Brian Hand · Mark McDermott
Vaughan Prain *Editors*

Using Multimodal Representations to Support Learning in the Science Classroom

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Chapter 1
Learning Science Through Learning to Use Its Languages

Vaughan Prain and Brian Hand

Focusing on the Medium of Science Learning

Over the last 30 years science education researchers have focused intensively on the role of language, and increasingly the languages of science, to understand how to deepen student engagement and learning in this subject. The medium for learning as well as the content has been foregrounded in this agenda. Partly this focus was prompted by Lemke's (1990) ground-breaking work on the key role of classroom talk in this learning, and the growing recognition that students in learning science had to learn a new literacy that underpinned and characterised scientific realities (Moje 2007). Partly this focus on richer pedagogy also arose from recognition that more effective teaching and learning practices were needed to address continuing widespread student lack of quality performance and sustained interest in this subject (Osborne and Dillon 2008; Weinburgh 1995). This led to an increased focus on researching the role of talk and writing as crucial epistemological tools for science learning (Halliday and Martin 1993; Prain and Hand 1996; Rivard and Straw 2000; Yore et al. 2003).

In this book we present a current international snapshot of classroom-based research on the role of language (and more broadly the languages of science, incorporating multi-modal texts with linguistic, visual and mathematical modes) in learning in this subject. Our intention is to highlight the diverse, generative classroom practices and challenges arising from this broad agenda. We also note the range of research methods used to track and analyse these new practices. Rather than provide a brief summary of the content of contributors' chapters, we overview

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the emergence of this agenda, its theoretical underpinnings, key recurrent pedagogical and research questions posed by this agenda, accounts of learning processes and learner capabilities, and the research methods used to analyse this learning. In noting these themes we outline the degree of convergence and diversity across contributor perspectives.

Early Focus on Writing

This research over the last three decades has sought to (a) identify what is or might be known and learnt by students through writing in science, and (b) explain how, and under what conditions, this writing promoted learning. In the 1990s two dominant accounts of the role of writing as a learning tool guided this research. The genrist approach (see Halliday and Martin 1993; Veel 1997), drawing on cognitive processing theories (Johnson-Laird 1983) assumed that language organized and represented thought, and that students needed to be inducted into science language practices. In this way, generic knowledge of the form/function of science texts, once internalised by students, "provides the basis for a new disciplined way of seeing and thinking" (Bazerman 2007, p. 8). From this perspective, knowing and reasoning in science depended on students' acquisition of subject-specific writing skills, evident in the writing practices of scientists (Halliday and Martin 1993). By contrast, advocates of a "learning through writing" approach (Sutton 1992; Hand and Prain 1995; Rowell 1997), claimed that to acquire the new literacies of science, students needed to write in diverse ways for different readerships to clarify understandings for themselves and others.

Both perspectives assumed that writing operated as a key epistemological tool for learning, in that drafting and revising processes enabled students to build and review links between classroom activities, conceptual understandings, and their expression. Both perspectives assumed that writing in science was fundamentally about disciplinary reasoning in this subject. The genrist approach emphasized the necessity of fidelity to disciplinary norms of expression for learning to occur, whereas the writing-to-learn approach stressed personal meaning-making through links to natural language and everyday communicative contexts. Both claimed that classroom research using these approaches aligned with the knowledge-production and representational practices of scientists. The genrists focused on representational norms, but this priority left open the question of how student would move from spectators of other people's reasoning to scientific reasoners themselves. The "learning through writing" researchers tended to focus on the need for students to experience first hand the creative reasoning that underpins the production of new knowledge by scientists. However, this left open the question of how and in what ways students would acquire an understanding of how to use experimentation and the symbolic systems of science (vocabulary, graphs, tables, diagrams) to reason persuasively in this subject. Both sides saw that students needed to be active meaning-makers rather than simply meaning-receivers, but differed about what exact learning experiences were to be prioritized to achieve this end.

Genrist Research

The genrist viewpoint assumes that the languages of science are broadly a stable, denotative, representational system that must be learnt in order for students to demonstrate science literacy. According to Martin (2000), Veel (1997), and others, students will learn effectively the rules and meanings of the particular language practices of science through the following teaching strategies: detailed analysis of linguistic features of textual examples; joint construction of genres with their teacher; and through an explicit extensive teacher focus on key textual function/form relationships and their rationale. In other words, researchers within this orientation favour a highly directed, explicit teacher-focused pedagogy that emphasizes the functional aspects of language features of this discourse. Classroom research based on this perspective has largely taken the form of case studies of reputed desirable or exemplary implementation (Martin 2000; Martin and Rothery 1986; Scheppegrell 1998; Unsworth 2001). While this research has established increasingly complex accounts of the tasks learners face in understanding and mastering specific multimodal genres, these studies have not assessed contrasting treatments, and have therefore not established a case for greater learning gains for this approach over others. The evolving nature of functional dimensions of web-based science texts has further complicated genrist attempts to move beyond descriptive accounts of texts to meta-functional principles and workable classroom practices.

