseren en vergelijken teksten op hun tekstenkenmerken om een bepaald genre te leren kennen. Voor onze onderwijsstrategie hebben we gekozen voor het onderzoeksartikel als genre met de daarbij behorende argumentatie en retorische genrekenmerken. We besloten ons vooral te richten op de retorische structuur. De retorische structuur in een onderzoeksartikel wordt gedefinieerd als de combinatie van specifieke tekstfragmenten in de tekst die samen de redeneerlijn vormen. Binnen deze redeneerlijn valt ook de argumentatie, zoals wij die opvatten als de onderbouwing van een conclusie met data. De tekstfragmenten, ook wel

retorische *moves* genoemd, vervullen een specifieke retorische functie in de tekst, zoals een doelstelling die weergeeft wat de onderzoekers willen weten. We gebruikten het *Scientific Argumentation Model (SAM)*²⁶ om studenten te introduceren in de retorische structuur van onderzoeks-artikelen. SAM is een heuristiek die is ontworpen om studenten te helpen bij het lezen en begrijpen van de argumentatie in onderzoeksartikelen. SAM bestaat uit een set van zeven retorische *moves* en een schematische weergave, die in onderstaande afbeelding wordt gepresenteerd.

Schematische weergave van SAM, waarmee de redeneringslijn van een artikel wordt getoond. De redeneringslijn start bij het motief van het onderzoek (het ‘waarom’) en eindigt bij de hoofdconclusie met implicaties, ondersteund door meerdere onderbouwingen en weerlegde tegenargumenten.

Het tweede perspectief dat we gebruikten voor de onderwijsstrategie is afkomstig van literatuur over de connectie tussen lees- en schrijfvaardigheden. Deze twee vaardigheden lijken voordelige effecten op elkaar te hebben: het lezen van een specifiek genre versterkt het schrijven ervan en andersom. We verwachtten daarom dat het onderzoeksartikelgenre met zijn argumentatie en retorische kenmerken als een model kan dienen voor bètastudenten om een argumentatie te construeren door lees- en analysetaken uit te voeren met behulp van SAM. De twee perspectieven hebben we samengebracht in een hypothese:

Het gebruik van authentieke onderzoeksartikelen gericht op de argumentatie en retorische genrekenmerken gecombineerd met lees- en schrijfactiviteiten zal bijdragen aan het construeren van een geschreven argumentatie door studenten.

De vooronderstelling hebben we vervolgens geëvalueerd door op basis hiervan een onderwijsstrategie te ontwikkelen en te implementeren in twee verschillende

26 SAM werd ontwikkeld door Van Lacum, Koeneman, Ossevoort en Goedhart (2016).

contexten. Eerst in een eerstejaars natuurkundecursus over biofysica met negen deelnemende studenten en daarna in een moleculaire biologiecursus voor 21 eerstejaarsstudenten. Het doel was om de (re)constructie van de argumentatie door studenten te onderzoeken wanneer ze deelnamen aan de cursussen. In beide cursussen werden de studenten in wekelijkse hoorcolleges geïntroduceerd in de retorische structuur van onderzoeksartikelen met behulp van SAM en in de methodes en vakspecifieke concepten uit verschillende onderzoeksartikelen. Na elk college kregen studenten een tekstanalyse-opdracht, waarbij ze de *moves* uit authentieke, niet-aangepaste onderzoeksartikelen moesten identificeren. De studenten discussieerden samen met de docent over de opdrachten en artikelen in groepsbijeenkomsten. In de cursussen stond een schrijfopdracht centraal. De natuurkundestudenten schreven een samenvatting van een onderzoeksartikel voorafgaand aan en na afloop van de cursus. In de biologiecursus schreven de studenten een kort literatuuronderzoek (*review*) op basis van twee onderzoeksartikelen tegen het eind van de cursus. Deze schrijfopdrachten waren een belangrijke databron, waarmee we konden analyseren op welke manier de studenten een argumentatie van een onderzoeksartikel reconstrueerden (in een samenvatting) en een argumentatie op basis van twee artikelen construeerden (in een review). We hebben alle teksten geanalyseerd vanuit een genre analytisch perspectief, waarmee verschillende tekstfragmenten konden worden geïdentificeerd en geïnterpreteerd. Daarnaast analyseerden we de teksten op het gebruik van specifiek wetenschappelijk taalgebruik (*metadiscourse*). Dit taalgebruik kan een schrijver helpen om een argumentatie kracht bij te zetten. Een voorbeeld zijn *qualifiers*, woorden, zoals ‘suggereren’ en ‘bewijzen’, die de mate van (on)zekerheid van een bewering weergeven. Om de lees- en schrijfervaringen van de studenten te verkennen, hebben we studenten geïnterviewd en een vragenlijst uitgezet. We hebben de docenten uit de biologiecursus geïnterviewd om vanuit een ander perspectief inzicht te krijgen in de uitvoering en effecten van de onderwijsstrategie.

