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LEARNING SCIENCE IN THE SCIENCE CLASSROOM IN ELEMENTARY SCHOOL: A MULTIMODAL APPROACH

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ABSTRACT

This thesis is about learning as semiosis and its multimodal realization in the science classroom from the pupil's perspective, framed in science education in elementary school in Israel. It looks at how grade five pupils use resources made available in the science classroom for representation and communication of scientific knowledge. This is accomplished by application of a multimodal and social semiotic theoretical framework in the analysis of case study examples of texts produced by pupils and their rhetorical staging of presentation events. Texts and presentation events are viewed as complex signs, influenced by pupils' interests and the context of learning. These signs constitute evidence of learning. The findings show that in the production of texts in response to the teacher's lesson and a writing task she set, pupils use the interplay of visual and linguistic resources in a variety of genres to resolve representational problems realizing expressions of scientific knowledge. In the rhetorical process of presentation events, pupils engage in the rhetorical orchestration of modal ensembles to communicate an experiment or a topic explored presented to the class as the audience. In presentation events and related communicative events emerging in response to presentation events, pupils presenting use combinatorial possibilities of the functional specialization of speech, visual, bodily and actional resources to communicate scientific knowledge. Actional and visual resources are not just illustrations of speech. They are used for rhetorical purposes, for negotiation of scientific meanings, are media of thought, and are used for the construction of scientific explanations. The findings also show that pupils draw communicative resources from presentation events and related communicative events which they integrate into their revised exploration reports. The thesis concludes with suggestions of new insights and messages concerning learning, assessment, teacher education and pedagogy.

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BACKGROUND AND EMERGENCE OF RESEARCH QUESTIONS

> Instead of talking about meaning making as something that is done by minds, I prefer to talk about it as a "social practice" in a community. It is a kind of doing that is done in ways that are characteristic of a community.
>
> (Lemke, 1995, p. 9)

INTRODUCTION

This thesis explores the practices of learning science in the science classroom in elementary school from the pupil's perspective. It focuses on two types of the many possible learning practices in fifth grade classes. The first is the pupils' production of their own texts: (a) in response to the teacher's lesson (b) on an independent selected experiment or topic of exploration. The second is the pupils' performance of presentation events for the class as an audience, on a selected experiment or topic of exploration.

THE RESEARCH QUESTIONS

This thesis addresses an overall research question: What use do pupils make of resources made available to them in the science classroom to represent and communicate scientific knowledge? Three sub-questions which emerged from the overall question are examined: (1) What use do pupils make of resources made available to them in the science classroom to realise expressions of scientific knowledge in texts they produce? (2) What use do pupils make of resources to communicate scientific knowledge in the rhetorical process of presentation events? And (3) how do pupils integrate resources they draw from presentation events in the production/revision of their exploration report?

This chapter is organised into two sections. In the first section I present my account of how I became interested in the subject of this thesis while considering relevant educational background issues. In the second section, I provide a summary of observations of characteristic episodes in the science classroom to illustrate the process in which the research questions evolved.

HOW I BECAME INTERESTED IN THE SUBJECT OF THIS THESIS

The subject of this thesis emerged from imminent expectations and requirements of my job as a pedagogical consultant in language and literacy education. It responded to

my great interest in children's learning, particularly as is evident from the form of the various texts they produce. It is not one particular event that led me to explore children's textual productions and presentation events in the science classroom, rather a set of concerns, discussions, debates and reflections on a professional level, over a period of time. The following brief anecdotal account provides the relevant background for my decision to examine this issue.

One of the prime concerns expressed by policy makers and practicing educators from different disciplines in elementary school in Israel, in professional discussions, was the range of texts made available to and produced by children within and across subjects of the curriculum. The background of these discussions was the increasing place literacy gained as the main concern among the subjects included in the school curriculum. From the years 1993-1994 the policy (e. g. of the ministry of education) was aimed at gradually moving elementary schools in Israel towards incorporation of the concept of genre into classroom practices in the field of language and literacy. Although the formal policy was aimed at teaching a range of genres from literature, factual, mundane and texts from the media, in practice, narrative texts were in the foreground in most classrooms. In language lessons, mainly in early grades, teachers provided children with a range of books, textbooks and other textual sources. They provided conditions and opportunities to increase reading and writing; they also allocated time and provided children various materials to use for the expression of their responses to texts in various modes: writing, discussions, drama, drawing and other kinds of creative artwork. Within language lessons children's responses to texts in different modes were optional, whereas producing written texts was implicitly obligatory. However, the written mode, in particular narrative texts, was most practised and evaluated (see also Martin, 1985). According to Lemke (1995) those schools would be defined as traditional schools. He pointed out that in traditional schools the focus is on pupils writing narratives, and less on explicit instruction of genres of power that will count in their future life.

The attempt to move schools towards a genre based pedagogy on the one hand, and the focus in practice on narrative texts on the other, has created a gap between policy and practice, which in turn has caused tension. This tension generated debates, discussions and reconsideration of the approach to texts not only within the subject language but also across subjects in the curriculum. Those interactions lead to attempts of co-operation, both on the level of policy and practice, between educators from different disciplines with leading literacy educators, in which I was involved as a pedagogical consultant in language and literacy education. Speculations and discussions focused on

the question of how to transform the approach toward texts in school curriculum, and its implications on learning.

Inspired by researchers in the Australian genre school, who advocate explicit teaching of genres (Cope & Kalantzis, 1993), some advocated a fixed list of genres, based on the view that perceives genre as schematic and staged, while others, among them, myself, supported a dynamic and flexible view of the aspect of genre as suggested by Kress (1993b). This view, in my opinion, seemed suitable to the nature of real texts, the dynamic nature of learning and the diverse and complex social and cultural Israeli context.

Within those discussions and debates, particular concerns were raised in relation to the subject of science. It has been argued, in the inter-disciplinary meetings mentioned, that the subject of science and, in particular, the language of science and written scientific texts are difficult for many children (see also Lemke, 1990; Halliday & Martin, 1993; Veel, 1997; Henderson & Wellington, 1998; Peacock & Weedon, 2002). Concerns and debates regarding science education intensified as the results of the Third International Math and Science Study (TIMSS) carried out in 4th grade in 1995 and in 8th grade in 1999 were made public. In these studies Israeli students' results scored very low in comparison to other participating countries. Though Israeli students' results were among the highest in International studies in the 60's, in the late 90's they were among the lowest (Ben-Shahar, Helpman, & Ben-David, 2000). In view of the fact that Israel spent one of the highest budgets per student in elementary education among the participating countries during the 90's (Central Bureau of Statistics, 2000) science education became a public issue.

The consensus in the interdisciplinary sessions mentioned above was that the starting point would be to rethink how to enhance pupils' engagement in and production of scientific texts, and how to enhance the engagement in scientific texts from the aspect of genre. The assumption was that this move might contribute not only to transforming the approach to scientific texts but also to serving as a starting point to shift the dominant focus from narrative texts towards children's engagement in and production of a more balanced repertoire of genres in the school curriculum. Science educators have suggested to examine science textbooks as a starting point since textbooks are deeply rooted in science classroom practices. This assertion is in agreement with research findings (Shimansky, Yore & Good, 1991) that textbooks remain an important instructional medium in elementary school science classrooms.

The suggestion was to examine the nature of texts in science textbooks in order to recontemplate their utilisation from a new viewpoint in science classrooms. In particular, this should be achieved from the aspect of genre, and how to incorporate this view in teachers' further education should be reconsidered. The expectation was that experienced leading literacy educators who deal with texts in the school realm and who are involved in teachers' further education would lead this move. As a pedagogical consultant in language and literacy education in Hebrew as L1 and L2, both in Germany and in Israel, I have been involved in further education of teachers and other leading educators (i.e. teachers' instructors, head teachers, supervisors). Prompted both by academic and educational colleagues and driven by my professional curiosity, concerns and commitment to enhance children's engagement with and production of a wide variety of texts, I was willing to take the challenge. This is how I became involved in the subject of science. At that initial stage, I preferred to start by exploring the scientific texts in the school realm, and not offer suggestions or plans for immediate implementation so quickly.

PRELIMINARY STEPS

The preliminary step I took was to examine science textbooks used in elementary schools. At that initial stage I used the TIMSS framework for analysis of learning materials in the subject of science (for further information on TIMSS see Appendix). In addition I interviewed science textbook authors, leading figures in science education and I examined the new science curriculum. All these steps were helpful in becoming involved in the subject of science, from a number of perspectives.

Science Textbooks

Textbooks used in science classrooms in elementary schools in Israel can be classified as previous versus current textbooks. This classification is linked to the new national science curriculum (since the early 90's a new national science curriculum integrating science and technology studies has been promoted for elementary schools nationwide in Israel, which was revised during the1998 -1999 school year and officially published in 2000). Broadly speaking, textbooks that were published previous to the new curriculum are perceived as old textbooks.

Current science textbooks differ in various aspects from previous textbooks (see also Kress & Ogborn, 1998). Since the science textbook in itself is not the concern of this thesis, I will not expand on the issue. Here, I briefly refer to the dominance of visual

representations and the reduction of the written mode, which is one of the main aspects that differentiate between previous and current science textbooks. This emphasis is in order to highlight the "multimodal" nature of current science textbooks, which has been remarkably influential on my rethinking the nature of texts and on the development of the subject of this thesis. Any text in which meanings are made by the joint co-deployment of two or more semiotic modes is termed as a "multimodal" text (Kress, Leite-Garcia & van Leeuwen, 1997; Kress & Ogborn, 1998; Lemke, 1998a, 1998b).

Current science textbooks for elementary school are highly visual. They integrate a range of representations in the visual mode with meanings in the written mode. The space images take in a current textbook is often dominant compared to the verbal text on the page. A page in a current textbook can be described as a "semiotic unit" (Kress & van Leeuwen, 1996, p. 185). Photos, drawings, images, diagrams, tables and other various graphics dominate the page and represent essential meanings. In addition a set of integrated salient features of orthography and typography also carry meanings. For instance, different typeface and colour signal different degrees of prominence of the information or a shift in genre. In previous textbooks there is less variation in typeface and the print is much more densely spaced than in current science textbooks. The use of colour in previous textbooks is sparse, often designed in black and white. The reading path in current science textbooks is often different from the linear path in previous textbooks. There are successive pages that have different reading paths. Images can be on the top, the bottom or spread over the entire page. Often a two-page spread is covered with visuals and segments of written text, which are spread in non-linear ways on the pages. The overall material quality and design of current science textbooks is aesthetically produced, projecting an effort to be contemporary, to please and to motivate children.

Textbooks are viewed as a means for the introduction of children into a culture's values, and what is perceived as "true", "valid" or "legitimate" knowledge (Olson, 1980; Luke, 1988; Apple & Christian-Smith, 1991). In current science textbooks the "true" or "legitimate" knowledge is represented visually no less than in the written mode. Since the pupil is addressed in current science textbooks through a range of visual representations and less through written texts, I asked myself how to approach these texts. Questions evolved in respect to how the shift in representation of curricular content in images might affect the child's disposition to phenomena in the world, towards knowledge and science learning. The set of questions, which arose at that stage, were not all included in this

research. Nonetheless, they did direct me towards readings and to observations in science classrooms.

It became clear to me that the reduction of writing as a mode in current science textbooks and the prominence of visual representations and their interrelations require a different view from a common linguistic approach in order to understand how these texts work. I realized that the concept of text as linguistic exchanges of meanings (Halliday, 1978) cannot stand alone with reference to texts in current science textbooks. Although it is acknowledged in science education that certain aspects of content of the science curriculum can be better represented through modes other than language, such as images or models, the concerns and discussions in the interdisciplinary professional meetings mentioned focused on scientific texts viewed as linguistic constructs.

This tendency is common and deeply rooted in the schooling tradition. Gardner (1983) discussed the effects of the transition in forms of schooling from "direct" forms of knowledge, to informal forms of schooling, to traditional schooling and then to modern schools. He pointed out that there has been "a steady minimisation of bodily, spatial and interpersonal forms of knowledge... in favour of linguistic forms" (p. 364). In Western culture it is a long tradition, which highly values language, in particular the written language, as the principal mode of communication. As Macken and Slade (1993) asserted "gaining control of the written mode is essential to learning in all subject areas" (p. 206). Being fully articulate, thinking logically and rationally as expected in the frame of science learning is commonly perceived as mainly a linguistic accomplishment. "And the more 'articulate' learners are judged the more 'knowledgeable', whence the privileges awarded to linguistic skills" (de Beaugrande, 1997, p. 425).

Martin (Halliday & Martin, 1993) who referred to schools in Australia expressed related considerations on the nature of texts in current science textbooks. He regards the removal of old textbooks from science classrooms as an obstacle to science learning. Martin suggested that this is because current textbooks are a compound of fragmented models of scientific texts; as a result, students are exposed to fewer and fewer models of scientific texts. This view is demonstrated in "writing science" (Halliday & Martin, 1993), which is focused on the analysis of the grammatical structure of written scientific texts. The authors discuss the role of grammar and language in the development of scientific thought, and hence highlight writing and learning science as a linguistic accomplishment. Yet approaching texts in current science textbooks uniquely through the linguistic dimension, as demonstrated in "writing science", could not provide a framework that would account for how these multimodal texts work. In addition, in my view and within

the multimodal approach applied in this research, the removal of old forms of scientific texts is not a problem of pupils' learning rather a problem of assessment, in older forms, which are commonly no longer available as models.

GETTING STARTED

Exploring science textbooks was only a preliminary step, and not the aim of this study as an end in itself. What interested me, though, is not the textbook in itself.

"It is not the texts as objects, nor the speech as verbal text, that makes meaning, but our activity in interacting with these, producing and interpreting them that makes meaning" (Lemke, 1995, p. 159).

I was interested in exploring how children use the science textbook and any other available resource in the practices of learning science and from which they might draw on as material for the production of their own texts, providing evidence of learning. Therefore, I embarked on observations in science classrooms. I started my fieldwork by observations and collection of materials in 5th grade classes in four science classrooms of four different elementary schools. In the progress of research I narrowed down the collection of data in two 5th grade classes taught by the same science teacher in the same science classroom. I will expand on this in more detail within the description of the research design in chapter three, the methodological chapter.

During my observations I came across the practice of presentation events performed by pupils in the science classroom. The term presentation event refers to a planned communicative event, in which individual pupils or small groups present their chosen experiment or topic of inquiry to the class as an audience. My interest in exploring pupils' presentation events is in addition to their textual productions since the presentation is a practice that puts the pupils more in control of their own work, which allows more freedom to follow their own interests than traditional school work. It is a practice through which pupils express scientific knowledge in public and present themselves as science learners. Similar to the teacher they conduct communicative actions as young "pedagogues" in an attempt to communicate the topic they explored presented to the class as an audience (consider observation 5 in this chapter). In other words, pupils are engaged in considerations of how to design and rhetorically shape the presentation events. It was an opportunity to explore the practice of presentation from the rhetorical aspect of the pupil's perspective; a practice, which to the best of my knowledge, had not yet been explored.

EMERGENCE OF RESEARCH QUESTIONS

The purpose of this section is to present the process in which the questions of this research emerged. In order to accomplish this I present summary descriptions of observations of characteristic episodes in the science classroom where I gathered the data for this thesis. This is followed by a discussion to clarify significant issues that arose. The sample observations and the related discussions illustrate issues that gave rise to the research questions of this study through a process of reflection, and rethinking by means of review of a large collection of materials of various kinds.

The observations and the samples of pupils' textual productions considered in this section are chosen from different lessons and they are not intended to provide a sequence of a whole lesson, or the development of a topic in a series of lessons. To be more precise, they are snapshots of episodes at different points in the course of the topic "systems in the human body", studied in the framework of the wider topic "health" which was studied in one of the two 5^{th} grade classes where I collected the data for this study.

To illustrate the wider picture in which the described episodes were embedded I will characterise some of the classroom practices in the science classroom under discussion. Broadly speaking the lessons in both 5^{th} grade classes observed can be classified into three types. One type involved the teacher's assembling of the class as a group for a portion of the lesson (about 5-25 minutes). The teacher used this type of lesson for different shared pedagogical purposes, such as, framing a shared topic, demonstrations, experiments, establishing a base of knowledge, leading class discussions, or setting task frameworks. Following the teacher's part of the lesson, pupils were usually engaged in learning activities framed by the teacher, which were directly related to the teacher's lesson. The pupils were usually engaged in short tasks accomplished in the lesson in small groups or individually.

A second type of lesson was used for pupils' independent experimentations and explorations, which was loosely framed by the teacher as a longer term task. In these lessons the teacher did not assemble the class as a group; she encouraged the pupils to immerse themselves in their selected experiment or topic and to independently explore, plan and structure their activities. The pupils were engaged in various activities such as, reading, experimenting, investigating, manipulating models and constructing models, producing texts, working in the computer centre, discussing with peers and/or the teacher, writing a report and planning and designing their presentation for the class. During pupils' independent work the teacher provided guidance or outlined instructions to small groups or individuals and she did not exercise much control over their activities.

A third type of lesson was used for sessions of pupils' presentation events. A session included usually 3 – 5 presentation events. The presentations concerned experiments or topics independently explored framed in the wider rhetorical framing of the shared topic in class, outlined by the teacher. The teacher made a wide range of resources and materials available to the pupils, which were freely accessible during their independent work.

A SUMMARY DESCRIPTION OF SAMPLE OBSERVATIONS

Observation One – Brainstorming - Various Forms of Textual Productions

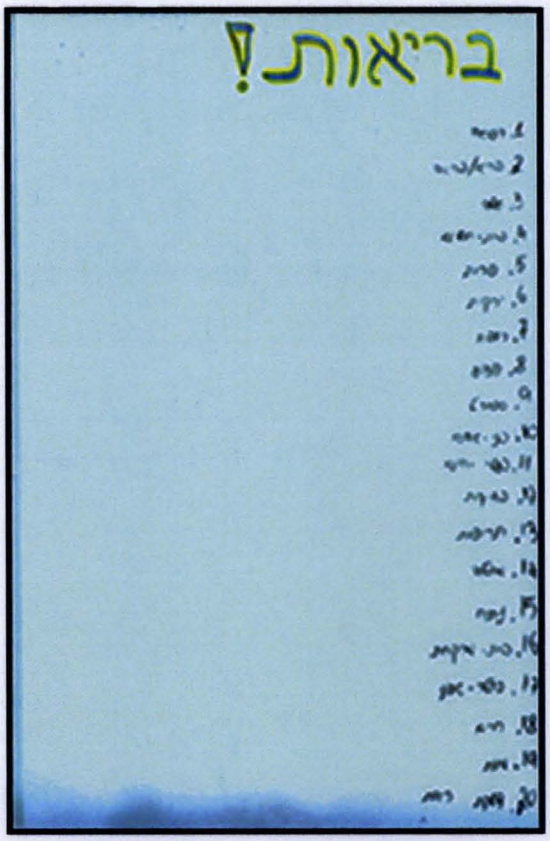
This observation, at the beginning of the year in an introductory lesson on the topic "health", served as a framework for the main topic "systems in the human body". The activity, which is termed in school as "brainstorming" is a common strategy used by teachers in elementary school, at the opening of a unit in different subjects. This kind of prompt, i.e. raising words that surface in association with a topic or concept is used as a means for pupils of early grades to respond and reveal prior concepts and knowledge, which can lead to the development of significant ideas, discussions and questions for further study.