Writing to Learn Science Research

Researchers within this perspective, such as Levin and Wagner (2006), Hand and Keys (1999), Rivard and Straw (2000), Rowell (1997), Wallace et al. (2004), and others, assert that students, in striving to clarify networks of concepts in science topics, should be encouraged to write in diverse forms for different purposes. Descriptive studies where diversified science writing tasks have been used have reported positive effects on students' attitudes towards, and engagement with, the subject (Prain and Hand 1996). Comparative studies of contrasting treatments have been conducted by Hand and his colleagues around diversified writing types, including the use of a framework called the Science Writing Heuristic (Keys et al. 1999; Hand and Keys 1999; Hand 2007). This framework of a modified laboratory report leads students through a reiterative process of knowledge construction in science through making and justifying claims, gathering and representing evidence, and reflecting on the progression of ideas. Gunel, Hand, and Prain (2007) noted that using writing-to-learn strategies was advantageous for students compared to those students working with more traditional science writing approaches. In another study Gunel et al. (2004) reported that students' performance in answering higher order cognitive questions was enhanced when students used a modified writing genre, when contrasted with student use of the traditional laboratory report, although the teacher's implementation strategies were viewed as a major factor in this outcome. The researchers claimed that writing serves learning when (a) writing tasks are designed to require students to focus on conceptual understanding, and also require students to elaborate and justify these understandings of the topic; (b) the target readership is meaningful for the students, (c) students are provided with sufficient planning support, and (d) planning activities engage students in purposeful backward and forward search of their emerging texts.

Writing Within Multiple Modes of Representation in Science

Parallel to this research on writing, there has been growing recognition of modal interdependence in science knowledge production and in interpreting and constructing science texts, with an increasing emphasis on visual modes. As noted by Wise (2006, p. 75), much of the history of science has been about "making new things visible, or familiar things visible in new ways", where images "form both what and how we know" (p. 82). In applying this focus on multimodality to the classroom, Lemke (2004, p. 41) pointed out that students needed to "integrate multiple media simultaneously to reinterpret and recontextualize information in one channel in relation to that in the other channels". Students have to translate, integrate and reinterpret meanings across verbal, visual and mathematical expressions, as well as connect these modes to earlier experiences of science activity. This is evident when students interpret the individual and relational meanings between a diagram, an accompanying text, and its referents in the world. Equally, students participate in similar processes when they construct their own text to clarify or elaborate on the meaning of an accompanying graph, photograph or diagram. For Lemke (2004, p. 2), writing's forte is its capacity to enable "reasoning about relations among categories" because it operates primarily by categorical contrasts and exclusions. Quantitative meanings such as rates and angles of change, and alterations to shape and motion, are more suited to visual and mathematical representation. In this way, Lemke argued that science is necessarily about reasoning across interdependent modes of measurement and explanation. He further argued that the use of natural language, and by implication writing, enabled links to be made between qualitative observation and linguistic reasoning about verbal categories, concepts, and their justification.

However, in the messy world of the classroom there are often significant challenges students face to achieve shared well-founded understandings of target concepts and scientific reasoning processes and resources. In commenting on the epistemological role of language, and by implication writing in learning, Anderberg, Svensson, Anderberg et al. (2008) argued for the dynamic and ambiguous character of the relations between students' meanings, conceptions and expressions. They noted that reproducing disciplinary language does not ensure disciplinary understanding, and that students' intended meaning for an expression is often arbitrary, associative and contextual rather than convention-dependent. Anderberg et al. (2008) asserted that for language to serve learning students must reflect explicitly on the adequacy of the links they are making between intended meanings, conceptions, and different or diverse expressions. These researchers further noted that this use of language as a knowledge-constituting activity is a developmental recursive process. Students need to reflect on the ways they change or develop intended meanings, and to recognize the same meaning across different contexts, different conceptions, and different expressions and modes. These researchers further asserted that students are likely to proceed through a sequence of understandings that starts with isolated local lexical meanings, and superficial relationships between meaning and expression, and develops into more holistic, integrated linkages between concepts, their expression and their referents. By implication, the capacity for student writing to function as an epistemological tool depends on the robustness and coherence of these links. More broadly, the capacity for students to reason multi-modally, to make links between concepts, practical experiences, and their re-representation in writing and other modes, also depends on these linkages. However, what is relatively easy to theorize presents significant challenges in classroom practice.