De resultaten lieten ten eerste zien dat de studenten in beide studies over het algemeen een goed begrip hadden van de onderzoeksartikelen, waarin de groepsbijeenkomsten een grote rol speelden. Ten tweede stelden we vast dat SAM de studenten bleek te helpen bij het begrijpen, het selecteren en het organiseren van de informatie uit onderzoeksartikelen voor hun teksten. Daarnaast hielp SAM de docenten in de uitvoering van de discussies over de onderzoeksartikelen en in de beoordeling van de schrijfopdrachten. Ten derde lieten de tekstanalyses duidelijk zien dat de studenten de meeste retorische *moves* die deel uitmaakten van de argumentatie (doelstelling, bijna alle onderbouwingen en de hoofdconclusie) uit de artikelen hadden geïdentificeerd en gepresenteerd in hun samenvatting of review. Uit de interviews en de vragenlijst werd duidelijk dat de sommige *moves* lastiger te identificeren waren. Tegenargumenten zijn bijvoorbeeld vaker verstopt in de tekst waarvoor gedetailleerde vakkennis nodig is om ze te lokaliseren. Ten vierde zagen we dat de natuurkundestudenten de argumentatie uit de artikelen bijna compleet en

correct hadden gereconstrueerd in hun samenvatting. Uit de interviews werd duidelijk dat de studenten ook meer bewust waren om *moves* te verwerken in hun tekst. We moeten hier echter voorzichtig zijn om te concluderen dat de onderwijsstrategie heeft gezorgd voor betere samenvattingen. Uit de analyses bleek namelijk dat de studenten in de samenvatting vooraf aan de onderwijsstrategie ook al een goede reconstructie hadden gemaakt. Er kan sprake zijn van een zogenaamd plafondeffect of het verschil in moeilijkheidsgraad van de artikelen kan een effect hebben gehad. De meerderheid van de biologiestudenten maakte een synthese in hun review door de inhoud en *moves* van de twee artikelen met elkaar te verbinden, ondanks dat het als een moeilijke opdracht werd ervaren. Uit de analyse van de *metadiscourse* concludeerden we voorzichtig dat de studenten uit beide cursussen er zeker gebruik van maakten, maar niet in hoge mate en niet altijd op een adequate manier.

De bovenstaande resultaten lieten de uitvoerbaarheid zien van de onderwijsstrategie in twee verschillende cursussen. We concludeerden dat daarmee de onderliggende vooronderstelling ondersteund wordt: het lezen en analyseren van onderzoeksartikelen hielp de studenten in zekere mate bij het schrijven van teksten op basis van onderzoeksartikelen, waarbij SAM diende als een lees- en schrijfhuristik en waarmee de constructie van de argumentatie door studenten kan worden ondersteund.

Scientific epistemologies in relatie tot het schrijven van teksten

In een vervolgonderzoek keken we naar de wetenschappelijke epistemologische opvattingen (*scientific epistemologies*) van studenten in relatie tot hun geschreven teksten om meer zicht te krijgen op hun schrijfproces tijdens de onderwijsstrategie. Deze opvattingen hebben betrekking op hoe studenten denken over de aard van wetenschappelijke kennis en de ontwikkeling daarvan. Traditionele opvattingen beschouwen wetenschappelijke kennis als absoluut, dat wil zeggen dat die niet wordt beïnvloed door de opvattingen van wetenschappers. Moderne opvattingen beschouwen wetenschappelijke kennis juist als een product waarover meerdere perspectieven tegelijkertijd kunnen bestaan en dat ontstaat in samenspraak tussen wetenschappers. Onze hypothese was dat studenten met deze moderne opvattingen eerder een kritische houding zullen aannemen bij het evalueren van onderzoeksartikelen en op een weloverwogen manier informatie zullen afwegen om daaruit een conclusie te trekken. Voorgaand onderzoek had tot dusver tegenstrijdige resultaten laten zien over de effecten van *scientific epistemologies* van studenten op het schrijven van een wetenschappelijke tekst. We onderzochten daarom hoe de *scientific epistemologies* van de biologiestudenten van invloed waren op het evalueren van en schrijven over onderzoeksartikelen. Voor dit doel analyseerden we de reviews, verzameld in de biologiecursus, op de aanwezigheid en presentatie van de *moves* uit de onderzoeksartikelen en de evaluatie daarvan. Met een vragenlijst bepaalden we de *scientific epistemologies* van de studenten. Uit de analyse van de vragenlijst bleken we

grofweg twee groepen studenten te kunnen indelen naar hun opvattingen: een groep van tien studenten met voornamelijk moderne opvattingen en een tweede groep van zes studenten met traditionele standpunten. De overige vijf studenten konden niet duidelijk worden ingedeeld door de hoge variatie aan reacties van de studenten. In tegenstelling tot wat we verwachtten konden we geen duidelijke relatie leggen tussen de *scientific epistemologies* van studenten en de manier waarop de studenten de artikelen evalueerden en een argumentatie construeerden. De 'moderne' groep maakte iets meer gebruik van *qualifiers* in hun conclusies om de mate van (on) zekerheid aan te geven. Hoewel ze de artikelen iets vaker evalueerden waren ze niet kritischer door meer zwakkere aspecten in de artikelen aan te wijzen in vergelijking met de traditionele studentengroep. Deze verschillen waren echter klein en op basis hiervan concludeerden we dat er geen duidelijke relatie was aan te wijzen tussen de *scientific epistemologies* van de studenten en hun reviews.

Op naar een bètacurriculum met aandacht voor wetenschappelijk schrijven

Met de vier studies uit dit proefschrift hebben we laten zien dat wetenschappelijk schrijven van bachelorstudenten in bètaopleidingen meer aandacht verdient en dat met een specifieke onderwijsstrategie een begin kan worden gemaakt om schrijfonderwijs te integreren in een bestaand curriculum. Op basis van ons onderzoek hebben we voor docenten en onderwijsontwikkelaars een aantal richtlijnen opgesteld om de onderwijsstrategie toe te passen en verder te ontwikkelen en om schrijfonderwijs te integreren in de opleidingen. Hiermee hopen we een impuls te geven om schrijfonderwijs deel te laten uitmaken van bètaopleidingen en daarmee studenten klaar te stomen voor een wetenschappelijk georiënteerde carrière.

DANKWOORD

DANKWOORD

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CURRICULUM VITAE

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Currently, she is working as a youth librarian at the public library in Amersfoort (de Bibliotheek Eemland). Together with the education team she develops activities and learning material to promote children's reading pleasure and reading skills.