The teacher wrote the word "health" on the whiteboard and prompted the class to individually write down the associations that surface in relation to the concept of "health". She framed the activity according to the following stages: (a) individually writing the words which surface in association with the concept of "health" on a blank page; (b) pairs or a small group writing the words on slips of paper, organising them in groups under categories, and pasting them on a blank page; (c) a class discussion following the assignment based on the pupils' productions.

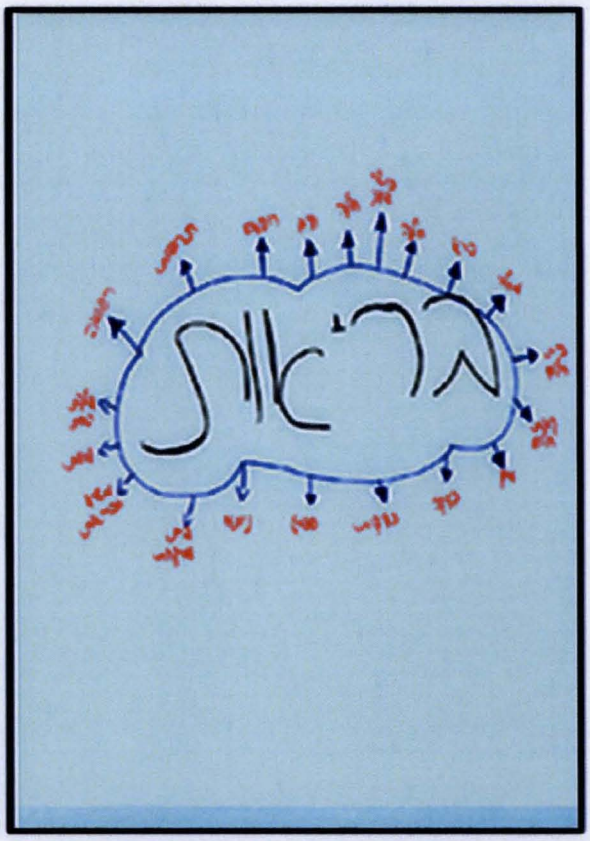
A number of different types of pupils' productions emerged in response to the teacher's prompt and framing. One was in the form of a written vertical list of words under the heading" health", where some pupils used a pen or pencil and others used different colours for each word. The second type was in the form of the term "health" written in the centre of a blank page surrounded by arrows pointing to written words. The third type was in the form of words written on slips of paper pasted on the page, classified into groups under categories as headings. The fourth type was also in the form of words written on slips of paper classified into groups under categories but illustrated or combined with drawings. And finally, there was a type in the form of images comprised of cuttings pasted on a blank page combined with drawings.

Two small groups (8 pupils) that worked in pairs had particularly caught my attention. They were not following the sequence of the teacher's instructions regarding the framed activity. Instead they were selecting images from colourful prospectuses and periodicals located in a container near their seats. Cutting the images out, they manipulated them as objects by organising them into a new combination pasted on a blank page. In this manner they constructed a new context and meaning designed in combination with drawings around or under the heading "health". Although they worked very quickly this type of production took more time than the other types of productions. All forms produced in class were a basis for the class discussion that followed. The producers of the last type, namely the texts comprised of the cuttings of the images, were no less involved in the discussion than others in the class. Finally the teacher collected all the pupils' productions but she displayed only the last type of productions on the wallboard under the heading "health". These texts dominated by images, varied in their form of design from images spread over the page, in such a manner that I was unable to establish the principles of classification, to images organised and classified into groups under written categories. Figure 1 displays copies of samples of the various types of forms of production.

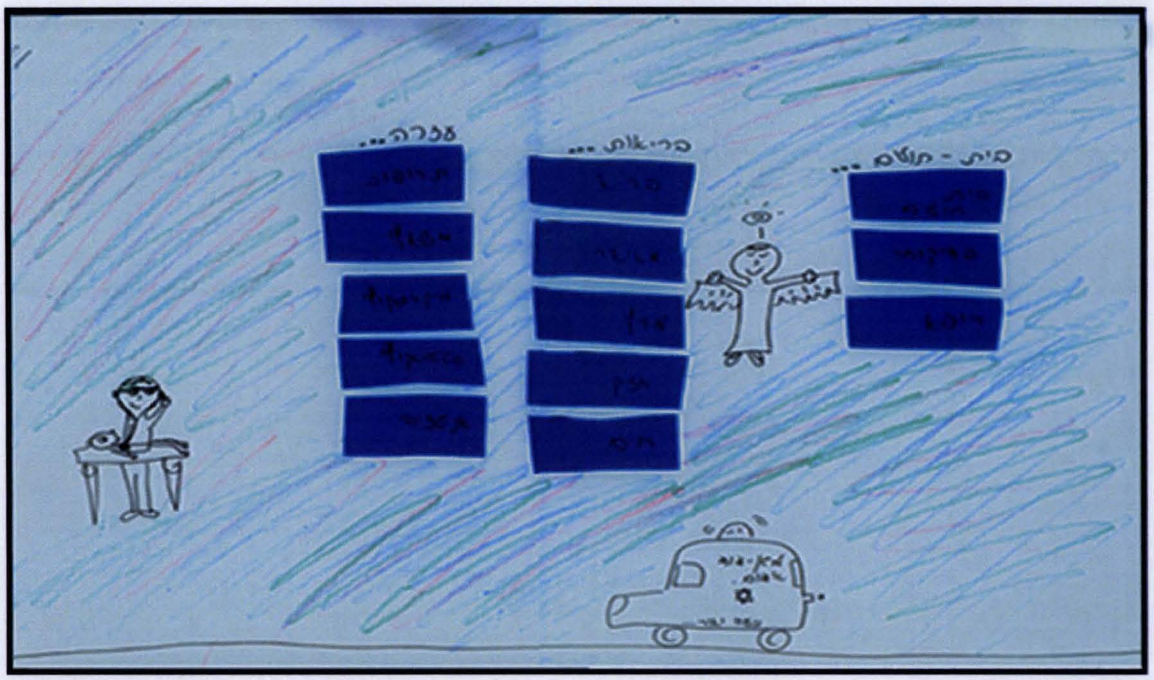
Although the activity described can be perceived as a common and unremarkable activity in science class, it raised some significant issues to be considered at the start of my observations. The procedure of the activity is usually accomplished in the written mode followed by a class discussion from which questions for further exploration are derived. Children are acquainted with the procedure from early grades in elementary school. In my observation I noticed that some of the pupils skipped the first stage of the activity as framed by the teacher, namely the writing of words on a blank page in an unclassified form. Instead they started from the second stage by writing words on slips of paper, which they manipulated and pasted on a page classified in groups under categories. Furthermore, several other pupils did not follow the teacher's instructions at all regarding the activity. Instead they worked, as described, with cuttings of images in association with the concept health, which the teacher allowed.



(a) List of words under the heading "health"

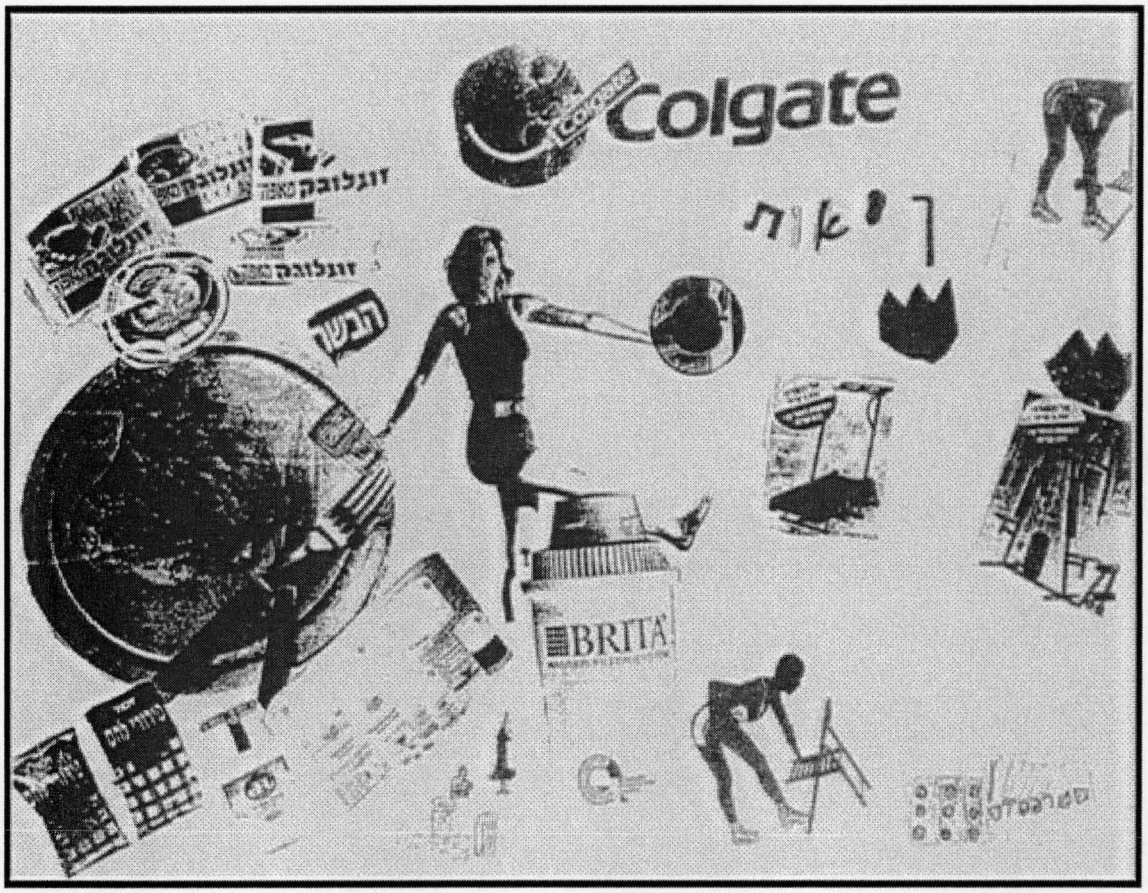


(b) Words surrounding the notion of "health" appearing in the centre

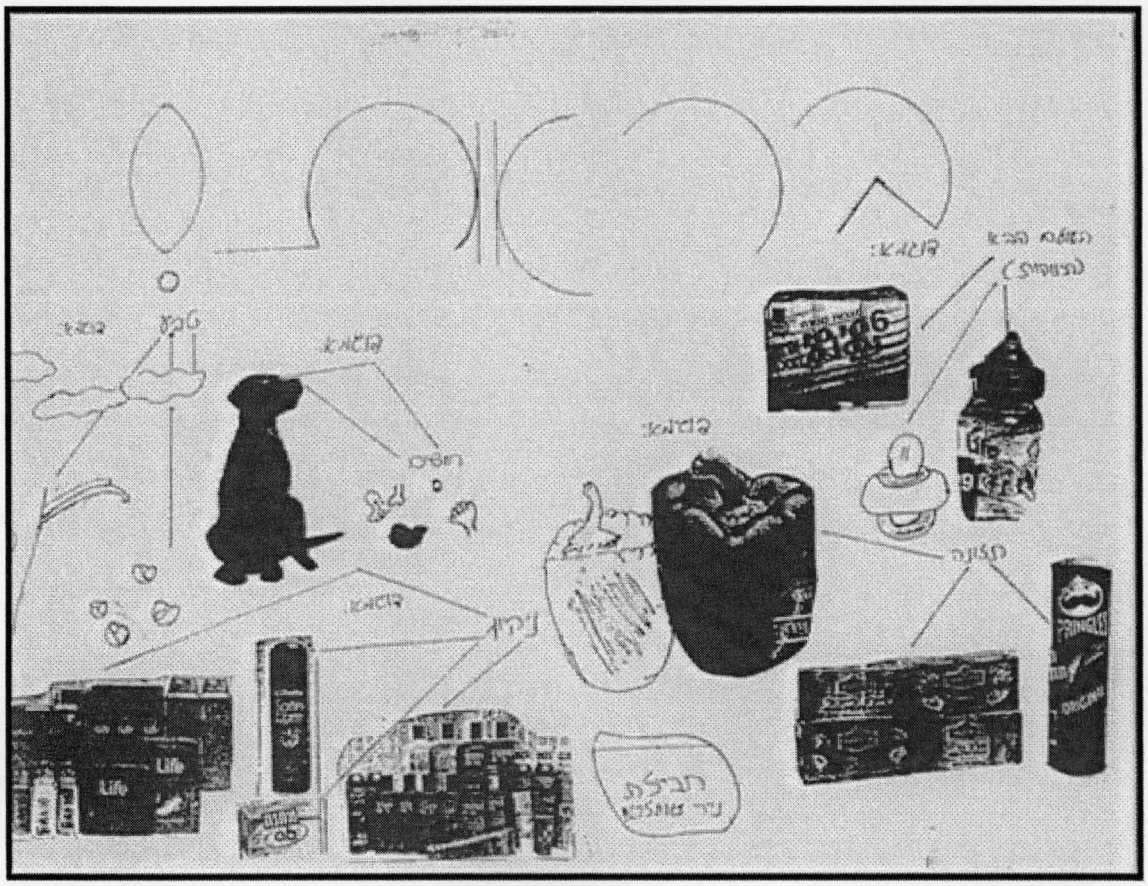


(c) Words classified under categories combined with drawings

Figure 1. Types of textual productions surrounding the notion of "health"



(d) Images spread over the page under the heading "health"



(e) Images classified under categories under the heading "health"

The variability in pupils' productions in response to the same prompt and pedagogical framing is interesting in itself. The first issue I regard in this observation is that two small groups (8 pupils) did choose images as the primary mode to represent meanings. This was remarkable since usually this is a linguistic activity. Conversation during the activity in pairs referred to organisation of the practical work; the writing of commentaries or categories followed the choice of images and construction of the composition of the text. Conversation for communicative purposes came after the whole production, in the small group and during the class discussion.

Another issue to be considered is the pupils' choice to "invest" more "work" and time in the whole process of production, which the teacher tolerated. Selecting images, cutting and pasting, instead of accomplishing a common and simple linguistic activity is time consuming. Since the producers of these texts were no less involved than others in the discussions, it could not be argued that their choice stemmed from them being communicatively incompetent. In addition, the cutting and pasting activity is usually associated with younger children (see also Kress, 1997). Thus, I wondered what motivated their choices.

In a brief discussion I conducted with a small group, the pupils raised two points, which highlight the underlying principles through which pupils' learning science can be understood. Their first point was that they came to study in the science classroom with expectations to work with *material stuff* (throughout the thesis I will use the convention of italicizing excerpts of speech and of written texts from the science classroom observed), which they indeed fulfilled. Their expectations and attitude toward science learning is in agreement with Osborne's (2002) report on research findings. Osborne explored pupils' attitudes toward science and found that the engagement with the material world and practical work is greatly valued and enjoyed by pupils. The second point raised in the small group was that they used images to attract the attention of the class *because pictures appeal to children much more than words*. (Since my collection of data for this study was carried out in science classes in Israel, I translated all the data samples and excerpts considered throughout this thesis from Hebrew into English).

Their first point raises one of the principles applying to children's making sense of the world. Namely, they have a need to operate through material resources, re-using and transforming resources in different ways, in particular, concerning the study of the physical world as they had expected in science class. The second point raised in the small group indicates the distinction Kress (1997) pointed out between representation and communication, on the theoretical level. The distinction is significant in understanding

the underlying principle of the expressions of learning. Having in mind the class as the audience, the producers of the image-dominated texts considered not only what to represent but also how to communicate their intended meanings. These are the two inseparable sides of meaning making that pose different requirements from the meaning maker. Considerations of what to represent are focused on the meaning maker's interests. Considerations of how to communicate are focused on the receiver's interests. In this case the pupils used the visual mode as a means for realising intended meanings and at the same time as a rhetorical means. These two aspects of a message – the communicational focused on the audience and the representational focused on the meaning maker – are central in understanding meaning making, in this case in the science classroom.

Observation Two – "Imagine You Have a Third Eye"

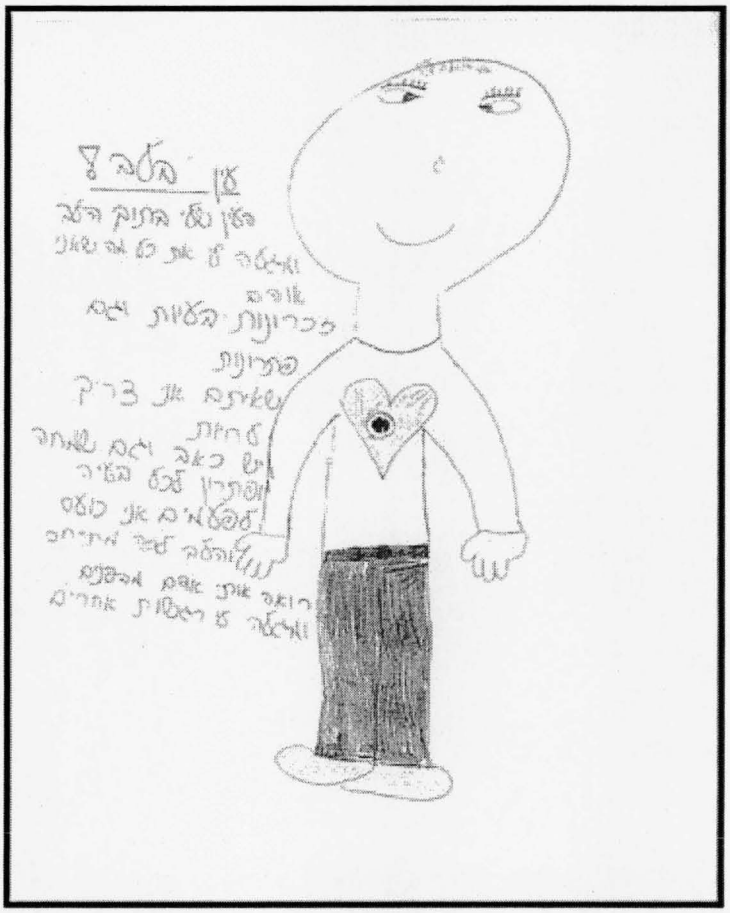
In the introduction lesson on the topic "systems in the human body", the teacher prompted the class as follows: *Imagine you have a third eye, which can only look into the body. Where would you position that eye? Describe what is reflected in that eye.* The majority of the pupils responded visually through drawings and some responded in multimodal forms, combining drawings with written text. The visual productions, which emerged can be classified into two types. The first type can be described in terms of empirical representation of inner organs in the human body in drawings as they envisioned it. The second type of productions can be described in terms of scientific representation of inner organs in the human body. The multimodal texts were comprised of a figure with the imagined eye located in the centre of the figure or in the heart combined with a written text mainly in the form of a poem they composed. However, all the pupils in class located the imagined third eye in the centre of the body, either in the heart or in a central point but not in a specific organ in the body. Samples of the different types of productions are presented in figure 2. One multimodal sample will be considered in more detail in chapter two in order to illustrate theoretical notions.

As the teacher explained to me, she used this prompt as a strategy for a purpose similar to that in observation one. The idea was that the pupils would express what they thought/knew was inside themselves in order to take these into account in her teaching plans. The pupils' choice to realise what thinking might have been, in the visual mode or multimodal, recurred here, but in this case it was in fact the choice of the majority of the pupils in class and not only the choice of two small groups as was the case in observation one.