Chapter contributors in this book draw on this broad mix of theoretical perspectives and diverse foundational starting points to research classroom practices that seek to promote student multimodal reasoning. Some contributors build on insights from genrist perspectives on writing requirements (see Tang and Ho, Tolppanen et al.), while others draw more on sociocultural accounts of learning as context-dependent induction into particular roles and purposes as science learners (see Linebarger and Norton-Meier, Tytler and Hubber, Carolan). There is convergence around the need for teachers to induct students into the mix of visual, verbal and mathematical resources that are the purpose-built tools for claim-making in science texts. While acknowledging the necessary interdependence of modes for students to make convincing claims in these texts, contributors generally assume that talk and writing are the superordinate modes to generate, judge and organize meaning-making in the classroom. They argue that other modes need to be integrated with (or embedded within) written texts, raising complex practical challenges around effective teaching and learning tasks and sequences. As noted by Gunel and colleagues (Chap. 4), Nam and Cho (Chap. 7), Simon (Chap. 2), Tolppanen and colleagues (Chap. 3), and Villaneuva (Chap. 5), in learning about any science topic, students necessarily need to understand the form/function of different modes, and be able to integrate/embed these modes into a coherent multimodal case to make convincing claims. By implication, the meanings students attribute to their writing depend on the meanings they construct from other modes and their capacity to integrate these meanings with their writing.

Explaining Multimodal Reasoning and Learning in Science Classrooms

Our contributors tend to draw on multi-theoretic lenses to guide and justify their approaches to interpreting student reasoning and learning gains from interpreting and constructing multimodal science texts. These lenses include cognitivist perspectives, where learning is broadly understood as guided problem-solving mental work by individuals and groups to come to know and apply scientific concepts, methods and processes (see McDermott and Hand; Carolan; Nam and Ho; Gunel et al.; Tytler and Hubber). Many contributors also draw on Lemke's (2004) socio-semiotic perspective, where learning is understood as induction into the purposes, affordances and opportunities of the multiple sign systems of science, using everyday language and the domain-specific languages of science to make sense of classroom scientific activities/explanations over time (see Gunel et al.; Tytler and Huber; Carolan; Tang et al.). Tang and colleagues further draw on structural functional linguistics to characterise the complexity of the learning tasks facing students as they re-represent experiences, data, concepts, and processes across modes to integrate/construct scientific accounts of phenomena.

There is broad agreement amongst contributors that students are likely to learn this multimodal disciplinary literacy through purposeful guided immersion in these meaning-making practices. However, this raises further questions about what kind of immersion, what roles and tasks for learners and teachers, are productive and manageable when students' practice inevitably precedes competence in acquiring this new literacy. Our contributors broadly agree that quality learning is enabled when students (a) are motivated to represent and justify causal claims about topics, (b) have multiple opportunities to re-represent, translate, justify and refine understandings through processes of experimentation, collaborative peer learning, consultation, and teacher-guided consensus around representational adequacy, (c) come to understand the form/function of different visual, verbal and mathematical scientific representations, and (d) can integrate these modes to interpret and create convincing textual claims in this subject.

However, this agreement about macro conditions for quality science learning raises further questions about how to optimise student success at the micro level of learning about particular topics. This micro level focus includes teacher choices around key concepts in topics, effective task challenges, sequences and learning experiences, the relationships between classroom activities and their representation, and the choice of representations to be considered and integrated. Other issues include the timing and amount of explicit teaching of form/function relationships in scientific representations. Should a toolkit of representational options be taught first rather than learnt in use (or as needed) on particular topics? Does this depend on the topic and/or the age of the students? Are there general principles or conditions that apply to all student learning about how to engage successfully in multi-modal reasoning in science? By contrast, are different strategies required for different age groups depending on likely student capabilities and background knowledge and representational resources? What learning tasks or task sequences will enable students to understand why and how to integrate modes to practice scientific reasoning? How can learners be encouraged to take up the perspective of an ideas-tester, a creative problem-solver, a multi-modal reasoner about phenomena, rather than a bystander at received, proven "solutions" of others? How should teachers understand and enact their roles to put students on a productive epistemological footing? What are appropriate methods and modes to assess this complex disciplinary literacy learning?

Needless to say, our contributors provide varied and sometimes partial answers to these questions, but they all capture the excitement of grappling with these issues, and are optimistic about the potential value of this agenda. In the rest of this chapter we review some key recurrent research questions that they address.

Recurrent Questions

One major question revolves around how the mode of writing could or should relate to other modes, and identifying conditions that optimize effective multimodal learning. Chapter contributors generally concur with Gunel and colleagues (Chap. 4) that writing is "a powerful tool for the construction of scientific knowledge", provided this writing functions to constitute new student knowledge and is complemented by, or integrated with other modes. As proposed by Tolppanen and colleagues (Chap. 3), writing is the dominant mode for representing understanding, supported by other modes such as tables, graphs and diagrams embedded in the text. These researchers claim that writing is a crucial resource for moving between modes, and clarifying the purposes and claims made by the other modes. Simon (Chap. 2), in reporting on Year 10 Austrian students' attempts to explain the roles of non-verbal modes in published expert accounts of science topics, argues that writing is the key structural building block of this multi-modality. In researching multi-modal construction of science understandings by very young students (grades 1–3), Linebarger and Norton-Meier (Chap. 6) note that verbal language provides the main foundation and organiser for this learning and meaning-making, even when these students often favour visual and gestural means to represent their emerging understandings. They claim that this verbal language is crucial for developing very young students' "representational flexibility". Villanueva (Chap. 5) points out that in the context of second language English learners in South Africa, teachers need to know how to negotiate between these learners' everyday language and the understandings implied in the authorized vocabulary and multimodality of science texts. For Nam and Cho (Chap. 7), Year 8 Korean students' written language is the crucial mode for developing and communicating science concepts, where this mode is necessarily supplemented by other modes.

Other contributors elaborate on the necessity of non-verbal modes in learning and communicating science concepts and claims. Tang and colleagues (Chap. 8) confirm the critical roles of talk and writing activities as organizers of science learning, but also claim these modes need to be holistically connected to other activities, such as physical manipulation of objects, experimentation, and student drawing of their explanatory claims. They emphasize that that teachers need to make explicit to students the key role of multimodal connections in developing and justifying any scientific explanation. This increased focus on the affordances of all the modes used in scientific explanations is also proposed by Carolan (Chap. 11), and Tytler and Hubber (Chap. 9). For Carolan, (Chap. 11) learners have to view all modes, including physical enactment as well as symbolic modes, as tools to enable them to be active constructors of possible scientific explanations. In this way, experience of the physical properties of beads can enable learners in grades 4 and 5 to construct a verbal and visual understanding of a particle model in the topic of change of state. For Tytler and Hubber (Chap. 9), students can use artifacts such as a mini-globe and LED torch to explore explanations of day and night cycle, seasons and eclipses, and thus come to understand the differences between geocentric and space-centric perspectives when describing and explaining astronomical phenomena. While guided teacher discussion is crucial to these learning gains, student 2D visual re-representation of their understanding, appropriately annotated, is also claimed to be critical to this learning.

Another recurrent question posed by contributors is the issue of which communicative tasks and representational challenges are likely to support students learning (a) the function of multiple modes in scientific texts, and (b) how to embed/integrate these modes to make persuasive claims in their own scientific texts. The contributors offer a range of procedures and task to achieve these learning outcomes. Some authors, such as Simon (Chap. 2), McDermott and Hand (Chap. 10), and Tolppanen and colleagues (Chap. 3), focus on the need for explicit student analyses of expert science texts to identify how authors use a range of cohesive ties to signal how modes are linked to develop a coherent claim or claims. These analyses are then expected to be the bases of student transfer to their own multimodal text production. Simon reports on how students in his study were supported to develop criteria for judging the effective use of modes in published texts, such as the use of illustrations, diagrams and graphs to attract reader attention, clarify processes, and persuade readers of the reliability of authorial claims and findings. McDermott and Hand (Chap. 10) designed a specific lesson to highlight strategies used to embed multiple modes of representation within writing tasks. Students were expected to generate a matrix for assessing science texts by how well different modes were integrated and the degree of cohesion of the text as a whole. Tolppanen and colleagues (Chap. 3) proposed a similar approach where three classes of Year 8 students in Finland were expected to analyse published science texts to develop criteria to assess the value of different modes in these texts, and then apply these criteria to generate an effective multi-modal text of their own. These criteria included the soundness of claims, logical ordering of modes, explicit cohesive verbal ties between modes, and where textual explanations were in close proximity to relevant non-verbal modes.

Other contributors, such as Carolan (Chap. 11) and Tytler and Hubber (Chap. 9), tend to focus on the need for students to be given tasks that entail a representational challenge, where students apply emerging understandings to make a multi-modal causal claim about some new aspect of the topic, or new context. In this representation construction approach, the students are expected to explain their representational choices, be guided by their teacher to judge the adequacy of their own and peer representations, and reach a class consensus about both (a) what counts as a persuasive claim in this topic, and (b) effective multi-modal representational choices to communicate this claim. This approach implies some flexibility about how teachers focus on form/function of modes, and options to achieve student understanding of how modes can be integrated through cohesive ties. For Carolan (Chap. 11), a key issue is how teachers frame what is required of students as participants in knowledge-making and knowledge-testing activities.