(a) Empirical representation of inner organs

(b) Scientific representation of inner organs

Figure 2. Types of textual productions representing what pupils envisioned inside themselves



(c) Image combined with a poem

However, in both activities the visual representation came first, and talk, commentaries and discussions in class were subsequent. Since, in this case the pupils deployed visual resources to express their understandings the question about realizational modes emerged, i.e. can meanings be better realized through visual resources than through linguistic resources?

Observation Three – Transforming an Experiment into a Written Report

The class was gathered in the meeting area. The teacher posed the question *what is the difference between the inhaled and exhaled air?* The pupils raised assumptions about the difference between the construction of inhaled and exhaled air. The teacher conducted an experiment in order to "see" the invisible difference between inhaled and exhaled air.

First she demonstrated the mixing of baking soda with vinegar, which resulted in fermentation, thus causing the emission of the gas CO_2, which was invisible. She immediately approached an empty plastic bottle with exaggerated slow and gentle movements. The pupils wondered and responded by asking her *what are you doing with the bottle*? She said that although invisible it is an already scientific proven fact that

mixing baking soda with vinegar causes fermentation that emits CO_2, which she is collecting in the bottle for a further step in the experiment. She wrote that scientific fact on the whiteboard.

In the second step, she poured a small amount of the red phenol liquid in each of three test tubes. In the first tube that she stored the CO_2 in, the red phenol liquid transformed into a yellow-orange liquid. After a short discussion, she wrote the second fact on the whiteboard. As pupils asked for explanations of how the transformation transpired, she said: *it is a complex chemical process, which we are not going to inquire. We accept it as an already scientific proven fact that when red phenol and CO_2 meet the red phenol's colour turns to yellow orange*. Based on these two facts that she demonstrated to them, a pupil was invited to "inject" air from the environment into the second test tube. The red phenol maintained its colour. Another child was invited to exhale into the third test tube, and the red phenol's colour turned into a yellow colour as in the first tube. They made inferences about the difference between the constitution of inhaled and exhaled air. Finally the teacher guided the class to write a scientific report. Jointly constructed they transformed the experiment into a written experimental report step by step. This was one of the steps she made in apprenticing pupils into generic conventions of a written experimental report.

Wells (1993) discussed the notion of discourse as a tool for doing science in primary classes. Following Vygotsky, Wells argued that discourse – and particularly spoken discourse – is the most powerful and versatile of all the tools in the semiotic tool-kit. Considering this observation, Well's argument is problematic. In the experiment described, realising meanings was based on various kinds of action. It is action with objects and materials, which lends power to the experiment to enable pupils to see for themselves. It made it possible for pupils to move from what they had actually seen to what they "ought" to see as scientific proven fact (the constitution of air as gas, the emission of CO_2 caused by the fermentation of mixed baking soda with vinegar, the difference between inhaled and exhaled air). To bridge the gap between actual experience and scientific proven facts, action of various kinds were used in integration with speech. Furthermore, the meaning of doing science, resides in this experiment not only in the material results and conceptual inferences, but also in the way the teacher positioned herself in relation to objects, materials, and the class. This could be observed in her gestures and movements, the way of handling objects and materials differently, and her gaze and facial expression in integration with talk and writing. All this in combination provided a multimodal ensemble in which action was in the foreground.

The issue I am referring to is the problem of ranking meaning making resources, on a principal level, in order of primacy in communication in the science classroom. Kress, Ogborn, Jewitt, & Tsatsarelis (1998) suggest that it is rather a relation of foregrounding and backgrounding between modes, which operate in co-operation and comprise a combination that results in a coherent interrelated multimodal text throughout a lesson.

From the pupil's perspective engaging in science at school involves construing and making meaning through different modes and learning generic conventions of the subject, in this case a written experimental report. The issue that interested me is to explore how pupils use generic conventions in the production of texts independently in the science classroom.

Observation Four – Transforming Resources into Texts

The teacher introduced the organs in the respiratory system by shifting between three semiotic objects, the torso model, her own body and a large colourful map with diagrams of the inner structure of the breathing organs. She introduced the breathing organs and described the passage of air step by step from the environment through the openings of the nose (or mouth), the pharynx, the breathing tube, the bronchi and the lungs. While doing so, she posed the question: *What are the requirements of air from the environment in order to be utilised for respiration?* This question remained open for further investigation. She shifted from the model to her own body touching relevant parts. Then she shifted to the corresponding organs in the diagram. At certain points she acted with the three semiotic objects while simultaneously linking the action with speech.

The task she set was a writing task to be accomplished in the lesson individually or in small groups. She asked them to study the inner structure of organs in the respiratory system in more depth, by means of resources she made available to them. The writing task was worded as follows: *write* (in plural) *what the structure of the breathing organs is in the order of the entrance of air from the environment into the lungs.* The form of text to be produced was not discussed. The resources she made available in addition to her part in the lesson were: the torso model, the map with the diagrams, information books, a relevant chapter in two different textbooks, and her instructions for the task. In addition interactions with peers in a small group were also a resource to draw on in the accomplishment of the task.

The pupils' activity resulted in different forms of textual productions. These forms included diagrams of the respiration organs illustrated with written commentaries,

flowcharts of various types, different kinds of graphics in various compositions and combinations with writing on the page and a variety of arrows and text boxes. Some pupils combined images in the flowchart; written reports, or reports in combination with images or the textual production was in the form of tables. The headings of the different forms of texts also varied in content and layout.

The first issue taken into account is the remarkable differences between the texts pupils' produced in terms of content and form, in response to the teacher's lesson and task, given that all the pupils attended the same lesson on the same topic, received the same task and were offered the same resources made available by the teacher. Two related questions arose. First, why did pupils' produced texts differ so remarkably? Second, how can these differences be interpreted and understood. It could be argued that the differences are caused by individual factors such as motivation, writing and graphic skills, and attention or lack of attention during the activities in the lesson. It seems reasonable that individual differences do influence expressions of learning. These might explain to some extent the differences between the produced texts but do not provide a convincing explanation for the remarkable differences.

The second issue I have considered is the distinction between the possibilities and constraints of the resources, which constitute the different objects and the range of communicative modes that the teacher used surrounding these objects to communicate scientific knowledge. The teacher shifted from object to object (model, body, diagram), on the one hand to exploit semiotic possibilities. On the other, she did so to compensate for the semiotic limitations of the resources, which constitute the different objects (i.e. the body enacted dynamic motion that the model and diagram are limited to represent).

The third issue I have considered is the teacher's ensemble of the body, objects, strategies and communicative modes in order to communicate scientific knowledge. In Kress, Ogborn, Jewitt & Tsatsarelis' (1998) terms, the teacher acted as a rhetorician. She rhetorically orchestrated resources from different semiotic modes in integration to shape pupils' scientific knowledge.

Observation Five – Pupils' Presentation, a Multimodal Event

The class gathered at the meeting area for a session of pupils' presentation events. About three weeks before the presentation of the given task the pupils were to select one organ in the respiratory system, explore it in depth individually or in small groups in the classroom. They were to write a report according to guiding headings the teacher set and in addition present the topic explored to the class in order *to share and disseminate*

knowledge. The guiding headings for the written task were as follows: the structure of the organ, the function of the organ, adaptation of the structure to the function, reciprocal relations between systems in the body. The teacher made a number of resources available: a torso model, a map with diagrams of the breathing organs, worksheets, information books, relevant chapters in two different textbooks, and different types of matters and material things, and she assisted if needed. The activity resulted in various forms of pupils' staging of their presentation events at the front of the classroom with their fellow classmates as an audience. I present three different examples from this observed session.

Presentation one. Nitza stood at the front of the class, where the teacher usually stands. She introduced her topic: *relations between the oesophagus and the breathing tube.* First she posed a question to the class: *How can we eat and breathe at the same time?* She held a 3D model in her hands. She constructed the model from half a roll of toilet paper pasted vertically on a cardboard plate, with rings of pipe cleaners representing the rings of the breathing tube. A red balloon, which was loosely linked to it, represented the oesophagus; a straw emerged from within the balloon, which represented the mouth and pharynx. She briefly introduced the elements of the model and posed a question to the class: *How does the air have enough space to pass through the breathing tube when we eat?* To explain that phenomenon she demonstrated the function of the oesophagus by means of the model. By blowing air into the straw the balloon became bloated, serving as an analogy to the expansion of the oesophagus when swallowing food. She explained that for the purpose of demonstration the air she is blowing represents the food resulting in the expansion of the oesophagus. When food enters, the expansion takes space, *so how does this not interfere with the passage of air?*

Using the model in combination with her body, speech, gesture and gaze, during a 5 minute period she demonstrated and explained how the characteristic structural features of the oesophagus and the structural features of the breathing tube enable both the expansion of the oesophagus when we eat (demonstrated by blowing up the balloon) and the passage of air, due to reciprocal relations between their structure. This, she explained, is possible due to the structure of the breathing tube (the rings are open in the back), which in turn leaves the breathing tube free for the passage of air. She pointed out that she focused on the relation between these two organs because it had not yet been dealt with in class. Using the model as a basis she also referred to the reciprocal relations between the digestive system and the respiratory system. Following her presentation pupils responded, by asking for clarifications of the model itself to which she responded. Others pointed out the new information they gained, and some commented on her overall performance. One

pupil noted that she did not mention the role of the epiglottis, and its different functions in two different positions as we breathe and as we swallow. Following the presentation and discussion Nitza revised and improved her written report.

Presentation two. Eleanor also explored the breathing tube, but she focused on characteristics of its inner structure and explained how these are adapted to the function of preparing the air for respiration. Eleanor deployed representational modes different from Nitza's. She based her explanations on images. She used the overhead by first showing a photo of the inner structure of the breathing tube she scanned from a source book (in the library outside school) in order to show *what it really looks like in reality.* Then she displayed a transparency with a schematic diagram she had drawn focusing on the hair and the mucus to stress their function in preparing the air for respiration. She used pointing and tracing movements, speech and gesture to mediate scientific meanings represented in the visual mode.

Presentation three. Katya, explored the inner structure of the nose. She also used material items. She pasted Play-Doh in different colours and forms on a wooden board to represent characteristic elements of the inner structure of the nose in a relief style. In addition she prepared a key on the wooden board to guide the viewer. The resources she used were the materials that included the Play-Doh, colours and forms in combination to signify and differentiate between key players that she represented. For example, blue and circle forms signified air, yellow in a *funny* form (as she defined it) denoted mucus, and red in the form of long strings were capillaries. She explained the function of the inner structure of the nose in preparing the air for breathing (humidity, cleaning the air from germs and dust, balancing the heat and cold of air). Through her model she also pointed out the reciprocal relations between the blood system and the respiratory system, using pointing and tracing movements, speech, gesture and facial expressions to mediate meanings.

The samples described and discussed reveal that the pupils' presentations were multimodal events. The practice of staging presentation events, which has only partially been described, is a process that can be considered from many aspects. I will focus on two complementary aspects. The first one concerns the rhetorical aspect and the second concerns the function of semiotic modes in the process of presentation.

The teacher gave the presentation task about three weeks prior to the event described. Her instructions and framing included headings she provided, a sequence of content to be covered and procedural instructions of how to get organised in order to accomplish the task (resources, time schedule, and so on). That is, she guided the pupils

in regard to what she expected to be represented but not how or in what form to communicate the topic of inquiry to the class as an audience. The pupils independently made decisions of how to fashion their knowledge and how to communicate it in class. Many pupils collaborated with peers, some consulted with the teacher, but it was the pupils' final decision how to design their presentation event. Standing as a peer pupil at the front of the class is a demanding social and rhetorical task involving power relations. The class' interest as an audience cannot be taken for granted. That is, the task of presentation places rhetorical requirements on the pupil, which are different from those required in the accomplishment of a written text task.

To illustrate this notion, I will turn now to the sample presentations described above. The three pupils were engaged in explaining phenomena in the human body in scientific terms framed in the wider rhetorical framing of the shared topic in class and the task framework set by the teacher. Each pupil deployed different kinds of objects in integration with different strategies and semiotic modes. They manipulated existing semiotic objects (i.e. photo of the inner structure of the breathing tube) or self constructed semiotic objects (i.e. the oesophagus model, the relief model of the inner structure of the nose). They used different strategies and communicative modes surrounding these objects. Take for example Nitza's presentation (observation five, presentation one). She used the oesophagus model that she constructed as a rhetorical means. To provide scientific explanations she used a number of rhetorical strategies in integration with various communicative actions around the model. The rhetorical strategies she used include: introducing the subject of exploration/presentation; naming structural elements by means of the model and her own body; initiating questions; demonstration and constructing explanations. She manipulated the model in integration with speech, gesture, and gaze. In addition, following the overall communicative event, that is, her presentation and the class discussion in response, she revised her written report as the teacher had suggested which resulted in an improved written text.

A set of related questions emerged during these observations. In what ways do the different objects, strategies and communicative modes being used and integrated by different pupils contribute to the rhetorical process of the presentation event? How do they contribute to the rhetorical functions to communicate scientific knowledge? What types of communicative actions can be considered as semantically meaningful, i.e. does gaze or do gestures have a separate semiotic function? What is the contribution of the different communicative modes operating in the overall presentation event to the resources pupils draw on in the revision of their written report?

COMMON NOTIONS AND IDEAS

The observations described and discussed have a number of notions and issues in common, which were influential in generating the research questions of this thesis. I present these ideas in brief, in an organised manner, in relation to the research questions outlined in the introduction of this chapter:

- The science classroom is a "multimodal environment" (Kress et al., 1998, p. 34) in which the teacher makes a range of resources of different types available to the pupils.
- The pupils are actively engaged in the practices of learning science. These involve motivated selection of elements from the teacher's lesson, material items, and a range of resources made available in the science classroom, which they rework and transform into their own produced multimodal texts and presentation events. Pupils' textual productions and presentation events differ remarkably. Each production involves the use of a range of resources deployed differently for representation and communication of scientific knowledge.
- Learning science in the science classroom involves learning certain generic conventions of school science. Yet the form of texts to be produced is usually not discussed; pupils independently make generic decisions in the production of their own texts.
- The performance of presentation events requires pupils' rhetoric considerations and decisions in relation to how to stage the presentation interestingly in real time at the front of the class as an audience and how to communicate their topic of exploration.
- Following the overall communicative event of presentation pupils may choose to, and many actually do, revise and improve their written report on their topic of exploration.

In the course of my observations and from reflection on materials I acknowledged that I could not account for scientific texts in the school realm, as expected of me on the professional level, based on the traditional conception of what constitutes texts. The common conception considers the written language as the primary mode for representation and communication, and shares the conception that to cognize, that is, to think is a linguistically mediated action. Yet evidence from the science classroom, as exemplified by the observations, reveals that children in the science classroom mediate what thinking might have been through a range of modes. "Cognition is wider than words, and the forms through which our cognition is given public status are as diverse as the social forms of representation we use in culture to convey meaning" (Eisner cited in Guba, 1990, p. 91). The underlying assumption is, that the two different views, one

through a "linguistic lens" (Gardner, 1983) and the second through a "semiotic lens" (Lemke, 2000) imply inconsistent far-reaching pedagogical implications.

Based on a range of evidence and readings it became clear to me that to account for pupils' presentation events, textual productions and other material outcomes of the process of science learning, I would have to search for a comprehensive theoretical framework, which equally considers, on a principal level, any semiotic mode deployed for representation and communication of meanings in the science classroom.

The theory of *multimodality,* which developed as a domain in social semiotics, provides such a framework. As a theory, multimodality and social semiotics deal with the construction of meanings in all acceptable modes of representation and communication in a social cultural context. The multimodal approach to learning in the science classroom applied in this thesis is developed by a number of research projects in science classrooms (Ogborn, Kress, Martins & McGillicuddy, 1996; Kress & Ogborn, 1998; Kress, Ogborn, Jewitt & Tsatsarelis, 1998; Kress, Jewitt, Ogborn & Tsatsarelis, 2001). These projects contributed a significant bulk of research knowledge on the multimodal nature of communication and the kinds of rhetoric that teachers and pupils use in the science classroom in secondary schools in England.

This thesis stands in line with these projects in the sense that it explores learning in the science classroom from the aspect of multimodality and rhetoric. In view of the fact that the mentioned projects focused on communication in the science classroom in secondary schools in England, this study is different from a number of aspects. This study focuses on communication in the science classroom primarily:

- From the pupil's perspective;
- At primary level schools;
- In Israeli schools, hence a distinct culture and a distinct semiotic system.

To the best of my knowledge the notion of multimodality has not been approached thus far in Israel in classroom research, in the field of education in general and in science learning in particular. My aim in this study is to describe and better understand the different ways in which pupils deploy a range of available resources in learning practices in the science classroom to represent and communicate scientific knowledge. In addition, I suggest a different view of how to track evidence of science learning from the pupil's perspective by reading the outcomes of the process of learning from a multimodal view. Basic notions and principles in the theory of social semiotics and multimodality will be considered in chapter two, the theoretical chapter of this paper.

CHAPTER 2
A MULTIMODAL AND SOCIAL SEMIOTIC THEORETICAL FRAMEWORK

> Meaning (acting semiotically) develops along with doing (acting materially) as interdependent modes of human behaviour; and both depend on interaction with the physical and social environment.
>
> (Halliday, 1994b, p. 7-8)

INTRODUCTION

The purpose of this chapter is to specify the conceptual and theoretical framework that shapes this research and the underlying rationale behind its application. The theoretical framework of this thesis is based on the theory of multimodality, which is considered a domain in the theory of social semiotics. As a theory, multimodality was developed on the basis of Halliday's model of language as social semiotic (Halliday, 1978; Halliday & Hasan, 1985, Halliday, 1994a). Halliday's concept of language as a function in context enables the application of his model to account for any act of meaning in a range of semiotic modes. Semiotic modes are systems of meaning for representation and communication of meanings in the various fields of life.

In early stages of this research the range of collected materials was an unstructured source of evidence, which drove me to reading. The selection of readings, mainly from the social semiotic tradition, was based on the attempt to find a theory that explains the multimodal nature of texts produced for and by pupils. Specifically, this was a search for an explanation for the multimodal nature of the practices of learning science in the science classroom, including the rhetorical aspect from the pupil's perspective. That is, my reading of research literature was in search for a theoretical framework, which could explain my collected materials rather than verify a given theory. As I formulated the research questions a part of the materials became data. That is, the collection of data was inspired by the research literature which I read. Furthermore, the generation of the framework and categories of analysis (presented in detail in chapter three) drew on notions from research literature discussed in this chapter.

The selection of readings was in accord with the requirements of the central issues generated from the observations, materials and data, but it was also influenced by my personal and professional educational philosophy and experience. "Researchers may be attracted to a particular theory on the basis of its compatibility with conceptual frames and preferences they already have" (Goetz & LeCompte, 1984, p. 41). The view of

learning as a dynamic transformative process of sign making within the theory of multimodality and social semiotics responded to my pedagogical view of learning. It also responded to my interest to derive a better level of understanding of the meanings of pupils' differing semiotic communicative actions, rather than to view these in terms of their behaviour or individual differences.

This chapter is organized into seven sections. First, the notion of multimodality will be considered from a macro perspective of contemporary communication and from an educational perspective. Then, I present basic terms, notions and principles in the theory of social semiotics. I continue with the theory of multimodality, which is based on social semiotic principles. Subsequently the nature and function of communicative modes, which are used in communication in the science classroom, will be considered on a theoretical level, based on the literature review. Next, the conceptual aspect of rhetoric in science education will be discussed as a complementary feature of the multimodal aspect. Afterwards, the notion of school science will be reviewed and learning science at school will be conceptualised in terms of "habitus" (Bourdieu 1984, 1991). Finally, the conception of a "text", "event" and the approach to "genre" applied in this thesis will be discussed.