Our contributors also seek to encapsulate what enables students to learn and apply this new literacy to different topics and different levels of schooling. Variously they highlight the value of affordances in the tools and processes (see Tang and colleagues; Tytler and Hubber; Carolan), the necessity of re-representation and translation work across modes (see Tang, McDermott and Hand; Linebarger and Norton-Meier; Gunel and colleagues; Nam and Ho), appropriate fit of modes and task sequences to student capabilities (McDermott and Hand), and explicit instruction on how modal embeddedness and integration are achieved by expert science communicators (see McDermott and Hand; Tolppanen and colleagues; Simon; Villanueva). The chapters collectively point to the complexities entailed in achieving enhanced learning environments for learners of different ages engaging with different topics, and using different resources. Our contributors also draw on various research methods to track and analyse classroom processes and outcomes. These include quasi-experimental, pre-posttest design (see Gunel and colleagues; McDermott and Hand), tight track of learning sequences (see Tang and colleagues; Tolppanen and colleagues), multi-theoretic lens case study (Carolan) case studies (Linebarger and Norton-Meier; Simon; Tytler and Hubber), content analyses of relevant literature (Villaneuva), and content analyses of artefacts and contexts (see especially Tang and colleagues; Tytler and Hubber; Carolan).

We are excited by the insights and findings reported by our contributors as they take up this generative lead into quality learning in school science. We recognize that many questions raised by this agenda remain open-ended or in need of more extended examination. However, we present these studies as indicative of the promising scope entailed in this focus on the resources for meaning-making in this subject.

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Chapter 2
Writing Popular Scientific Articles, Development of Interest in the Natural Sciences, and Non-textual Representations in Student Texts: The "Young Science Journalism" Program in Austria

Uwe K. Simon

Interest in and Attitudes towards the Natural Sciences amongst High School Students

A typical student attitude toward science is that it is either too difficult to understand or boring and unrelated to real-life. Scientists in turn are often perceived as males with little social interaction with others. This prejudice is often encountered when talking to young people, and several studies show that many teenagers have little interest in the natural sciences, or even a negative attitude towards them (e.g. Krogh and Thomsen 2005; Osborne et al. 2009). In the European Union, one consequence of this attitude has been a lack of qualified graduates in science and technology to fill the existing need in the job market (e.g. Bundesagentur für Arbeit 2012; Gago et al. 2004). However, scientific topics seem to be viewed differently by male and female students. Comparing the figures for study choice of German A-level students, Holstermann and Bögeholz (2007) noticed that there was a significant sex-bias for specific subjects. Many more first year students in physics courses at the university level were male. This predominance of male interest was less noticed in chemistry, and biology was the most preferred of the three subject areas for females. A consistent finding was observed when students for each sex were asked to rank their preferences in these three science areas. The greatest number of males preferred physics, followed by chemistry and then biology, while this trend was exactly reversed in females (Holstermann and Bögeholz 2007).

Similar data were found for Austrian students (Statistik Austria 2012) (Table 2.1). However, it is interesting to note that almost twice as many female students compared to male students had enrolled in coursework to become chemistry teachers. One potential explanation for these figures could be the social aspects of

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Table 2.1 Number of first-year students in natural science-related subjects at Austrian universities in 2011

	Physics	Physics teacher studies	Technical physics	Chemistry	Chemistry teacher studies	Technical chemistry	Biology	Biology teacher studies	Biomedicine and biotechnology	Molecular biology
Male	211	39	315	213	27	152	468	84	4	129
Female	63	16	71	197	50	101	855	222	15	299
Sum	274	55	386	410	77	253	1323	306	19	428
% of all Austrian first year students	0.65	0.13	0.92	0.98	0.18	0.6	3.16	0.73	0.05	1.02

Source: Statistik Austria (2012)

teaching and the chance to combine job and family. All biology courses are female-dominated, even those focusing on molecular biology and biomedicine/biotechnology. This seems surprising, since these latter subjects are much more technology-oriented and require, at least in the second case, more physics than regular biology and findings from research in this area tend to indicate less preference for technology and physics courses by females. For instance, a report from Holstermann and Bögeholz (2007) found that Swedish, English and German female teenagers were much more interested in human biology and medical topics than males, while the latter preferred to know more about physics, technology and electronics than their female counterparts.