MULTIMODALITY

Before discussing the underlying principles of the theory of multimodality, the notion of multimodality will be considered. This will be accomplished first from a macro perspective of contemporary forms of representation and communication and then from a micro perspective in the context of education. Recently multimodality has incorporated the increasing understanding that any occasion of communication involves an ensemble of multiple communicative modes at the same time. Nonetheless, "multimodality is not a new phenomenon" (Kress, Leite-Garcia & van Leeuwen, 1997, p. 257). Coexistence of visual-graphic representations with language in scientific texts is not a recent development. Since the seventeenth century, illustrations and drawings gradually evolved in different domains and contributed to the emergence of modern science (Olson, 1994). However, this coexistence of language and images was based on the presumed superiority and highly valued status of language as the main mode of expression (Bolter, 1998).

In fact, multimodality is not a characteristic of the domain of science only; all texts are multimodal, even texts that are essentially verbal combine different modes. Resources such as orthography and typography, the layout on a page or screen, the colour and the typeface are visuals that matter in making meaning. That is, a verbal written text

is also a visual object. When people speak they also act multimodally, with gestures, intonation to convey meanings, and moving and integrating with language in other symbolic ways.

A SHIFT IN THE SEMIOTIC LANDSCAPE

Although multimodality is not a new phenomenon, it has been recently studied in different sites. The increasing awareness and interest in multimodality is founded on new realities. These new realities are the shifts in forms of representation and communication, a process in which values are involved. The recent shifts in modes of representation and communication in every day life is also projecting a shift in value, related in particular to the visual mode. The recent shift in forms of representation and communication is a global move (The New London Group, 1996) i.e. mass media, advertisements, and school textbooks combine visuals, language and other resources. These shifts have raised a body of research that attempts to understand new forms of representation and communication in a wide context. Therefore, first, the larger picture is briefly discussed, and then the paper focuses on communication in the micro-context in education.

Kress and van Leeuwen (1996) have taken up the challenge to provide a framework for the analysis of the increasingly multimodal nature of communication (in Western culture) with focus on the visual mode. They propose the metaphor "semiotic landscape" (p. 33-34) to conceptualise contemporary communication in the macro-context. They suggest that like an element in a landscape that can be understood only in its wide environment, any mode can be understood in the large context. Researchers (The London Group, 1996; Reinking, 1998) suggest that shifts in forms of communication are not only an effect of technological developments, but also a result of large global social and cultural forces. These forces include multiculturalism, global flow of information and global economic developments, which cross and blur semiotic boundaries no less than political borders.

Change in forms of representation and communication is also due to the particular properties of semiotic systems. Lemke (1995) has pointed out that semiotic systems are dynamic open systems, which persist through constant change, happening over long stretches of time, through constant use, in interaction with the environment. Dynamic open systems may remain temporarily stable in a stable set of environmental conditions, but are likely to change as the environments change. This is the case with shifts in the semiotic landscape in light of contemporary new realities.

The new reality of the semiotic landscape is most salient in everyday life, and far less acknowledged in school and academic contexts. Outside school, in everyday life, the written language is losing its dominant role in different domains of life. In addition, visual resources play a powerful role in meaning making, so much so, that media theorists and art historians speak of a visual culture that we are living in (Reinking, 1998). Yet, inside school the shift in the semiotic landscape is not yet seriously considered (Kress & van Leeuwen, 1996). This means that children move and mediate between two landscapes of communication. One landscape is a mode of communication available and valued in school and the second is a mode of communication outside of school. Reinking (1998) argues that despite the rapid development of multimedia technologies that facilitate the production of multimodal texts, at school, children are not taught how multimodal texts work. Peacock and Weedon (2002) contend that the difficulties elementary school children experience when using science texts are not fully addressed; in particular the use and interpretation of visual elements in science texts is given limited attention.

In fact, "children act multimodally" (Kress, 1997, p. 97). From the moment children are born they enter a process of "semiosis" in a multimodal world. The notion "semiosis" embraces the ways people make meaning; how they shape meanings; how they represent meanings, and how they respond to meanings. Hodge and Kress (1988) describe the process of semiosis as an interactive, dynamic, transformative process in which children act as semiotic agents. Young children are constantly engaged in construction and reconstruction of meanings through a range of media accessible in their surroundings. The materiality and the shape of things carry meanings which young children take into consideration in the transformative process of meaning making.

Children gradually learn to differentiate between semiotic resources, such as writing from drawing, (Ferreiro & Teberosky, 1982) as independent systems "thus opening up larger combinatorial spaces for using them in co-ordinated ways" (Lemke, 1998b, p. 288). Young children know how and indeed act multimodally, by integrating meanings in different modes. For instance, they read picture books while speaking with others about it, and/or acting out characters and events from the book by means of toys and other objects. They are also accustomed to transforming, with ease, meanings from one mode to another. They transform experience into two dimensional drawings and writing. They retell stories from T.V. or video and transform elements from picture books into a 3D construction. The child's "transformative practice" (Kress, 1997, p. 13) remains but it is more and more applied to existing cultural formed materials.

When children enter school they bring with them a repertoire of semiotic resources both for interpretation and representation. This repertoire offers diverse potentials for the making of meaning, and therefore offers different affective, cognitive and conceptual possibilities (Kress, 1997). However, the transition to school, as an institution, sets constraints on the child's use of semiotic resources; what Bourdieu calls "rites of institution" (Bourdieu, 1991, p. 117). This transition, according to Bourdieu, sets a kind of boundary between the child's semiotic experiences before schooling and in school. A child is expected to reframe his semiotic experiences and knowledge, in order to adapt to school practices and ideologies. This causes children to abandon other semiotic resources they are experienced with, in favour of the written language.

Teachers encourage young children in early grades to use visual resources, for example, for illustrating their writing, or for drawing and other artwork. However, this is usually perceived as a means of personal expression rather than communicating meanings. Although teachers support young children's reading by attending to images in picture books, the images are regarded as secondary to the written text. The implicit conception is that the meaning of the image is secondary and depends on the written text. Similarly, the relation to visual representations in scientific texts was perceived as secondary to the written text in interdisciplinary professional discussions mentioned in the preceding chapter.

By attending to images as secondary to the written text teachers act, most certainly in an unconscious way, in accord with Barthes' (1977) view on the anchoring function of language in relation to images. According to Barthes the written text directs the reader through meanings of the image. He viewed images as too open for interpretation, and the function of language as an anchorage. "Anchorage is a control... with respect to the liberty of the signifieds of the image, the text has a repressive value" (p. 40). Thus, according to Barthes, the written text expresses more definite meanings. Kress and van Leeuwen (1996) challenge Barthes' position, in light of the shift in forms of representation and communication. They suggest that "the visual component of a text is an independently organised and structured message – connected with the verbal text, but in no way dependent on it and similarly the other way around" (p. 17).

Various semiotic features, such as large images, or colour, are perceived as easily and immediately comprehensible. This derives from a strong Western tradition that images can present reality transparently (Kress, Leite-Garcia & van Leeuwen, 1997). The Renaissance invention of linear perspective has led to the claim that artists can present the viewer the world as though they are looking through a window into the real scene. This

argument was even strengthened by the invention of photography, which is perceived as a technology that automatically records the light, which is actually out there without the artist's interpretative intervention (Bolter, 1998). Kress & van Leeuwen suggest that visual communication is not transparent and universal but always coded and culture specific. It seems transparent only because we know the code in our culture.

THE THEORY OF SOCIAL SEMIOTICS: BASIC NOTIONS AND PRINCIPLES

First, basic notions and principles in the theory of social semiotics need to be clarified since the theory of multimodality is rooted in the theory of social semiotics. As a theory, semiotics deals with the question of how human beings make sense of the world and how they communicate with each other in exchangeable symbolic forms. A conventional approach considers semiotics as the general study of the signs, "A science that studies the life of signs" (Saussure, 1974). Halliday (1978) suggests a modified definition whereby semiotics is considered the study of sign systems. That is, Halliday's definition puts stress on semiotics as the study of "meaning" in a most general sense. Sign systems are semiotic resource systems, through which people make meanings. A semiotic resource system provides possible ways of meaning making in a culture, from which people can make choices based on their interest.

The Nature of Sign and Sign Making

The key notion in semiotics is the sign, which consists of the relation between form and meaning, the signifier and the signified. The emphasis in the process of semiosis is on the relation between the signifier and a meaning - the signified. Researchers in the social semiotic tradition are departing from conventional forms of semiotics, for example, from Saussure's work (1974) that views the relation between form and meaning of a sign as pre-existing and arbitrary. An essential notion in social semiotics is that signs have to be constructed by a sign creator. That is, the emphasis in the process of sign making is on agency, on the active role of the meaning maker. It follows that signs are not arbitrary. Signs are always a motivated conjunction between the signifier and the signified, constituting marks of the sign maker's "interest" at the moment of production. This is a process, in which the sign maker has a meaning, (which is the signified) and he/she chooses the best available form to express the intended meaning, which is the signifier. In Kress' view (1993a) the notion of "interest" is any act of meaning making arising from an individual's positioning at a particular moment, which is comprised of multifaceted components. These components include social, cultural and psychological history, power

relations, purposes and intensions. Accordingly, "interest is a direct consequence and an expression of the sign maker's subjectivity" (Kress, 1996a, p. 20). As the sign is the result of the interest of the sign producer, it can reflect, at least hypothetically, the cognitive and affective action of the producer of the sign (Kress, 2001).

However, signs are not entirely new creations since they are constructed on the foundation of available resources and within social constraints in a culture. People are aware of social conventions and constraints in their culture. Being socially constrained does not prevent an individual from being creative. Young children are not yet constrained by their culture's conventions as fully competent people are. They gradually learn to act within social conventions in their culture. Kress (1997) has pointed out that the view of a sign as arbitrary and as a stable relation between meaning and form has far-reaching pedagogical implications. It can lead to a mismatch of pedagogy with the child learner's potential and abilities. In the light of this view of the nature of sign and sign making, a text or event is perceived as a motivated complex sign. The second point, which is an essential characteristic of signs, is the multimodal nature of the sign. "All signs are multi-modal" (Kress, 1993a, p. 187). Even mono-modal texts in the written mode involve visual semiotic such as orthography and typography, which influence the construction of meanings.

The link between semiotic and social indicates that social semiotics as a theory is concerned with the social system as a system of meanings, and that signs, in their constitution, are always social. It indicates that semiotic resources are deployed for social purposes and that all semiotic acts and processes are referred to "as social acts and processes" (Hodge & Kress, 1988, p. 122). Social semiotics encompasses all systems of meaning, which people use and not just language as speech or writing. It includes gestures, facial expressions, clothing, making music, drawing, dancing, and everything that is recognisable as meaningful, which "taken all together, constitute human culture" (Halliday & Hasan, 1985, p. 4).

Learning as a Transformative Process of Sign Making

A major principle in the conception of the process of the making of signs is that signs are not simply chosen from existing signs and re-used. Rather, it is a creative and innovative transformative process of available resources. In order to illustrate this process consider the text under the heading "Reflected in that Eye", figure 3, produced by Ofir. He produced this text in response to the teacher's prompt that the pupils should imagine that they have a third eye which can view only the inside of the body.

The task was given following a class discussion on the issue: *how to enhance our health care*. Ofir selected elements from the class discussion (children's real stories on heart-attacks in the family, discussion on causes, treatment and prevention) and combined it with a range of his available affective, cultural and textual resources, which he transformed into an innovative complex sign – an entirely multimodal text. My suggestion is that he views the relation between the images and the verbal elements in his text as conveying the message simultaneously not as one of illustration. Ofir, as many other pupils in the class (consider observation two in chapter 1), located the imagined third eye in the heart area. In everyday life (in some cultures), the human heart denotes affective and cultural meanings, values and beliefs, which are not necessarily congruent with the relevant scientific body of knowledge. Ofir selected a ready-made existing signifier, the everyday common image of the heart. He used the same image in various combinations. He expressed interpersonal meanings through the drawings of two figures, a boy and a girl, on which he drew the image of the heart. In an unmarked separate space of the page he represented "scientific" meanings in the visual mode. He used the same signifier, the common image of the heart, but in a new composition, which he constructed to signify salient features of a sick heart versus a healthy heart, which Kress (1997) terms "criterial characteristics" (p. 11).

Although here again he used the same common sign to signify the heart, the new combination he created expresses "scientificness" although not in a conventional graphic form. Scientificness is achieved by representing the heart as an isolated object in the form of a diagram in an analytical way detached from the context of the human body. This is in contrast to the same image of the heart on figures of a boy and a girl he drew, which denote affectionate meanings. "Scientificness" is also expressed by the EKG framed graphs corresponding to each represented heart. That is, creativity in the process of sign making evolves from novel use of existing resources (Kress, 1995). Although unconventional, Ofir conveys a range of transformations of resources in the visual mode for the expression of scientific meanings in learning in the science classroom.

This creative transformative process is also evident in his generic choices in the written elements in his text, i.e. a poem, which he composed on the loving heart and a list of feelings of the heart. It could be argued that Ofir's generic choices are "inappropriate" in the context of science learning. The genre of a poem has become in our culture a sign of affective meanings rather than ideational meanings. Literary texts versus scientific texts are traditionally perceived as deriving from two cultures, scientific and humanistic.

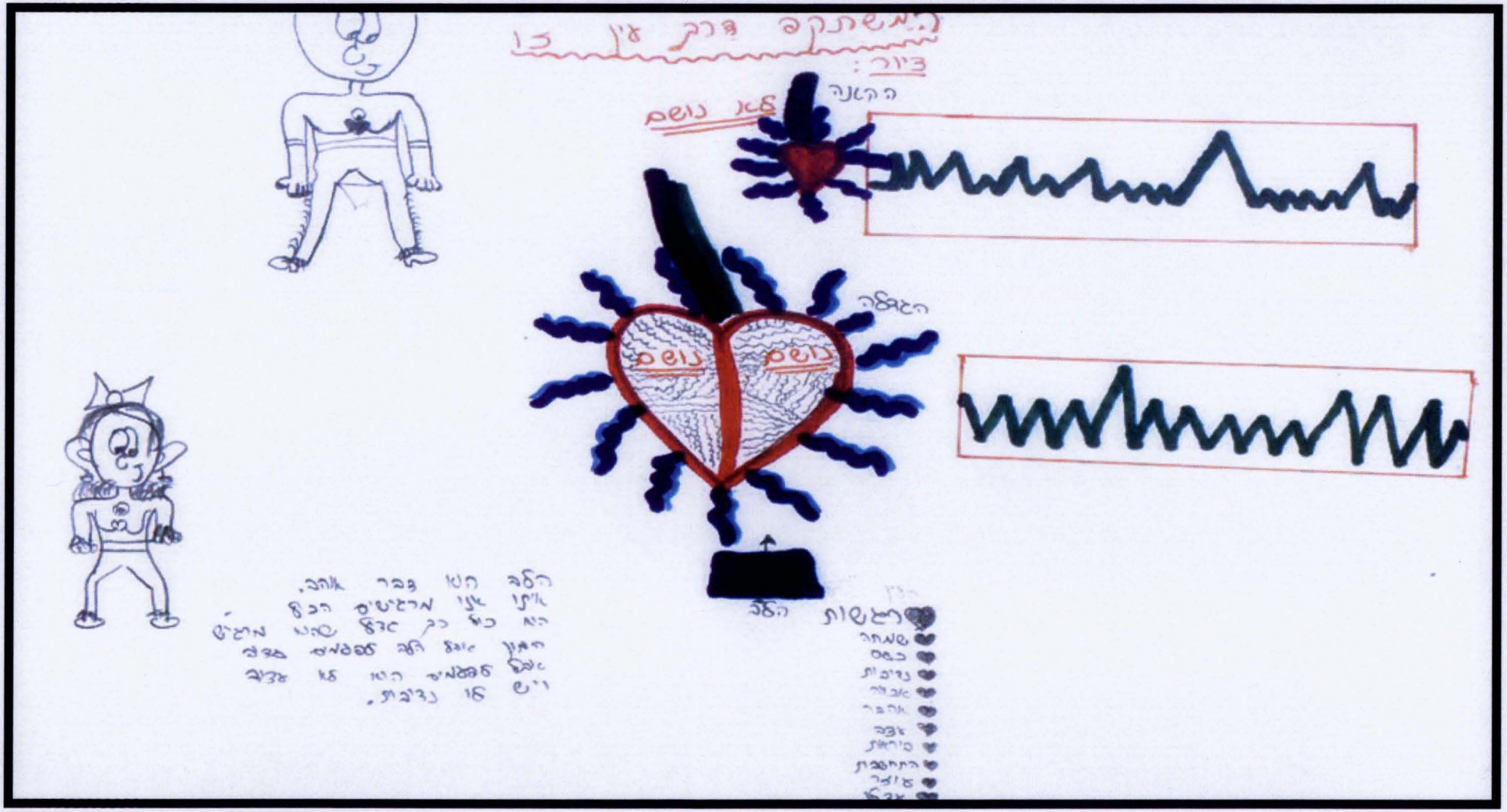
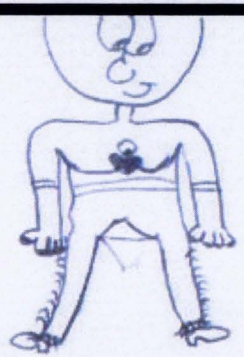
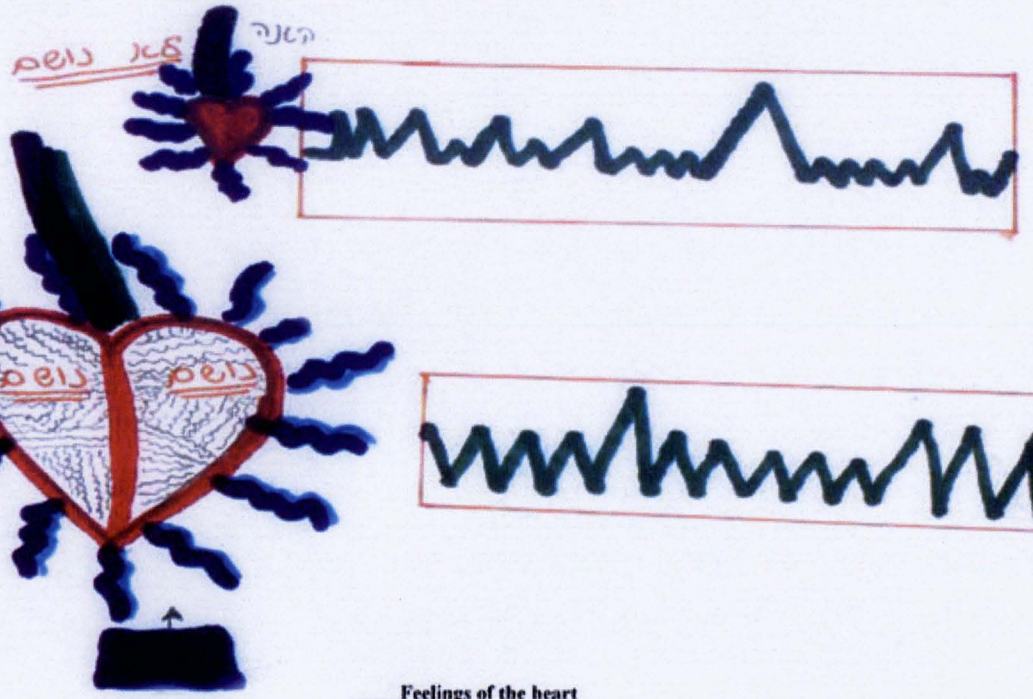


Figure 3. (a) "Reflected in that eye"; (b) Translation of the original text



Reflected in that eye



The heart is a loving thing
With him we feel everything
He is so big that he feels a lot
But the heart is sometimes sad
But sometimes he is not sad
And he shows generosity.

Feelings of the heart
Joy
Anger
Generosity
Brotherhood
Love
Sadness
Health
Being considerate
Helping
Lazy

(b)

The first culture, scientific, prioritizes ideational meanings and the other, i.e. humanistic, prioritizes interpersonal meanings (Halliday & Martin, 1993). Hence, a poem on the loving heart and a list of feelings of the heart are assumedly unexpected genres in the context of science learning. A social semiotic approach to learning views Ofir's choices as marks of his interest expressing his subjectivity at the moment of production. Motivated by the context in the science classroom, it is Ofir's interests, which led him to deploy specific generic forms from his available resources.

The example under discussion demonstrates that the process of meaning making involves transformation of a range of resources that arise from the individual's affective, social cultural and psychological history and positioning in the world, which result in the production of a multimodal sign/text. The underlying assumption is that nothing in the process of semiosis is done incidentally. Meaning makers do not just re-use existing signs. They make active choices, and mould and transform available resources for the creation of texts and events or namely, complex new signs. Such a process necessitates "work" and "action" (Kress & Ogborn, 1998). That is, meaning making is viewed as action, in Lemke's (1995) terms "making meaning is a practice" (p.157). Thus I speak about the concern of this thesis in terms of the practices of learning science from the pupils' perspective. In accord with the conception of the nature of sign and sign making, the position taken in this thesis is that learning science is not viewed only in terms of a mental accomplishment but also as a social and textual practice (Luke, 1993).

In texts or communicative events the individual meaning maker represents himself. He represents a part of his cognitive - conceptual and affective inner world, and at the same time, the moment he or she engages in the process of semiosis, he remakes and transforms his available resources of representation. The process of meaning making is a constant dynamic process of transformations, which in science learning involves transformation of everyday knowledge into scientific knowledge (Halliday & Martin, 1993; Bernstein, 1996; Christie, 1998). Within the theory of social semiotics, to"know" something, is to have transformed it into meaning, and what is usually called "understanding" is the result of the process of that transformation (Halliday, 1996).

This is again illustrated in Ofir's text production. In a text he produced about a month later, under the heading *after I know* he expresses this process as depicted in figure 4. For example: ...*the difference between today and a month ago is that I thought that the heart looks like that* (drawing of the common image of the heart) *but the heart has an elliptic form and I also thought that the heart breathes but the lungs do the breathing the heart leads oxygen in the blood*...

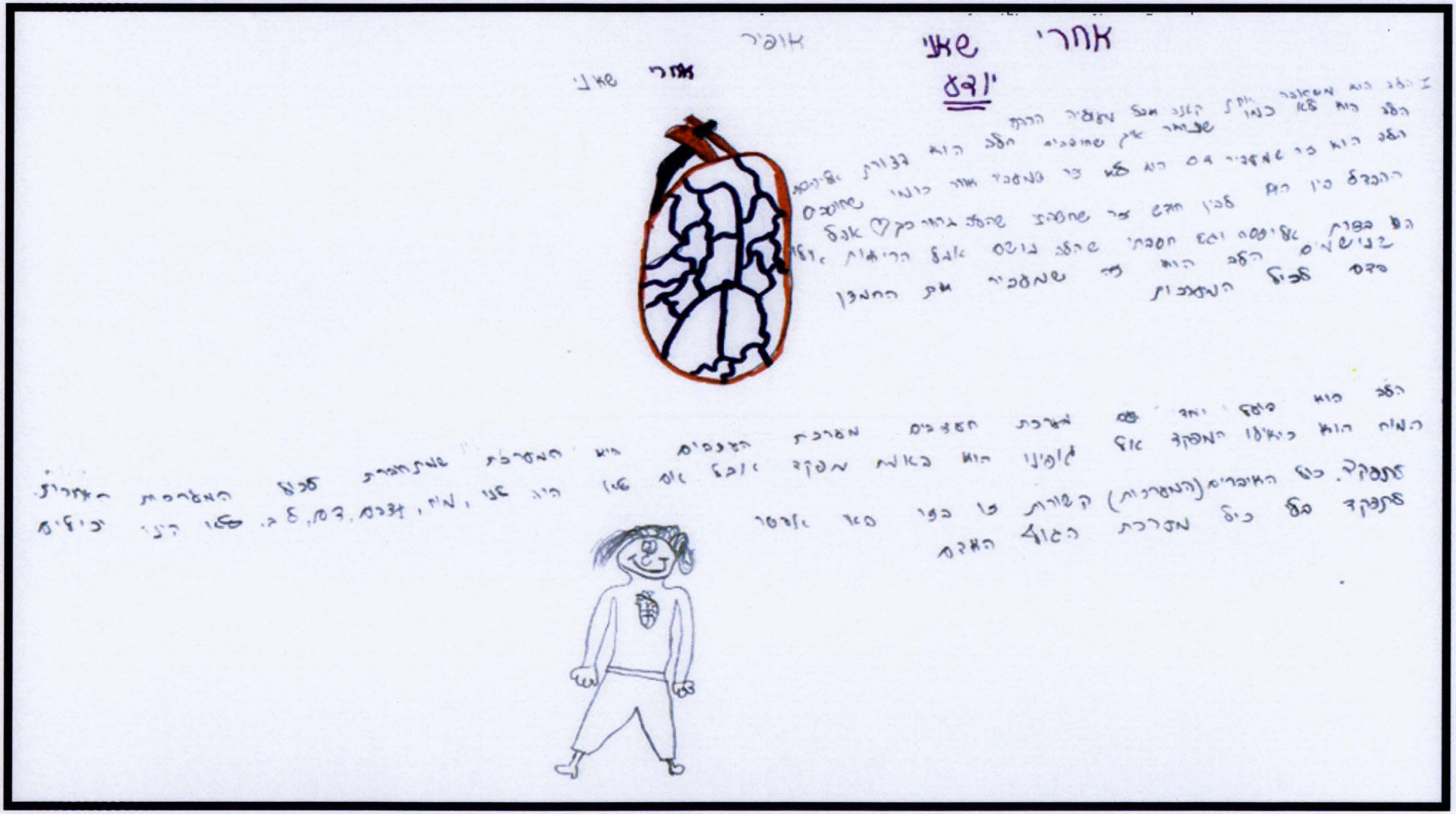


Figure 4. (a) "After I know" ; (b) Translation of the original text

After I know

The heart is a small pump but it is very excellent
the heart is not shaped as commonly thought of the heart
is oval shaped the heart is the one transferring blood
it is not the one transferring air like one would think
The difference between today and a month ago is
that I thought that the heart looks like that (common image
of the heart) but it is oval shaped, and I also thought that
the heart breathes but the lungs are the ones breathing,
the heart is the one transferring the oxygen in the blood
to all the systems

The heart works together with the nervous system the nervous system is the system that connects to all the other systems
the brain is like the commander of our body it is really the chief but if we hadn't had a brain, nerves, blood, a heart,
we could not function. All the organs (systems)
are linked to each other and you can't function
without all the systems in the human body

(b)

In his latter text, Ofir's work is guided by scientific codes of representation, which can be seen as being in accord with the worldview and the knowledge of science, which the school aims to apprentice children towards. In his later text (figure 4) he drew an image of the heart in a scientific form of representation; he provided factual information; he left out the affective dimension, which took significant space in his earlier text; and he reflected upon his former text by reframing and transforming it in relation to knowledge and affective and epistemological dispositions. In science class Ofir developed a resource of criteria in order to consider what expressions of knowledge are relevant to the subject of science.

The discussion on Ofir's texts demonstrates that the making and remaking of signs – of meanings, is a dynamic creative process influenced by the meaning maker's interest, which involves the transformation of the inner state. In this case, Ofir's affective and cognitive conceptual inner world was transformed, which is indeed the nature of learning. That is, the process of learning, of making meaning is a "constant transformation of both resources and of subjectivity" (Kress, 2001, p. 407). It follows that texts and presentation events, as any other material outcome of "transformative action" (Kress et al., 1998) in the process of science learning, are evidence of learning. The meaning of the term "transformation", in a morphological sense, indicates this process. It suggests that there is a "connection between an earlier form and an emerging form, connoting a degree of tentativeness" (Reinking, 1998, p. XVIII).

In the process of sign making transformation involves a process of analogy, guided by the sign maker's subjective interest. Sign makers can use pre-existing cultural semiotic matter such as a generic structure and transform it into new meanings. For instance, a guided tour could turn into a signifier of a report on the voyage through the organs in the respiratory system. A sign maker can use existing materials and transform them into new signs. For example, a balloon can be a signifier of an oesophagus. Through a process of analogy a new metaphor is produced. Flexibility and extension, characteristic criteria of the oesophagus, are materially expressed by analogical material qualities of the balloon. An analogy is created according to the interest of the individual, which determines the characteristics that are to be selected and to be represented at the moment of production.

With time children increasingly adjust the making of signs to the communicational environment not only by representing what they want, but also by including considerations of communication in their interest. This involves considerations

regarding the different people with whom they communicate (i.e. parents, friends, teacher, and an audience) and what they want to achieve by the act of communication. Accordingly signs arise from a "double social motivation" (Kress, 1997, p. 93). One, they arise from who the sign maker is and his or her history and two, they ensue from the sign maker assessing the needs of the communicational environment.

The discussion indicates that a social semiotic view challenges the conception of learning as "acquisition" of arbitrarily constructed signs, which are extraneous to the learner, and teaching as the "transmission" (Bernstein, 1996) or "knowledge telling" (de Beaugrande, 1997). My conception of teaching and learning is consistent with the social semiotic approach, which views learning and teaching as a motivated process of meaning making.

Halliday's Theory: Meaning is Choice

A basic principle in Halliday's theory is that language is a system of potential. As a theory it deals with the question of what people can do with language, on a level of abstract potential. People can potentially alternate within a range of alternative options in each of the systems, which comprise the linguistic system (the semantic system, grammar and phonology). In this model the semantic system, which is the primary concern in a sociolinguistic context, is viewed as "networks of meaning potential". "A network is a network of options, of choices" (Halliday, 1978, p. 40). Within the set of options, of meaning alternatives, the individual makes motivated choices in order to express his/her intended meanings. Hence, a text or event is defined as an "actualised meaning potential" (p. 109). In Halliday's terms "text is meaning and meaning is choice" (p. 137). As an actualised meaning potential a text has a concrete material existence. Multimodal researchers (such as Kress et al., 1998, 2001) view meaning making as something beyond choice; meaning making is an active productive process that necessitates action and work.

The Functionality of Language as a Semiotic System

Another underlying principle in Halliday's (1978, 1994a) theory is the functionality of language. Halliday has pointed out that language is organised as it is in light of the function it serves in people's lives. Within this functional theory any exchange of meanings, namely any text/event is viewed as a product of the interplay between three kinds of integrated meanings, which operate simultaneously: ideational meanings, interpersonal meanings and textual meanings. Though not all three types of meanings are

always equally in the foreground they must be there in any exchange of meanings. The ideational function represents the speaker's meaning potential as an observer. Ideational meanings express the content, peoples' experiences of the world, and the phenomena of the environment. Ideational meanings also express the "metaphenomena, things that are already encoded as facts and as reports" (Halliday, 1978, p. 112). Interpersonal meanings express the status and role of relationships in a situation, expressing the speakers' relations, attitudes, judgements and influence on others. Textual meanings represent the meaning maker's potential of text forming. Textual meanings provide the texture, and they organise the text as a coherent message. Textual meanings fulfil the function of enabling the realisation of the ideational and interpersonal meanings in integration.

THE THEORY OF MULTIMODALITY

As a theory, multimodality is considered a domain in the theory of social semiotics. It focuses on the constitution and function of semiotic modes, with emphasis on the materiality of modes both on a physical and abstract level of representation (Kress & Ogborn, 1998). Researchers in the social semiotic tradition developed a multimodal theoretical framework on the basis of Halliday's social semiotic account of language. The basic assumption is that Halliday's categories of the three kinds of meanings, ideational, interpersonal and textual, are seen as general requirements of any semiotic mode to function as a meaning making resource, and not specific to language alone. In multimodal signs/texts/events the three categories in and across each mode multiplies the possibilities of interaction between the three kinds of meanings (Lemke, 1998b). Lemke suggests that in multimodal texts the combination of semiotic modes constitute "more than the sum of what each mode could mean separately" (p. 288).

Extending Halliday's model of language as social semiotic to other communicative modes implies that the same general social semiotic notions and principles, as discussed in this chapter, constitute the multimodal theoretical framework. Accordingly, like language, visual images and forms of action developed more or less into articulated semiotic modes comprised of networks of interlocking options. As mentioned, Kress & van Leeuween (1996) applied a social semiotic conceptual framework to the visual mode. They conceptualised Halliday's notion of grammar as a meaning making resource (Halliday, 1994a), as a tool for exploration. Halliday views grammar as a resource for representing patterns of experience, which enables building a mental picture of experience and reality. They extended Halliday's notion of grammar to the visual mode, describing principles of composition in the visual mode in terms of

"visual grammar". Just as grammar in language describes relations and combinations of linguistic elements, visual grammar describes relations and combinations between elements in visual representation and communication of meanings. The focus in Kress & van Leeuwen's work lies in the analogue of grammatical/syntactic structures of visual representations. They approach visual representations, even aesthetic visuals, from the point of view of representation and communication rather than from the point of view of "expression" as it has been usually referred to in relation to works of art (Kress et al., 1997, p. 260). By principles of visual grammar they describe how "depicted people, places, and things combine into visual 'statements'" (Kress & van Leeuwen, 1996, p. 1). They propose a detailed framework for the analysis of representation and communication of meanings in the visual mode based on the assumption that the visual mode as any semiotic mode has the potential to create motivated signs in respect to the three general functional meanings (i.e. ideational, interpersonal, textual). Later in this chapter, under the heading "the visual mode", I will outline some principles of their suggested framework, relevant to the data analysis in this thesis.

A relevant development in the theory of multimodality, of particular significance to this thesis, is the extension and application of the multimodal theoretical framework to research projects in science classrooms. For example, the project "explaining science in the science classroom" (Ogborn, Kress, Martins & Mcgillicuddy, 1996) provides a framework for the description and analysis of how and by what means teachers in the science classroom construct explanations of scientific ideas. Teachers use different strategies such as creating difference, constructing scientific terms and entities, which create what Ogborn et al. term an "explanatory context" (p. 115). This context invites, justifies and creates the resources for an explanation. This framework provides a micro perspective by looking at structures of explanations and the function of all the co-operating resources deployed by teachers in the act and art of explaining. That is, explanation is one of many rhetorical strategies science teachers employ to shape pupils' knowledge and view of phenomena in the world. At the same time this framework provides a macro perspective, pointing out ways of linking the explanation of scientific ideas to the multimodal nature of communication.

In the project "rhetorics in the science classroom: a multimodal approach" Kress, Ogborn, Jewitt & Tsatsarelis (1998) applied a multimodal framework to explore the ways in which different semiotic resources contribute to the rhetorical functions in the science classroom (see also Jewitt, Kress, Ogborn & Tsatsarelis, 2000, 2001; Kress, Jewitt, Ogborn & Tsatsarelis, 2001). They acknowledged that science teachers rhetorically

orchestrate language resources, visual resources and forms of action including the body, movement, manipulation and interaction with objects, to provide pupils a coherent scientific account of phenomena. They extended Halliday's notion of grammar as a meaning making resource to explore how meanings are realized in the science classroom by interweaving speech, action and the visual mode. Each mode deployed and the interplay between co-occurring modes offer the rhetorician different ways to shape scientific knowledge in communicative events in the science classroom. Take for example, their account of the teacher's rhetorical orchestration of modes in a lesson on blood circulation. In the lesson the teacher used speech, image, gesture and action on a model to realise ideational functions; two key notions, namely the cyclical movement of the blood and the contraction of the heart. The teacher's body realised an interpersonal function; he used his body as a visual location for the information he provided in the lesson by speech and image. Finally the teacher orchestrated semiotic modes across the lesson into a coherent text by a range of textual features. This was accomplished, for example, by synchronisation of different semiotic modes in the description of the cyclical movement of the blood through speech, action and images.

Within the theoretical framework of multimodality, applied in that project, all semiotic systems are considered as sets of resources, which are shaped in order to achieve a "rhetorical entity" (p. 5), a text or an event. Kress et al. (1998) applied Kress and van Leeuwen's (1996) framework to explore the meaning and rhetorical function of images used and produced in texts in the science classroom. The project also explored the meaning and rhetorical function of forms of action and the constitution and function of objects acted upon in the rhetoric of doing science. In the rhetorical process of a lesson, the materiality of objects played a significant role in the overall rhetorical orchestration of semiotic resources in the science classroom.

THE CONSTITUTION AND FUNCTION OF MODES

A multimodal and social semiotic view of meaning making and of learning implies the attempt to trace the sign maker's interest by identifying the kind and nature of semiotic resources which the sign maker used and transformed and recognizing their function in realising meanings. This notion is incorporated in the overall research question and the sub-questions that this thesis addresses (presented in chapter 1). Thus, at a theoretical level I will consider the constitution and function of semiotic modes, which operate in the practices of making meaning in the science classroom described and

discussed in chapter one. The discussion on the constitution and function of semiotic modes is based on the relevant literature review.

The term "mode" refers to a meaning making resource, which evolved from a "medium". A medium is a material substance, which a culture shapes over time into regular means of representation and communication. That is, a mode as a resource for making meaning is both material and symbolic. Kress and Ogborn (1998) discuss the constitution and function of semiotic modes from a multimodal approach. They emphasise that the inherent characteristics of the materiality of a medium affect the "semiotic affordances", that is, the "semiotic potentials" and "semiotic limitations" (p. 7) of a mode. Semiotic affordances open up certain possibilities of representation and communication while at the same time it constrains the representation and communication of other meanings.

The developments of various media into modes in a culture derive from the semiotic possibilities and limitations of the material substance of each medium. Hence, this thesis deals with the question of the ability to describe and analyse how pupils make use of the possibilities and constraints of the range of semiotic modes they deploy in the process of learning science. As explained, within a multimodal and social semiotic framework, any act of meaning making in the science classroom, in fact any act of meaning, is considered as multimodal in nature. Nevertheless, considering the constitution and function of modes separately helps in noticing even seemingly transparent meaning making resources which operate to realise meanings. Thus, in the following section I will consider the modes separately, for the purpose of analysis.

Language as Spoken and as Written Modes

The mode of language as speech has been culturally shaped from the medium of sound. The materiality of the medium of human sound has the potential to provide a range of resources in co-operation with the semantic level of language. A characteristic of the medium of human sound is that it is temporarily sequenced. The sequence of linguistic elements is a semiotic resource for meaning making, as are intonation, pitch, pace, stress, all of which provide possibilities to affect meaning. That is, language as speech is multimodally constituted. However a range of available resources, which are significant to the production of meanings in the spoken language are commonly not represented in the written mode (i.e. pitch, stress or the pace of speech). Language as a written mode has been shaped from a different medium than the spoken language, i.e. from a visual-graphic medium. Hence speech and writing function as distinct semiotic modes because they

derive from different semiotic materialities. In contrast to spoken language, "writing is a visual medium; and so time and temporality are replaced by space and spatiality" (Kress, 1997, p. 16-17). The written mode is comprised of visual constituents in integration with semantic resources. That is, both speech and writing are multimodally constituted, reflect meanings on a symbolic level and have a material existence.