Overall, the number of students who enrolled in natural sciences in all Austrian universities in 2011 was rather low: 2892 out of 41,873, which is 6.9 % of all first-year students. At the same time, Austrian universities counted 3274 (7.8 %) first-degree students inscribed for law, 627 (1.5 %) for sociology, 825 (2.0 %) for business studies, 1355 (3.2 %) for pedagogy, 971 (2.3 %) for psychology, and 1241 (3.0 %) for German or German teacher studies. Thus, with the exception of biology, each of the natural science studies referred to in Table 2.1 was far less attractive than these other fields. However, job prospects, particularly in physics and chemistry are comparatively good, while they are less so in biology.[1] Clearly, the number of students interested in studying natural sciences is not meeting the demand for workers in these same areas, especially in the case of physics and chemistry.

Apart from economic concerns, future generations should be willing to engage in debates about significant societal issues such as nuclear vs. regenerative energy, the chemistry of synthetic products, biodiversity etc. To do so productively, students need to understand the related scientific concepts. In the words of Krapp and Prenzel (2011): "It is not only a question of gaining new blood in the field of science. Science concerns everybody – in both everyday and professional life" (p. 28). Finally, young people should be given the chance to discover science's inherent fascination. Yet all the above studies and figures indicate that there is urgent need to create a much more positive view about natural sciences amongst teenagers.

Science Communication: Writing About Science

Scientists often present their results in a written format. To be scientifically literate, students must understand the characteristics of written scientific discourse. This is even demanded in official school curricula (e.g. Austria: BMUKK 2008; Germany: KMK 2004). However, with the exception of documenting laboratory work writing

[1] Based on personal discussions with company and university representatives in all three subjects as well as on a rough screen of internet job offers in Austria: For example, there were 138 fulltime and permanent non-teacher positions open for biologists at http://www.careerjet.at, while there were 582 in physics and 533 in chemistry (in contrast to 314 in law) on October 21st, 2013. This means that with current figures and assumed that all first-year students will obtain their university degree almost every graduate from physics and chemistry, but only every 13th biology student and only every 10th law student will find a job broadly related to his/her studies in Austria.

is almost absent from school biology, chemistry or physics in many countries mainly because science teachers have not been trained for supervising writing in their courses (Leisen 2010). Accordingly, many of them do not feel adequately prepared to instruct and assess students in regard to written communication and many teachers do not consider this a part of their job. Yet beginning with 2015 every Austrian student who wants to pass A-levels will have to write a final thesis – and it might well be that some will want to do so in the natural sciences. This has created a situation in which there is pressure on teachers (and students) to make writing an integral part of final grades, but science teachers (and students) feel mostly unprepared to meet this challenge.

Writing to Interest Students in Natural Sciences: The *Young Science* Magazine

The previous passages clearly demonstrate the need to make studying the natural sciences at the university level more attractive to students, especially to females, and to create more situations to practice writing in science classes. Haste et al. (2008) have shown for 14 and 15 year-olds that females' interest in science was strongly linked to ethical considerations and to whether or not scientific issues were regarded as relevant to their lives. Therefore it seems that "offering a homogenous curriculum to all is a mistake – what interests females being unlikely to interest males and vice versa" (Osborne et al. 2009, p. 6). However, as long as co-education is the prevalent form of schooling in most countries, and as long as teachers are not specifically trained to identify issues related to and plan lessons according to sex-specific needs, teaching at school should relate to concepts that increase the likelihood that students of both sexes will become involved in biology, chemistry and physics to the same degree.

Yet students often encounter in their coursework science-related texts which are rarely interesting to read or even unintelligible to many (Sadoski 2001). This is especially true for chemistry and physics (Leisen 2010; Merzyn 1998a, b, c, 2010, 2013), less so for biology, and may be one possible factor explaining why chemistry and physics suffer a greater lack of interest among adolescents than biology. Typically, with younger students, science is presented less abstractly. Consequently, it is easier for younger children to become engaged with scientific issues. It has often been noted that there is a significant drop of interest in natural sciences during the primary-secondary and the lower-upper secondary transition (see Osborne et al. 2009). The nature of textbooks and classroom language might contribute to this phenomenon (Norris and Phillips 1994).

One potential solution for dealing with both the lack of interest in the natural sciences and the difficulties many students have with finding science learning relevant may be to allow students themselves to select the science concepts to communicate about. Several factors currently constrain this practice, including the following:

– Student choice of topics may result in the selection of concepts instructors feel they have little background knowledge in.
– Curricula constraints lead students to the conclusion that they have little time to engage in additional research and writing.
– For the same reason instructors may be unwilling to utilize instructional time for concepts they consider irrelevant for final examinations.
– As mentioned above, science instructors may feel they have inadequate training associated with improving students' writing abilities.