A functional theory of language, which is the basis of Halliday's account of language, is concerned with the use of language. Within this theory language as speech and writing are viewed as systems of meanings accompanied by forms through which meanings can be realized. That is, it is by means of grammar that expressions of linguistic meaning potential are realised (Halliday, 1979, 1994a; Halliday & Hasan, 1985).

The language used in different social situations is shaped by the relationships between the participants and the nature of the different social activities. For example, scientific activity has led to specific textual formats and certain linguistic preferences, which reflect the attempt to represent objective facts and general truth about phenomena in the world. These features appear particularly in written texts, but also in formal speech, including that of teachers.

The Visual Mode

The visual mode as a semiotic resource system is less articulated (in Western cultures) than language as speech or writing and therefore it is more open. The materiality of the visual-graphic mode has the potential to provide a range of resources such as, surface, shape, colour, size, strokes and space, organised spatially simultaneously. That is, the visual mode is multimodally constituted like speech and writing.

In the production of signs, the choice and integration of different constituents in the visual mode not only represent intended meanings but also reflect cultural meanings denoting symbolic significance at that point in time of the production. For example, the symbolic importance of cultural meanings is reflected in the use pupils made of colour, shape, lines, centrality and layout in their produced texts in the case of the imagined third eye task (consider observation two in chapter 1). Visual resources provide the potential to capture represented meanings simultaneously rather than in a temporal sequence, as in the case of linguistic meanings. Visual representations use the material substance of light and space, which provide possibilities of spatial simultaneous representations in combination with light effects, which multiply the meaning making possibilities. For instance, the visual graphic medium has the potential to better represent "topological" meanings (Lemke, 1998b, p. 291) because of its spatial simultaneous characteristic. Representing

the muscles in the human body by a realistic image or the structure of breathing organs by an abstract schematic diagram (consider observation five in chapter 1) is more efficient than a verbal description. This does not suggest that the reading of a schematic diagram or a topographical map is more accessible or available than a written description would be. The main point to be made here is what Ogborn and Kress term as "semiotic affordances" and "functional specialization" of modes. That is, there are meanings that can be better represented through the visual mode and in different ways than through language resources.

Kress & van Leeuwen's (1996) framework considers, in Halliday's meta-functional terms, ideational, interpersonal and textual functions the visual mode fulfils simultaneously, as required in any semiotic mode to function as a system of communication. They describe and classify patterns of representation of the experiential world (the ideational function) and patterns of interaction (the interpersonal function), which the grammar of visual design makes available. They suggest terms of description of how elements of visual design relate to each other and work in integration to construct a coherent composition (the textual function). With respect to representation of the experiential-ideational world, they distinguish in visual communication between a "narrative structure", representing the world in terms of unfolding actions and events, and a "conceptual structure" representing the world in more generalized terms, more or less stable and timeless, in terms of "class, or structure, or meaning" (p. 79).

Aiming to represent phenomena in the world as general truth and objective facts the field of science prefers "conceptual structures", in forms such as maps, diagrams, charts or 3D models. Hence the information is represented in these forms detached, impersonal and often abstract and analytical (Van Leeuwen, 1996). This is achieved by visual characteristics such as the absence of agency, reduced, or absence of, perspective, depth, background, colour, light, shadow and details. In conceptual structures, such as a diagram or a flowchart, two or more elements may be linked by an arrow, so signifying one as the origin, cause or actor and the other as the recipient, goal or effect.

Although naturalistic images or scientific photographs can almost represent meanings as objective and impersonal such as diagrams or maps, scientific texts used at school gradually move from naturalistic representation to abstract representation and from directly to impersonally addressing the learner in order to apprentice pupils in conventions of scientific representation of information and knowledge. Kress & and van Leeuwen (1996) use the term "participants" referring to represented things, items, places, objects or persons, instead of the term "elements" and use the term "process" for the

relations between the represented participants. They make the distinction between "represented participants" and "interactive participants" (p. 46). Represented participants are the subjects of communication (people, places and things, including abstract things). Interactive participants are the participants in the act of communication, such as the producer of images or 3D objects and the viewer. With respect to representing and communicating social relationships in the visual mode they identify a range of visual components, which indicate a set of social relationships significant in a given culture. For example, social distance may be encoded by the size of a represented participant or by its coded distance from the viewer. Attitudinal relations may be coded by the position of the viewer in relation to the represented participant such as in the front, side or margin. Vectorial relations may realize interactive relationships visually; for example the viewer is directly addressed through the gaze of depicted participants.

With respect to the construction of coherent texts the framework provides principles of social semiotics of "visual space" (Kress et al., 1997). The framework considers a page, overhead, screen, board, canvas, etc. as a visual space. The meaning of given participants in that space depends to some degree on whether they are positioned at the left or the right, the right or the left, at the top or the bottom, in the centre or the margin. The framework suggests that vertical top-bottom structures present the top element as the carrier of the generalized or idealized essence of information. In contrast the bottom element is more oriented to "here and now" to practicalities and facts. Therefore they termed the top element as Ideal and the bottom element as Real.

Western cultures socialize their members to encode ideas not only from top to bottom, but also from left to the right. Hence, according to Kress & van Leeuwen a second set of information values is carried by a horizontal left - right structure. The left to right structure is viewed as the spatial analogue of the dynamic from Given to New information in Halliday's (1994a) account of language. The meaning of Given is that an element or participant presents something that the receiver is supposed to already know, whereas the New is presented as something that is not yet known, thus carrying the crucial or problematic point of the message, which requires special attention. The division of the visual space into vertical and horizontal zones derives from the meaning maker's interest. Kress & van Leeuwen suggest further aspects of visual composition, which are independent variables of the structures discussed (i.e. Ideal – Real, Given- New). For example the aspect of "salience" relates to the degree to which elements in a composition draw attention to themselves due to their size, colour, sharpness or their place in the foreground. Another independent variable is "framing", which concerns the degree

elements in a composition are visually separated so as to present them as two distinct units, for example by frame lines or by leaving space between the elements.

Hebrew culture socializes its members to encode ideas from top to bottom and from right to the left of the writing surface. Unlike in English, in Hebrew the Given element normally appears to the right of the New element of a message. Nevertheless, on the level of principle, the framework and terms of description suggested by Kress & van Leeuwen can be adopted and adapted to explore the meanings of visual semiotics in the Hebrew culture as is done in this study. In addition, the new realities of "internationalisation and globalisation" (Kress, 1996c) of forms of representation and communication, the shift in the semiotic landscape, and the new technologies of communication, increasingly influence the current design of texts in the Hebrew culture in different domains of life including the field of education. The influence is particularly salient in the design of teaching and learning materials including science textbooks and other materials. Thus, one can hardly talk about characteristic visual semiotics in current school science texts in Hebrew culture despite the orientation of the Hebrew language from right to left. The semiotic situation is even more complex, since members of the Hebrew culture are socialized to encode numerical information from left to right and at the same time they are socialized to the direction of writing from right to left. This can often result in the progression from Given to New information on the same surface in two opposite directions at the same time, which may be confusing for young children.

Action as a Mode

The term "action" as a communicative mode is a broad term, which covers a wide range of forms of action. Action as a semiotic resource system is less articulate than language resources. The practices of making meaning in the science classroom described involve a range of forms of action. This does not suggest that all forms of action in the science classroom concern scientific matters. The question is when and what types of action function as semiotic resources that have to do with scientific matters. In this respect take, for example, in my data, the teacher's exaggerated, slow and gentle movements in handling the bottle with CO_2 in the experiment used to prove the difference between the constitutions of inhaled and exhaled air (consider observation three in chapter 1). Her actions in that context were not just instrumental and behavioural, but they were meaningful in the successful display of scientific proof. Her action played a role in realizing the rhetoric of making science.

Furthermore, the pupils' presentation events (consider observation five in chapter 1) involved a range of forms of action, which were not just instrumental and behavioural. Take for example Nitza's presentation, where she manipulated and demonstrated the function of the oesophagus model. She used gestures to trace the relevant parts in her body and elements on the model. She used gestures to represent the open vertebrae structure of the breathing tube in relation to the function of the oesophagus. Finally, she used her gaze as a means to monitor the class' uptake of the scientific ideas she communicated and to monitor the turn taking in the discussion following her presentation. These types of action played a significant role in the rhetorical framing of the event; in the construal and communication of scientific ideas; and provide evidence of Nitza's learning and understanding of the issue she explored. Therefore, within a multimodal and social semiotic theory we must attempt to enquire what meanings might be made by actions in the science classroom that are significant for scientific matters.

The Body as a Semiotic Resource

In presentation events the body plays a significant role in construing and communicating scientific knowledge. Thus it is significant to consider how theories view the body as a semiotic resource. Lemke (1995) speaks of the body as the "semiotic body" (p. 85). The body is a carrier of social meanings. People learn to read bodies, for example, patterns of movement, facial expressions, or gestures constructed by social practices characteristic in a community. In this sense the science classroom context can be seen as a school science community in which children learn to read the teacher's and other classmates' bodies in the practices of doing science. Furthermore Lemke (1997) views meaning making as a material process of bodies in the context of communities of practice. Accordingly the human being functions as "a hybrid of both material body and social-cultural persona, a body-subject" (p. 10). Bourdieu (1984, 1991) goes so far as to speak in terms of "inculcation" of the embodiment of social cultural practices in the human body incorporated in the notion of "habitus", which will be considered in more detail in this chapter under the heading "school science as habitus".

Franks (1996) explored the ways in which drama students make meanings by their bodies. He examined how the body orchestrates communicative resources and what the body signifies through communicative resources including speech, gesture, posture and relative positions of one body to another. Thus he speaks of the body as a form of representation. These approaches consider the body from a social rather than a biological perspective. Accordingly the human body plays a central role in the construction of signs

and in understanding action, which is semantically meaningful. That is, the human body itself is both a sign and a meaning making resource to produce signs.

Gesture

Gesture is a kind of action, which usually accompanies speech. Different questions regarding gesture have been the focus of various studies: Do gestures contribute to communication? What is the contribution of gesture from the speaker's point of view and from the recipient's point of view? Does gesture have a separate semiotic function for representation and communication of meanings?

McNeil (1989, 1992) used the term "gesture" for arm and hand movements co-occurring with speech. He argued that speech and gesture are fundamentally two different modes of representing meanings. Extending Vygotsky's argument that thinking comes into existence with words and it is not merely expressed through words, McNeil claimed that gesture is not only an expression of thought; it helps to induce thought as language does. That is, both gesture and language shape and mediate thought.

In contrast to McNeil, Rime and Schiaratura (1991) contend that gestures that co-occur with speech are a by-product of the verbal articulation. They may play a role for the speaker in facilitating the verbal expression, but the communicative function it may have is incidental. They based their argument on experimental findings: that recipients do not notice and remember gestures; in conversation it appears that whether participants can see each other does not affect comprehension; subjects were unable to guess the content of speech to which gesture relates.

Kendon (1990, 1994, 1996) found support in McNeil's studies and challenged Rime and Schiaratura's findings and arguments. Kendon claimed that gestures do play a role as an integral part of the speaker's intention and effort to communicate and it is this effort that shapes the communicated meanings. That is, gestures co-expressed with speech do make a difference in understanding speech even if recipients are unaware of the gestures. Kendon (1996) also considers gestures in terms of their "rhetorical work" (p. 125) from the speaker's and the recipient's perspective, within the context of interaction. Speakers often use gestures for rhetorical purposes to make the intended expression more vivid and interesting to others. At the same time in interactions meaning is conjointly constructed and participants rely upon and exploit the interplay between the different modalities used. In sign languages for the deaf, gesture is a fully articulated mode of communication. In the science classroom gestures appear to have a range of representative and communicative purposes though they are not as fully articulated as the linguistic resources.

Crowder and Newman (1993) and Crowder's (1996) studies confirm McNeil's and Kendon's argument regarding the mode of gesture as an act of communication and as shaping and mediating thought. Crowder and Newman explored how gestures function in 5th and 6th grade science classes, in children's explanations of the phenomenon of seasonal change by means of performance or semiotic objects. Their discussion considers gesture in relation to spatial science concepts. Their findings show that gestures are an expected mode of communication in the science classroom; can give insight into pupils' knowledge that is missing in verbal communication; may help pupils to clarify their understandings of phenomena; is often used by children developing a new idea; and can shape pupils' sense making and scientific insights. Crowder & Newman's definition goes beyond McNeil's definition of gesture. Under the term "gesture" they also include "gaze" and "movements" made with the whole body and meaningful manipulation of a physical model.

Wells' (2000) findings confirm the role of gesture in the construction and mediation of thought. He examined the contribution of different modes in the interaction between an adult and two 3rd grade pupils during a science experiment involving refraction. By closely attending to the participants' gestures he discovered that one of the pupils, whom he undervalued in the actual activity as uninvolved and incomprehensive, actually was constructing an explanation at the moment mainly through gestures. The pupil's gestures revealed his contribution and involvement; his speech alone might have misled one to judge him as less fully engaged in the activity in comparison to the second participant who was dominantly verbal and articulate in the interaction.

Kress et al. (1998) include gesture under the broad term of action as a mode of communication. However their definition of action, adopted in this thesis, goes beyond the definitions mentioned thus far including also body posture and position, the movement of the body in space and time as meaning making resources, and manipulation of objects, i.e. action on objects as ways of making meaning in the science classroom.

Space and Time as Meaning Making Resources

Presentation events unfold in space and time. Thus considering how pupils move in space and time as meaning making resources is significant in the analysis of presentation events. The physical organisation of the classroom in presentation events is transformed from a space divided into small groups and individual activities into a single space, divided into two. One space, the smaller area, is the floor at the front of the class, and the second the larger space, is occupied by the class as an audience. Although there is

no physically marked line serving as a boundary between the two spaces, the boundary exists on a symbolic level, marked by the spatial organization of the science classroom and by the differing occupation of the two spaces by the participants. That is, spatial boundaries are not only in external terms, they are also the way in which persons perceive or represent their spatial orientation with respect to the participants and the objects and artefacts under focused attention (Duranti, 1985). Kendon (1990) suggests that the arrangement of space is motivated and carries meaning, since it signals to the participants their orientation in the interaction.

Hodge and Kress (1988) consider the spatial orientation and physical relationships of participants in space in terms of "spatial codes" (p. 57), which carries complex social meanings. The ways in which pupils use spatial codes to signify the framing of the presentation event have a distinct semiotic and rhetoric function. For instance, the presenter shifting from the teacher's usual position at the front of the class, extending the space of the floor by invading the audience's space could signal the intention to establish close interpersonal relationships. In contrast, taking an unusual distant position from the audience or physically marking the spatial boundaries between the floor and the audience by a bench, which is usually not there, could mark an orientation to distant interpersonal relationships. Both cases may have a different impact on the interaction and communication.

Gaze

Kendon (1990) asserts that the function of facial expression in social interaction has not been extensively studied. In communicative situations a gaze is often used with other facial expressions or in co-operation with language and action resources. The question is: can a gaze be considered in terms of a semiotic resource and function? Hodge and Kress (1988) speak of a gaze in terms of a sign system and as one of the transparent communicative resources among facial expressions, since it is "the most flexible and the most easily under control" (p. 56). To return to the science classroom observed, indeed gaze is a significant resource used by pupils in presentation events (consider observation 5 in chapter one).

In summary, the main point under discussion is that each of the modes of communication not only mediates thought but also thought is shaped in each of the modes. The observations described (in chapter 1) show that teaching and learning in the science classroom involve various forms of action. Nevertheless, pupils' use of bodily

resources such as gesture or other forms of action for shaping and mediating thought and communication of scientific knowledge is generally not valued in the educational context.

Gardner (1983) has pointed out that bodily intelligence is one of the multiple human intelligences. The sharp disjunction between mental and physical-kinaesthetic activities is an approach that is rooted in the Western culture tradition. Lemke (1995) attributes the "alienation from the body" (p. 98) to middle class culture, which has traditionally identified the mind with higher social orders and the body with the lower ones. Though forms of action are less fully articulated than language resources in the science classroom, different forms of action operate as significant semiotic resources in the practices of making science in the science classroom (Franks & Jewitt, 2001).

A multimodal and social semiotic theoretical framework enables one to address the range of communicative modes including meaningful forms of action and to consider these in terms of their semiotic affordances in the practices of learning science. A multimodal approach also enables one to consider the interrelated contribution of the operating modes in communicative events to the resources pupils can draw upon in writing science. This notion is incorporated in the third sub-question of this thesis. It considers how the operation of communicative modes in pupils' overall presentation events, namely speech, action and the visual mode, can contribute to the resources pupils' may draw on in the production/revision of their written exploration report.

RHETORIC IN THE SCIENCE CLASSROOM

Science has the reputation for avoiding rhetoric and "simply" reporting natural fact (Bazerman, 1988; Sutton, 1992). The community of science and of science education has generally not acknowledged the rhetorical character of practices of meaning making in the field of science and of science teaching and learning. However, there are researchers who have addressed the rhetorical aspect of science. I will consider a number of relevant notions and studies. Weimer (1977) referred to science within the community of science in terms of a "rhetorical transaction" because of its argumentative character. Overington (1977) viewed the individual scientist in terms of a speaker, the research in terms of a "rhetorical situation" and the scientific community in terms of a "rhetorical audience" (p. 156), which is able to influence the research process itself. Similar to Weimer's contention, Overington referred to science from a rhetorical point of view because the construction of scientific knowledge involves argumentation and persuading the community of science as an audience. Bazerman (1988, 1998) has pointed out a range of significant rhetorical choices within science, such as shaping and pursuing research

programs, writing scientific texts and the choice of investigative tools, which are ways of transforming phenomena into symbolic representations. He specifically examined the rhetorical character of the genre of experimental report in sciences, its many transformations and its diffusion to the social sciences.

Whilst the studies mentioned contribute to highlighting the issue of rhetoric in science, their focus on the rhetorical character of language use in the written mode, mainly in scientific publications, cannot provide a conceptual theoretical framework for the multimodal and social semiotic theoretical basis of this thesis. That is, the nature of data in this thesis needs a theoretical framework that includes emphasis on a wide repertoire of resources of different semiotic modes deployed by pupils in the rhetorical process of presentation events. To meet this requirement I draw on the theoretical framework developed by Kress et al. (1998) in the project mentioned above "rhetorics of the science classroom: a multimodal approach". Unlike the traditional approach to rhetoric, which centres on formal relations between elements in a text and the special means that make discourse "more memorable and hence more persuasive" (Van Dijk, 1997; p. 12), Kress et al. consider the different semiotic modes as rhetorical resources available to the teacher and pupils in communication in the science classroom.

Before discussing how communication in the science classroom is rhetorically shaped it is important to consider what impels communication. On the one hand communication in the science classroom, as in any event of communication, depends on some shared understandings and knowledge (Bazerman, 1988). By contrast what fundamentally drives communication is that there is a difference between what one participant knows and the other does not know, or presumably does not know. In everyday situations, when there is a difference between what one participant in the interaction knows and the other does not know, one has legitimisation to open a conversation. Differences can be of various kinds, such as a difference of knowledge, interest, power or realm of feelings. The kind of difference, which concerns science teaching and learning, is the difference between the teacher's and the pupils' knowledge of science (Ogborn, Kress, Martins & McGillicuddy, 1996).

When needed, science teachers expose differences in various ways, making the difference relevant to pupils, in order to explain scientific ideas, to shape pupils' scientific knowledge and view of phenomena in the world. Science teachers use a range of resources from different modes, and they employ "rhetorical devices" and "rhetorical strategies" (Kress et al., 1998, p. 2) to achieve effective communication. Kress et al. highlight the function of semiotic resources and the realisation by science teachers of

presenting a coherent rhetorical account of phenomena in the world. In this process the different semiotic modes are considered as rhetorical resources available to the teacher and pupils. Kress et al. view multimodality and rhetoric as dialectically related. That is, rhetoric is realized through multiple semiotic modes and at the same time semiotic modes are shaped by rhetoric. According to this view the selection of communicative modes is a part of creating meaning and the rhetoric of making science in the science classroom.

When pupils face the task of presentation, they are not only concerned with questions of content, i.e. what to represent, but they are also engaged in the considerations of how to communicate scientific knowledge and at the same time how to captivate the class as an audience. For the duration of the presentation (about 3 – 6 minutes) the pupil presenting becomes a "teacher". Similar to the teacher the pupil needs to make rhetorical choices, consciously or unconsciously. The pupil needs to consider what resources to use and from which modes to communicate scientific knowledge in the rhetorical process of the presentation event. This notion is incorporated in the second sub-question of this study. Thus, the theoretical framework and the framework for analysis of the data in this thesis also include the rhetorical aspect in the practices of making science from the pupil's perspective.

Drawing on the notion "frame" suggested by Goffman (1974) for description and interpretation of principles, which govern the organization of social events, Kress et al. (1998) suggest the notion of "rhetorical framing". The conception of rhetorical frames serves as a unit of analysis of the teacher's orchestration of the multimodal communication in the science classroom. They analyse the construction of a lesson or series of lessons in terms of rhetorical framings, which can be identified by textual shifts. I adopt their conception of rhetorical frame as a communicative message or unit in a communicative event for the analysis of the rhetorical process of pupils' presentation events.

Frames are usually not explicitly marked in a communicative event (Fowler, 1996); they can be inferred from manifest communicative actions. A rhetorical frame in presentation events can be inferred from a configuration of a range of factors, which are identified as semantically and rhetorically significant such as: the starting point of the unit, positioning in relation to knowledge, the choice of content, the foreground mode, the objects of action used, the position and orientation in relation to objects of action and in relation to the class, movement, the rhetorical strategies employed, and the type of interaction.

SCHOOL SCIENCE

School Science as Recontextualized Science

Exploring practices of learning in the science classroom requires taking into account the characterisation of science at school as an institution at a general level. Science teaching aims to transform children's everyday "common sense" knowledge to "un-commonsense" (Halliday, in Halliday & Martin, 1993) scientific forms of knowledge. In Bernstein's terms there is "specialised knowledge" as opposed to everyday knowledge (1996, p. 170). One of the problems in science learning is that entities that exist in the world of science may have no corresponding existence in the child's world. It is the science teacher's task and aim to make these entities real and meaningful for children (Driver, Leach, Scott & Wood-Robinson, 1994). For instance, this aim can be seen in the actions taken by the teacher to move pupils from the everyday conception of air to a scientific conception of air as a compound of gas, based on proof through an experiment (consider observation three in chapter 1). The process of transformation of earlier understandings and forms of knowledge to new understandings and forms is cumulative. It happens over a period of time and involves learning characteristic practices, texts and genres of the school subjects (Christie, 1993, 1997, 1998). What children learn on the subject of science at school is not the same body of knowledge, texts and genres as produced in scientific communities. Hence, the term school science is used in this thesis.

Institutions have characteristic discourses, that is, ways to organize knowledge related to the nature and the place of an institution (Kress, 1985, 1999, Kress & van Leeuwen, 2001). Accordingly, the collectivity of the community of scientists as an institution, "which legislates what is called science" (Polanyi cited in Overington, 1977, p. 146) produces scientific discourse. Specifically, this includes the characteristic ways to organize contents; the possible statements within its terms; ways of engaging in scientific problems and practices involved in the production of scientific knowledge.

School as an institution does not produce scientific knowledge, and it does not deal with "contents" in the same way that scientists produce it within the community of science. School as a pedagogic institution takes aspects from the field of science produced in the community of science and relocates it by taking it from that context to the pedagogic context. In other words, school re-contextualizes scientific discourse appropriated to the learners, which finds its expression in appropriated practices, texts and characteristic generic forms. This is what Bernstein (1996) terms "recontextualized genres".

Research literature has documented how recontextualized genres in school science are realized linguistically (Halliday & Martin, 1993; Martin & Veel, 1998); it includes conventions such as the use of procedure rather than narrative, the use of verbs of relation rather than verbs of material action, the use of the present tense, the passive voice, effacing agency, addressing the reader impersonally, the use of specialized terms, and specific textual formats.

As children start disciplinary learning in the science classroom, in elementary school, they might produce signs/texts full of meaning but often out of conventions of recontextualised genres, which have been developed in the subject of science at school. The science teacher's expectations, implicit and explicit, and her responses to texts pupils produce might be crucial in apprenticing children into conventions of scientific forms of texts at school (Sutton, 1992). Hence, in my data I classified the texts pupils' produced in response to the teacher's lesson (chapter four) as "expected" or "unexpected" in the science classroom according to the teacher's responses observed.

Tracing evidence of science learning in texts pupils produce involves tracing linguistic and visual conventions taken up by pupils as resources deployed for representation of scientific knowledge. This also entails some level and degree of syntactic analysis as a part of the textual analysis. Take for example the issue of agency, which is essential in the expression of scientific knowledge. The structure of clauses in a text indicates how the producer of the text conceptualizes issues or phenomena described, as causal processes and events or as self contained processes or events without any indication of who did what to whom; and how she/he addresses the reader and positions him in relation to scientific knowledge.

The syntactic analysis in this thesis draws on Hodge & Kress' (1993) theoretical framework. They outlined three fundamental syntactic models that describe the interrelations of objects and events. They consider the models as basic schemata that derive from the visual perceptual processes of human beings. These schemata serve to classify events in the world. One model type is the "transactive model" that minimally involves, in its simplest form, two entities related by a process. In this model one of the entities is causing the action and the other is affected by it. The second model is the "non-transactive model" that minimally involves one entity related to a process. In this model action is restricted to one entity. As there is only one entity in this model it is difficult to know whether it is the actor or the affected. However both the transactive and non-transactive models are about action. Although Hodge & Kress discussed these models in relation to English they can be used to describe relations also in the Hebrew language,

since transactive and non-transactive are labels of actional models with a particular meaning. That is, the same question is considered regarding clauses in Hebrew: is an action passing on from an actor to an affected (the Hebrew term "poal yotze") or is the action restricted to one entity (the Hebrew term "poal omed")? The third model is the "relational model". This model concerns relations between entities, which are of a different type than relations of action or process. This may be between two entities or between an entity and a quality. Relations between two nouns are often equative and relations between nouns and qualities are often attributive.

School Science as Habitus

In Bourdieu's terms (1984, 1991) it is the science teacher's task to bring pupils into the "habitus" of school science. The notion "habitus" incorporates sets of cultural dispositions, which, through interacting with the social and material environment, are directly embodied in persons. Bourdiue places emphasis on the body rather than on the mind as a state of being. Thompson (1991) describes mundane practices through which dispositions are internalised, such as table manners, body posture, ways of standing, walking, speaking and thereby feeling and thinking. Through training and learning these mundane practices "literally mould the body and become second nature" (p. 12). Specific contexts of experience imply specific habitus. In this sense learning science in the science classroom is a specific social practice, which inscribes the habitus of science that is converted into dispositions. These dispositions are internalised through interaction with the material environment, which consists of other people acting out of these dispositions. In this sense pupils embody the habitus of school science, which include characteristic practices of doing science.

Learning science is accomplished through direct action and interaction with the semiotic material and the social environment in the science classroom, and through reading the teacher's and others' communicative actions. The kind of representational resources pupils receive in the science classroom are likely to be crucial in the inculcation of the habitus of school science (Kress, 1996a). The habitus is inscribed and converted into dispositions, which are capable of generating practices and perceptions. Dispositions orient individuals and give them a practical sense of how to act and respond without determining their actions. People act and respond within specific social contexts or settings. Hence generated practices and perceptions should be seen as the product of the relation between habitus on the one hand and the context on the other. In the case of the habitus of school science, the science classroom environment in general terms provides

the context. Dispositions can be transferred and applied to new situations "beyond the limits of what has been directly learnt" (Bourdieu, 1984, p. 170). Accordingly, pupils may transfer "inscribed" dispositions to the new and demanding situation of acting as rhetoricians in presentation events at the front of the class before their classmates as an audience in the science classroom.

TEXT, EVENT, PRESENTATION AND THE ASPECT OF GENRE

Text

The concept "text" is a basic concept in the discussion on learning science in the science classroom, which needs consideration in the light of the multimodal nature of texts that pupils use and produce.

The term "text" refers to the material realisation of meanings, traditionally to a piece of a whole written work. Within the tradition of discourse analysis the term text refers both to spoken and written language (Fairclough, 1993; Lemke, 1995). Within social semiotics "a text may be either spoken or written, or indeed in any other medium of expression that we like to think of" (Halliday & Hasan, 1985, p. 10). According to Halliday the concept of text has no implications on size. It may refer to a speech event, speech act, narrative, an episode and so on. That is, text refers to different types of exchanges of meanings. Halliday's account is focused on language. In his discussion on the nature of text, he pointed out that although when written down it seems to be words and sentences, a text cannot be viewed in terms of a sentence, but rather as a semantic unit. As stressed by Kress (1997) people do not talk in sentences, people "speak, write, and interact in tightly integrated, coherent units" (p. 117). According to Bakhtin (1986), in reality interaction (i.e. spoken and written) transpires in the form of concrete "utterances" of individual speaking people, in his words, "speech subjects" (p. 71). His view of the utterance as a unit of communication is in contrast to those linguistic analyses that focus on the word and sentence as a unit of language, which according to Bakhtin "has no author ...and it belongs to nobody" (p.84). The main point regarding the nature of text is that it is the material realisation of meanings. A text is an object in itself, a semiotic object (Halliday & Martin, 1993) - a complex multimodal sign.

Event

Halliday views a text both as a product and as a process resulting from an interactive event (Halliday & Hasan, 1985). It is this notion that I draw on by using the

concept "event" versus the concept "text" in this thesis. When referring to a pupil's presentation to the class I use the concept "event", focusing on the aspect of the exchange of meanings in process. Essentially the performance of a presentation is a social exchange of meanings in a process that unfolds in time during an event. When referring to a pupil's material text I use the concept "text" seen in its product aspect.

Pupils' texts and presentation events are viewed as evidence of learning; as the material outcome of the transformation of semiotic resources in the multimodal environment of the science classroom. Thus the samples of pupils' texts and presentation events analysed in this thesis are treated as "semiotic objects" (Halliday cited in Halliday & Martin, 1993, p. 93) mediating pupils' differential interests motivated by the context in the science classroom. Reading and interpreting pupils' texts and presentation events as the reading of any produced sign, is only with partial success. It is hypothetically possible by reconstruction of the meaning maker's interest marked in the sign, which in turn is in itself a transformative action guided by the reader's interest (Kress, 1996a; 1996b; 1997).

Presentation

Presentations are communicative events planned and designed in advance and in a setting framed in science class. A session of presentations carries a ritual character. Rituals according to Hodge & Kress (1988) are occasions in which some "social roles are waived or reversed, or transformed in some way" (p. 74). In presentation events, the focus of the attention is reversed. The attention is on the pupil presenting and not on the teacher as it is usually. By the pupil taking the floor, the teacher's position and role at the front of the class temporarily transforms their social roles. The teacher steps back and for the time being suspends her control over the event and the class. The situation is even more complex. Although the presentation is to the class it is in fact accomplished as a task for the teacher. Though the teacher steps back as the pupils take the floor, she is very present in the class. She is most certainly in the performers' mind and might be perceived as a different "audience" with different expectations from that of the class, which may impact the semiotic and rhetorical choices. In presentation events pupils address the audience by virtue of their right of being "experts" on the topic of exploration. That is, this power is by virtue of the right bestowed by the scientific knowledge they presumably possess which the class does not. Similar to the teacher, pupils presenting are expected to captivate the audience, which drives pupils to use rhetorical strategies.

Adopting Kress et al.'s (1998) terms, the practice of presentation can be referred to as a rhetorical task, the unfolding event as a rhetorical process and the pupil presenting as

a rhetorician. The class is expected to take the role as an active responsive audience. This role gives the class a kind of power to respond to aspects or elements from the presentation, and to reject or judge the presentation. This is a social situation, which involves power relations that impact the rhetorical process of the event and the type of interaction and forms of communication. Within the theory of social semiotics, the basic assumption is that social relationships shape meanings and communication and visa versa (Halliday, 1978; Hodge & Kress, 1988). Presentations are communicative events that illustrate that basic assumption.

Genre

The range of forms of pupils' textual productions in the science classroom raises the need to clarify in more detail the conception of genre in this thesis. Although genre has been considered primarily within literary and linguistic theories, the concept has been discussed and broadened by theorists from different fields, such as film, media communication, and cultural studies, particularly in the last decade (Stainton, 1996). When the movement of the use of genre in the field of literacy pedagogy began in Australia in the early 1980's it was already a heavily loaded term. The Australian genre school became wide and well known in different countries including in Israel. This school does not hold a unified view of genre.

Embedded in Halliday's (1985, 1994a, 1996) systemic functional grammar, the view of genre as a social process is commonly accepted within the genre school. The focus is on social structures and processes and their function in the construction of texts. Considered as a social phenomenon, generic forms have been seen as representing in their structure characteristics of the social situation in which they were produced. Regular and repeating social situations give rise to texts with similar stability, which result in marked generic conventions. The conception that social situations always reflect power relations, which are represented in the structure of genres, led the genre school to "explicit pedagogy for inclusion and access" (Cope & Kalantzis, 1993, p. 64). The aim was to provide all children access to "genres of power", i.e. to generic forms through which power is coded, in order to gain full participation in social cultural life. Accordingly children from marginalized groups need explicit teaching more than children who are comfortable with genres and cultures of power. The rationale behind this pedagogy was that if certain social situations bring about certain schematic generic forms, then all children need to be taught pre-existing schematic generic forms. This approach was in

conflict with existing conceptions of literacy education oriented to self-expression, creativity, and authenticity, which resulted in a controversy over genre.

Two differing views within the genre school are discussed by Kress in more detail (see Kress in Cope & Kalantzis, 1993). Martin, Rothery and Christie (cited in Cope & Kalantzis, 1993) view genre as a staged, goal oriented social process. They are interested in the question of how and in what stages genres achieve their social purpose. In Martin's model, and in Martin and Rothery's joint model, the category of genre embraces the entire complex of linguistic aspects in a text. The focus in their approach is on the "task that is being performed by or through the text" (Kress 1993, p. 32). By contrast, in Kress' approach the embracing category is text, and genre is under the category text, as one among other aspects, which form textual structuring (Kress, 1999). To illustrate this, consider again Ofir's texts (figures 3 and 4) discussed above. Each of his texts is much more than generic forms realised in language. To interpret his texts under the category of genre only is to look separately at different parts of his text and to miss the overall meaning. The meaning of his text, as of any text, is rather the simultaneous look into all interwoven meanings, which can be viewed from different aspects.

In Kress' approach the generic form of a text is an effect of the social conditions of the occasion of its production. The focus is on the goals and social relations of the participants in a particular occasion of interaction reflected in the text. That is, "the text which results from the interaction is a map of the social occasion in which it was produced" (Kress, 1996c, p. 189). This is an approach that leans toward a flexible view of generic forms. The Martin/Rothery approach tends to a firmer view of generic structure and with classificatory power. The theoretical framework in this thesis draws on Kress' approach, which views generic conventions taken up by pupils' in the production of texts as a resource rather than a classificatory means in terms of ideal models. However the concept "genre" is not restricted to language but can be used in an integrated analysis of multimodal texts (Van Leeuwen, 1993). Thus the notion of genre is incorporated in the first broad research question this thesis addresses, as an integral part of the considerations concerning the resources deployed by pupils in the practice of textual production.

Fairclough (1995) takes the standpoint that the schematic view of genre cannot be sustained as a general view of genre because many texts manifest complex mixed genres. He claims that the debate has failed to distinguish between actual texts and conventions as ideal types. There are texts that closely match ideal types and others that do not. People can learn conventions from concrete experience, and they produce or interpret texts in reference to conventions as ideal types but actual texts do not instantiate them. In fact,

there is always tension in actual texts between generic stability and dynamic change. The tension is a result of the various degrees of stability in social structures in contrast to the varying degrees of social change and individuals' transformative innovative actions. However, a genre does not exist apart from its history, and each new text produced within a genre "reinforces or remoulds some aspect of the genre" (Bazerman, 1988, p. 8). In this way history continues with each new text invoking the genre.

In summary the theoretical notions and principles comprising the theoretical framework of this research will be illustrated in the following chapters. This will be done first by its application in the analytical framework of this thesis presented in the methodological chapter (chapter 3). Second, the theoretical framework is illustrated by the application of the analytical framework in the analysis of the case study examples of pupils' texts and presentation events presented in chapters 4-6. The conclusions of this thesis will be considered in chapter 7.

CHAPTER 3

METHODOLOGY

> We need social theories to help us to identify what is important in the world around us and then, by analysis, to make something of it.
>
> (Silverman, 2001, p. 194)

INTRODUCTION

The purpose of this chapter is to describe the methodology applied in the course of this research. This chapter comprises two parts. The first part presents a detailed description of the research design carried out in this research and the organization and constitution of the main data in the following three chapters. The second part outlines the framework for analysis of the data on the foundation of the theoretical framework discussed in chapter two. The notions from research literature, discussed in the previous chapter, provide a theoretical conceptual basis and a language of description for the framework for analysis of the main data, namely case study examples of pupils' texts and presentation events. The case study examples of individual pupils or small groups' productions are seen as instantiations of the practices explored situated in the broader context of the science classroom.

THE RESEARCH DESIGN

Research Site

At the initial stage of my research I carried out observations and collection of materials in six 5^{th} grade classes in four science classrooms in four different elementary schools as summarized in table 1. The schools were regular national elementary schools (as opposed to special schools that focus on particular subjects of the curriculum such as arts or sciences) comprising between 550 – 700 pupils from 1^{st} grade – 6^{th} grade. The schools were located in different towns in the same region (the Sharon region in Israel). Schools A, C and D (consider table 1) also served a population from surrounding smaller settlements. As the pupils came from different socio economic backgrounds, the schools were defined as heterogeneous schools according to criteria of the Ministry of Education. About one third of the pupils came from a low socio economic background (underprivileged) one third from the middle class and one third from the high middle class. In School B about 40% of its pupils were from a low socio economic background and about 60% of the pupils from the middle class. The schools integrated children with

special needs in the regular classes supported by special programs and special trained assisting teachers. In contrast, the schools did not offer any programs for special gifted children. However the schools I observed were not considered exceptional schools.