Although these constraints exist, allowing students the ability to write about what they are truly interested in could lead to an increase in interest in the subject matter of science in general. This increase in interest could also lead to a greater motivation in class. To test these hypotheses regarding student interest and motivation stemming from choice in writing about science concepts the *Young Science* magazine was founded in 2012, which is, to our knowledge, unique in Europe. In this magazine, high school students write about topics from biology, chemistry, and physics. They obtain feedback both in terms of language and scientific content from the editorial board consisting of scientists and teachers from all three subjects. Articles are usually revised several times before they get published. The journal itself is distributed for free due to the cooperation with regional school authorities, funding from university and government agencies, and advertisements. Currently *Young Science* has a circulation of 10,000 copies and reaches about 150 secondary schools in four Austrian federal states. First articles from abroad (e.g. Italy) show that interest in this project is becoming ever greater. Figure 2.1 shows the first three covers of the magazine.

As can be derived from Table 2.2, the number of female teenage authors is higher than that of male authors. Only in the first edition are numbers equal, which stems from the fact that a grade ten biology class consisting almost

Fig. 2.1 Covers from the first three issues of *Young Science*

Table 2.2 Number of female and male student authors (single or in small teams) in each issue of *Young Science*

	Issue 1	Issue 2	Issue 3[a]	Issue 4 (in preparation)[a]
Female authors	7	6	3	4
Male authors	7	2	1	

[a]One additional article was provided by a whole mixed class

exclusively of males were specifically encouraged to write for the journal by its biology teacher. Otherwise, females seem to be more interested in providing texts for the journal. However, their topics are by no means exclusively related to humans or biology in general, but also deal with themes such as photo-acoustic imaging or chemiluminescence. Writing might therefore be one way to attract students and, in particular, females to become interested in the natural sciences or, at least, strengthen an already present but possibly tentative attachment to this domain.

Not every article can be published in such a magazine. Internal school journals or web pages, or, at least, a publication within the class presented to classmates and parents would be cheap and feasible alternatives. As will be shown later, the option to tell others about a self-chosen scientific topic is a great factor to motivate students to write such a text.

Apart from interest development, such article writing and publishing may also be seen in a larger pedagogical context to help students develop the writing competence they need to deal with scientific issues in the written format and to learn how to plan and structure such texts. This, of course, includes multimodal representations, since scientific articles use illustrations and tables to both attract the reader's interest and visualize and explain results and ideas. Students need to understand that pure text is unattractive to read for many, and that carefully selected or self-made visual aids may significantly contribute to a reader's understanding of a specific topic. In this respect our authors are encouraged to contribute pictures, graphs or other kinds of additional representations themselves, either by their own material or by asking for re-use of already published illustrations. This is different to the practice of many newspapers and magazines, but prepares for the requirements of scientific publication. By diligently choosing or creating suitable non-textual representations, students will be engaged with their topic from a different perspective: how to best present their main message and/or results in one or few key illustrations or tables. Consequently, this kind of article writing and publication trains students to compose scientific texts and helps them to understand how written scientific communication works by combining both text and non-textual modes. This will be even more efficient if the products of such efforts are published and discussed in class, giving the authors the feedback they need to improve their writing and choice of non-textual representations.

Research Projects to Study Interest Development in and Attitude Change towards the Natural Sciences after Writing Popular Scientific Articles

Creation of Interest

In school, students usually do what they are told to do. Very rarely are they given options to choose between. This might severely limit interest development. According to Krapp's "person-object-theory of interest" (POI) (Krapp 2005), the arousal of interest requires an "ongoing process of person-object interactions." However, there are certain preconditions that are typically necessary to develop interest in something. First, the task and/or goal must be regarded as meaningful and important and must cause some kind of positive emotions (Krapp 2005). Only then will interest become long-lasting as opposed to superficially and momentarily maintained, and only then can a "domain-specific situational interest and later a relatively stable individual interest of high personal relevance" be created (p. 383). Consequently, for students to become interested in natural sciences through writing about them, not only the topic but the writing itself needs to be considered as meaningful/important and linked to some kind of positive emotion. In the context presented here, the assumption was that students saw the writing they were asked to create as both good practice for the requirements of the final thesis and their later career (meaningfulness of task), and that the text they composed would create some sort of pride (positive emotion).

This alone, however, might not be sufficient. Decy and Ryan (1993, 2008) postulated that learning works best when three psychological basic needs are fulfilled: the feeling of competence, autonomy, and relatedness. Accordingly, students should realize that they can master the task, even if it is very new and possibly difficult for them – such as article writing in science classes. Secondly, students need to experience some kind of autonomy without having the teacher telling them exactly what to do and how. In terms of article writing they should thus be given a certain degree of freedom regarding topic choice and approach. Finally, students need to recognize that the task and its content are not only meaningful to the teacher and school curriculum, but also to others, ideally their peer group. For the program presented here this means that students realize that natural sciences have so many interesting aspects to offer that others (classmates, *Young Science* teenage authors from various schools) find them exciting enough to write and/or read about.

Measuring Interest Development

Interest development due to writing was measured through pre- and post-tests. In order to create the questionnaire to be utilized to measure this concept, it was necessary to determine how student "interest" and "attitude" could be dealt with as theoretical constructs. Consultation with the literature proved inconclusive. While both constructs are often treated as separate (e.g. Ellis and Gerberich 1947; Gardner 1996, 1998; Krapp and Prenzel 2011), other authors are less strict in their distinction (e.g. Christidou 2011; Osborne et al. 2009; Schreiner 2006; Vogt 1998; Vogt et al. 1999). Consequently, Schreiner (2006) concludes that "the boundary between them is still blurry" (p. 29). The situation is even more complicated by the fact that both "interest" and "attitude" themselves have been understood and defined differently by different researchers (cf. Krapp and Prenzel 2011; Schreiner 2006). The assumption for the exploratory project was that students would not see interest and attitude as something different, but rather be interested in a task or a topic which they would have a positive attitude towards. Consequently, both constructs were regarded as synonymous.

Concept

Following these considerations a workshop-based research program entitled "Young Science Journalism" was developed to test the idea whether writing about science and the use of an audience outside of classroom peers might increase students' interest in the natural sciences. In this program high school students write and revise popular scientific articles in class with both their science and their language (German) teachers participating. For their writing they also have to heed certain standards of communication about scientific concepts such as in-text citations. The effect of this intervention in terms of interest and attitude development is tested by means of questionnaires and interviews. In parallel, the development of writing competency of students is monitored by comparison of the different revisions they have to hand in after receiving feedback for their respective drafts. In the following sections, an overview of the pilot project is presented. In addition, data collected in regard to interest development and the use of different representations are presented and analyzed. Finally, the follow-up project which is currently being implemented will be introduced.

Pilot Project 2011/12

The program started with an exploratory project in the school year 2011/12. One grade 10 class with 7 females and 13 males aged 15 to 16 and their biology and German teachers (both female) participated. Students were introduced to the project in October 2011 and taught where to search for information and how to cite sources correctly. The criteria that would be utilized by students to rate the quality of popular scientific texts in newspapers, magazines and subsequently their own articles were discussed in class by the students, the project team, and an invited journalist during the first workshop. This list was slightly revised by the project team after the workshop and finally included "informative and attractive title", "examples from scientific work", "use and explanation of scientific terms" among other criteria. Students were given a recent newspaper article about feather-wearing dinosaurs and had to find and discuss a title. Then, they analyzed this and another (more complex) text according to the criteria collected in the workshop. As an opportunity to focus on characteristics most critical in creating effective scientific communication they were asked to find a topic of interest and to start researching this topic. A first draft had to be handed in six weeks later. This draft was read, analyzed and corrected by the project leader and the teachers. Topics had to relate to biology, since both the science teacher and the project leader were biologists. However, within the domain of biology, students had the freedom to choose their particular area of interest.

During a second workshop in January 2012 students were given anonymous copies of their classmates' drafts and asked to provide feedback about another student's article by using the criteria list, and then changing roles. Afterwards, students received individual feedback from the project leader and the teachers. The students were then asked to revise their texts. These revised texts were again read and corrected during another revision phase after a third workshop in March 2012 in which they received feedback from the project team and from a journalist. A final meeting in class ended the project in May 2012. During this lesson texts were read out on a voluntary basis and the project was discussed in retrospective. In the second workshop students were also encouraged to include non-textual representations in their articles, if they had not already done so.

Before, and after, the project students filled in questionnaires with items concerning their interest in natural sciences, reading and writing. Three females and three males from different achievement and motivation levels were additionally interviewed between workshop one and two and at the end of the project to gain further insight into how students approached this task, which problems they encountered and how they tried to solve them, and how they liked the concept of the project. Achievement level was based on biology grades from the past and current school year, motivation was judged by their biology teacher according to general engagement in class. Interviews were transcribed and analyzed using qualitative content analysis according to Lamnek (2010).

Results and Discussion

With very few exceptions students were quite committed to the project. Data from the interviews and teacher observation showed that females invested on average much more time and efforts than males. The second questionnaire allowed students to note what they liked and what they disliked about the project on a voluntary basis. Additionally, they could offer suggestions for future projects. Overall the project was rated positively by almost all students but with emphasis on different aspects. For example, four males referred to the preparatory effect for thesis writing required at the end of their school career ("practicing scientific writing"). No girl mentioned this aspect. Conversely, three females but no males highly valued the intensive text