The selection of the schools, more precisely the science classrooms, was a criterion-based selection (Goetz & LeCompte, 1984). The criterion for the selection of the science classrooms was actually based on the teachers' reputation, according to recommendations by colleagues and by science teachers' instructors. The final selection was also subject to the teachers' agreement to open their classroom for exploration, which not all the recommended teachers were ready to do, to the school principal's agreement and to the parents' agreement (The policy of the Ministry of Education dictates strict regulations in respect to parental consent regarding research in classrooms). The teachers I observed were special trained science teachers, with 3 – 10 years seniority in science teaching. They participated in courses concerning the new science curriculum and were in contact with teachers' instructors in various degrees of intensity. Jasmine, the teacher of the science classroom where I collected the main data for this thesis started her career as a regular teacher. After 8 years she shifted to science teaching and she underwent science studies and special training. In the year of my fieldwork she had 6 years seniority in science teaching and was guided by a science teachers' instructor on a regular basis.

The science classrooms observed were divided into two categories. Two of the science classrooms were pedagogically traditional oriented, more precisely, the teachers implemented transmission models of teaching. The other two science classrooms were pedagogically innovative oriented, that is, the teachers implemented more open classroom practices and "inquiry-oriented instruction" (Lawson, 1994) according to the new curriculum guidelines. Although on the level of manifestation the view of teaching as transmission of knowledge has been uncommon in elementary school education in Israel for over two decades, in actuality there are science teachers who still implement a transmission model of teaching, what Scott, Dyson & Gater (1987) call "closed" teaching strategies. Science teachers who implement closed teaching strategies are regarded as conservative and pedagogically traditional oriented, even though they use current materials and textbooks and teach the topics suggested in the new science curriculum. Nonetheless this distinction between the differing pedagogical orientations is not formal and not my terminology. I adopted the terms "innovative oriented pedagogy" and "conservative or traditional oriented pedagogy" used by practicing educators (e.g. science teachers' instructors, school principals) with no intension to evaluate the differing orientations. I am aware that the question of the interaction between curriculum and

pedagogy is a crucial issue in education but I am not dealing with this issue in the frame of this thesis.

In the progress of research I limited the collection of data to two 5th grade classes in one innovative oriented science classroom (labelled D in table 1). I realized that the types of school work the pupils in the traditional oriented classes (labelled A and C in table 1) were engaged in did not interest me as a subject of exploration for this study (i.e. responding to the teacher's closed questions, completion of declarative sentences, or writing comprehension answers in worksheets and notebooks).

By contrast, in the innovative oriented classrooms observed the pupils were engaged in more open school work which interested me, such as independent experimentation, exploration, production of texts and performance of presentation events. In addition, in the progress of research I realized that a smaller scale of data is required in order to trace learning as semiosis and to exemplify how a detailed multimodal analysis and rhetorical analysis can be used as a tool to understand pupils' differential outward expressions of science learning. Thus, I narrowed down the collection of data to one site of research, in Jasmine's (pseudonym) innovative oriented science classroom, in two 5th grade classes. The number of pupils in one of the classes observed, termed here as class 1, was 33 and the number of pupils in the second class, termed here as class 2, was 31. That is, in the course of fieldwork throughout the year 1999-2000 I closely observed learning activities of over 60 pupils.

Table 1. Summary of fieldwork in 5th grade classes in four science classrooms

Year/ period	Label of class-room	Pedagogical orientation	No. of classes	No. of teachers	Topic of study
1998-99 2 months	A	Traditional	1	1	Production and exploitation of electric energy
1998-99 6 weeks	B	Innovative	2 integrated	2 + 1 Assistant	Adaptation of living organisms to the environment
1999-2000 2 months	B	Innovative	2 integrated	2 + 1 Assistant	Population explosion
1999-2000 10 weeks	C	Traditional	1	1	The heart and blood cycle
1999-2000 Almost 10 months	D	Innovative	2 different & separate	1	1. Systems in the human body 2. Sound

In fact I modified my focus of exploration in the course of fieldwork. I centred my exploration on pupils' differing expressions of scientific knowledge in texts they

produced and their rhetorical staging of presentation events in the same science classroom taught by the same science teacher in two different grade five classes. This was instead of my initial intention to compare texts produced by pupils in differing pedagogically oriented science classrooms.

The Time Frame

The criterion for the time frame of my fieldwork in each class was not meant to assess change or development across time. The criterion was rather the duration of one complete unit of study. I considered the context of the broad topic, studied as a whole unit in class, as significant to understanding the variations in pupils' use of resources. It enabled me to examine the type and nature of resources made available to pupils and to better trace the resources being deployed and transformed by pupils into texts and presentation events.

In the case of Jasmine's science classroom the time frame in one class stretched over 26 lessons (covering the topic of "systems in the human body") and in the second-class over 14 lessons (covering the topic of "sound"). The length of the time for a topic was due to pupils' long-term activity of independent explorations and the periods of time allocated for the sessions of their presentations within the framework of each topic. In addition, though generally science class is regularly held twice a week, due to various school programs (i.e. sports day, family day, teachers' special courses) a number of lessons in the science classroom throughout the school year were cancelled, which also added to the time stretch of a topic and consequently of my fieldwork. A lesson in the science classroom was normally1 hour and 30 minutes, with the exception of some extended lessons of 1 hour and 50 minutes to 2 hours (overrunning into the recess).

Exploring Grade Five Classes

My choice to focus my research in grade five classes (age 10-11) was because grade five is a turning point in science learning in elementary school. It constitutes a transition from learning science as thematic units in the regular class (from 1st grade through 4^{th} grade, taught by the regular teacher) to disciplinary learning (taught by a professional science teacher) in the special appropriated environment of the science classroom. The science classroom environment may have a remarkable influence on children's attitude towards learning science at school (Osborne, Simon & Collins, 2003). The transition to the science classroom can open up new semiotic opportunities for pupils and at the same time set new expectations and constraints on them. However, the

selection of the specific classes to be explored was a decision made by each teacher coordinated with the parents' agreement.

The Data Collection

The data collection comprised two types of data. One type of data includes the various forms of texts I collected in the science classroom, namely texts produced by the pupils and texts made available to the pupils by the teacher. The second type was obtained through my recordings during fieldwork, the handwritten protocols and video recordings of pupils' presentation events, which were transcribed.

Although my interest focused on science learning practices from the pupil's perspective, the fine balance between teaching and learning inevitably also involved the collection of data regarding the teacher's communicative actions. Ogborn and co-writers discuss teaching and learning in terms of action. "To teach is to act on other minds, which themselves act in response" (Ogborn et al., 1996, p. 50). The teacher's multimodal communication in the science classroom is considered "semiotic material" (Kress et al., 1998). Pupils produce signs/texts/events in the science classroom in response to the teacher's communicative actions and the prompts, tasks and frameworks she sets. Therefore I considered it significant to also include the protocols that concern the teacher's communicative actions in the data collection. The detailed protocols of the teacher's communicative actions and the wider picture of the ongoing in the science classroom enabled me to better trace the range of resources pupils drew from in the production of signs/texts/events; and to better understand pupils' semiotic and rhetorical choices and some of the teacher's pedagogical considerations.

I decided not to include interviews in the data collection even though I occasionally conversed with the teachers and the pupils observed. I believed that this decision would better serve in explicating the answers of the research questions addressed in this thesis. The reason behind this decision was the fact that this study focuses on what the pupils were doing rather than on what they thought or felt about what they were doing. Pupils' responses to my occasional questions seemed to have justified this decision. For example, responses such as *we make comics because we love comics*; *we make comics because we are good at comics* were good explanations from the pupils' point of view. Yet this kind of response did not contribute to explicate the answers of the research questions.

In addition my focus on existing learning practices also seemed to better serve the aim of this study, namely to exemplify the application of a multimodal approach to

learning, as a tool science teachers can use in their day to day practices. Interpreting and assessing pupils' texts, events or other outcomes of the process of learning is more or less an integral part of the science teacher's work. In contrast interviewing pupils concerning the outcome of the process of learning is an uncommon task for the teacher in the regular setting in the science classroom. Furthermore, exemplifying the pedagogical potential of a new approach i.e. a multimodal approach, on the basis of existing teaching/learning practices seemed to me to be of more professional value to teachers.

It is true that although this study focuses on existing learning practices from the pupil's perspective, interviewing the teacher could have shed light on some of her pedagogical considerations. Nevertheless, interviewing the teacher was not an approach taken in this study due to the science teachers' sensitivity to questions about classroom practices at the time. The background of this sensitivity was the public debate surrounding the issue of science education which intensified following the publication of the results of the TIMSS study, mentioned in chapter 1.

THE MAIN DATA

CRITERIA FOR THE SELECTION OF THE MAIN DATA

The main data in this thesis comprises case study examples of three categories. Category one concerns pupils' texts produced in response to the teacher's lesson and a short-term writing task she set. The reason for choosing data from this category is the completeness of such a unit, which was relatively easy and accessible to me for exploration. This included selection of a specific lesson framed by the teacher, the resources she made available, the writing task she set, the possibility to observe the conditions of production of texts within the lesson, collecting the texts pupils produced and observing the teacher's responses to the texts after reviewing them.

I have classified the samples of pupils' texts according to whether they were expected or unexpected by the teacher. I interpreted the teacher's inexplicit expectations by observing her actual responses to pupils' texts after reviewing them. I consider this a significant criterion since the teacher's expectations and responses to texts pupils produce, in particular at the beginning stage of disciplinary studies, may be powerful in shaping their conformity to the implicit norms of the forms of texts in school science (Sutton, 1992). The criterion for the selection of a sample of the teacher's lessons was a typical lesson representative of the co-deployment of multiple communicative modes

commonly used in the practice of teaching in the science classroom observed followed by a writing task set by the teacher.

Category two in the main data concerns pupils' presentation events, which were the product of long-term enquiry work on a chosen experiment or topic framed in the broader shared topic in class. The reason for selecting data in this category is my interest in the rhetorical aspect of communication in the science classroom from the pupil's perspective. The criterion for the selection of salient case study examples of this category stemmed from my interest in the presentations from a pedagogical point of view. In the selection of samples I focused on individual pupils' presentation events. I also examined a small group's collaborative presentation if I was able to follow the individual pupils' contribution in the small group's work and the performance of the presentation. Tracing semiosis as expressed by an individual pupil is not an easy task and all the more so in the case of a collective production of a collaborating small group. Nonetheless, in the case of the individual pupil, tracing the practice of presentation is in a sense more accessible for exploration than a small group's activity. In Goffman's (1981) terms, the "animator" (the person who actually expresses the meanings) the "author" (the person who combines and puts the meanings together) and the "principal" (the person whose position is represented by the meanings) are incorporated into one and the same pupil. In the case of a collaborative small group, the division of work in the group along the path of semiotic and rhetoric action, was often quite unclear to me as an outside observer.

Finally, category three concerns pupils' written exploration reports on their freely selected topic of exploration, theoretical in nature. The reason for choosing data from this category is my interest in the range of modes pupils deployed in the process of science learning. This includes pupils' use of writing as a modal resource to transform resources they draw from communicative events into their revised report, which interested me as a part of the agenda of learning in the multimodal environment of the science classroom. The criterion for the selection of samples of this category is linked to the samples of category two. Pupils were expected to hand over the written exploration reports to the teacher, who was the ultimate reader of these texts, prior to their presentation. They were encouraged to revise their written reports following the presentation event, if the teacher deemed necessary. That is, the samples of this category concern exploration reports produced prior to the presentation and the revised reports produced following the overall presentation.

At this point it is worth noting that in my observations I realized that the practice of revision of texts was enacted concerning pupils' exploration reports theoretical in

nature. This was in contrast to experimental reports, which were clearly framed by the teacher (also consider observation three in chapter 1) and were not subject to revision. The teacher corrected the language or the factual information within the pupils' experimental reports when inaccurate. At times she suggested pupils correct, or add an element within the experimental report, but not to revise the text as a whole. Therefore the selection of the case studies in category three were from pupils' enquiry work theoretical in nature. Since the analysis of the samples of this category considers the relation between communicative modes in operation in presentation events and the revised exploration reports following the presentation I have selected samples of exploration reports of pupils whose presentations were already discussed in the second part of chapter 5.

In summary, the main data in this thesis comprises salient samples of pupils' texts and presentation events. I consider it very valuable to explore outward material expressions of learning in any sign, text or event pupils produce. These signs are expressions of how pupils engage in knowledge in the science classroom, thus they constitute types of evidence of learning. The samples in the main data that were selected according to the criteria discussed are drawn from a wider database. The intensive nature of multimodal analysis of the texts and the rhetorical analysis of the presentation events required a small scale of data. Thus considering the relation between writing and communicative modes in operation in the overall presentation from which pupils could potentially draw semiotic material required an intensive analysis and also a small scale of data.

Although my selected samples do not exhaust all the various forms of pupils' texts and presentation events in the data collection, they can provide the wider picture of the characteristics of these practices in the science classroom providing the possibility to answer the research questions. These samples allowed me to derive characteristics of how pupils transform available semiotic resources into various forms of texts, integrating visual resources and language resources in the written mode to realise expressions of scientific knowledge. Also I was able to conclude characteristics of the rhetorical process of presentation events, and the interrelated contribution of the different modes of operation in communicative events to the resources pupils draw from in the revision/production of exploration reports.

THE ORGANISATION AND CONSTITUTION OF THE MAIN DATA

I shall discuss the framework of the analysis in the second part of this chapter. The framework is applied in the following three chapters, four, five and six, which constitute case study examples, illustrating the theoretical framework and elucidating the answers to the overall research question (i.e. what use do pupils make of resources made available to them in the science classroom to represent and communicate scientific knowledge?) and the three deriving sub-questions.

Chapter 4 considers the answer to the first sub-question: what use do pupils make of resources made available to them in the science classroom to realise expressions of scientific knowledge in texts they produce? The chapter includes seven samples of category one, texts produced by the pupils in response to the teacher's lesson and a writing task she gave them. Three of the samples are what I classified as unexpected texts (by the teacher) and four samples are expected texts (by the teacher) in science class. In this case my selected sample of the teacher's lesson concerned the function of the muscles in the process of inhaling and exhaling.

Chapter 5 considers the answer to the second sub-question of this thesis: what use do pupils make of resources to communicate scientific knowledge in the rhetorical process of presentation events? The chapter, divided into two parts, includes five samples of category two, namely pupils' presentation events on their selected experiment or topic explored.

The first part of chapter 5 considers three case study examples, which are drawn from the 5th grade class termed as class 2. These presentations are the product of independent work that could be described as practical and experimental in nature. The presentations concern simple experiments that the pupils selected from a set of experiments suggested by the teacher framed in the topic "sound". The teacher framed a sequence of steps to be followed in the process of experimentation on the foundation of a basis of knowledge she established on the topic "sound" in class.

The second part of chapter 5 comprises two case study examples drawn from the 5th grade termed as class 1, framed in the topic "systems in the human body". In contrast to the presentations considered in the first part of the chapter, the presentations in the second part were the product of independent enquiry work, which could be described as theoretical in nature. In this case pupils' enquiry work was loosely framed by the teacher. Although the teacher established a basis of knowledge on one specific system in the human body, the respiratory system (considered in the observations in chapter one and in chapter four), pupils were to explore other systems in the human body that were not yet

studied at that time in class. That is, my division of the chapter into two parts is related to the distinctive pedagogical framing of pupils' enquiry work and each of the topics studied (i.e. "sound" and "systems in the human body") in which the presentation events were embedded. My assumption was that the differing pedagogical framing might be influential in the use pupils make of resources for rhetorical purposes, thus it may be significant in terms of the research question the chapter attempts to answer.

Chapter 6 considers the answer to the third sub-question: how do pupils integrate resources they draw from presentation events in the production/revision of their exploration report? The chapter comprises two case study examples of category three. This includes the two versions of the pupils' written exploration reports on the topics explored (i.e. "skeleton and motion" and "the blood system") considered in relation to modes in operation in the communicative events that unfolded between the production of the first version and the revised version of the report. The first version was produced prior to the presentation event and the revised report was produced following the overall presentation event.

DATA COLLECTION METHODS

Observation

I used the non-participant variety of observation (Cohen & Manion, 1989), twice a week, in each class observed, in the period of an entire topic studied. I carried out the observations from two different physical positions in the science classroom depending on the type of the lesson and the practices pupils were engaged in. One position was static and the second was dynamic. Observation from a static position was carried out as I sat at the back of the class during the teacher's part of a lesson, as she assembled the class as a group, and in sessions of pupils' presentation events. By contrast, observation from a dynamic and changeable position was carried out during pupils' independent work. The changeable position of observation was particularly suitable to the dynamic nature of the pupils' independent explorations and other activities in class. As pupils were engaged in explorations and worked independently they had free access to resources. They were allowed to move in the space between resources and activity centres, form small groups and to separate by choice, to collaborate with peers and consult the teacher. This allowed me also to move freely in the classroom. On the one hand, I was able to capture the wider picture of the class from different perspectives and on the other hand to follow the dynamics of individual pupils' exchanges and collaborations, or small groups that aroused my attention. I could closely examine how pupils interacted with the environment, the

procedure of work and to write protocols and occasionally converse with individuals and small groups. All this was initiated in an attempt for me to be sensitive, and to have as little effect as possible on the teaching and learning practices and routines (an explicit request of the teacher).

In time my focused observation in Jasmine's science classroom over a long period of time, unintentionally brought about a kind of familiarity. Nevertheless, pupils understood the message that I was not there as an assistant but just as an observer.

Protocols

During the observations I regularly wrote handwritten protocols. I used two basic formats to organize my handwritten protocols in the course of observation. One format was a running text in prose style, which I used to record the interaction in class, the teacher's communicative actions as she assembled the class as a group, pupils' presentation events, certain small-groups' or individuals' activity during independent work, to describe the resources made available by the teacher and the organization of work in the classroom.

Composing handwritten protocols of communication in the science classroom, multimodal in nature, involved two major problems. One was the problem of representing the many modes of interplay in communication. To overcome that problem, at least partially, I included notes on communicative actions such as the use of position, gaze, gestures, movements in the space, action with objects, writing, etc. In fact in my protocols the vulnerable point is that the written mode is given the prominent role over other modes present in communication. Second is the problem of recording speech and in particular the interactions in class. To overcome that problem, at least partially, I have used a number of devices of written language (i.e. question marks, full stops, comas, underlining of stressed words, (*) asterisks to mark the teacher's turn, (–) dashes to mark a pupil's turn, and occasionally I used numbers to mark a pupils' turn) to represent the essential sense of what was said so that I was capable of both speed writing and afterwards reading the protocols with minimal effort. A written transcript of speech, in general, fails to represent meanings conveyed through resources such as intonation, pace, stress, facial expressions, etc. I made comments on noticeable hesitations or pauses longer than the speaker's usual rhythm or on the pace of speech different than the speaker's habitual pace of speech.

That is, the page layout of the first protocol format integrates recording of speech, comments and descriptions of other communicative actions, descriptions of materials and objects of action used, occasionally notes of my conversations with pupils in a small group and from time to time my drawings of specific objects or actions. An excerpt of this format is presented in figure 5.

The second format of the protocols is a table like form presented in figure 6. I used this format to map the organization of the class during independent work according to the type of activity or according to the social organization into small groups or individuals around certain activities or a selected topic of exploration. During pupils independent work I usually used both text formats. First I described the entire picture of the ongoing in class and then I recorded salient activities of specific small groups or individuals who caught my attention or whom I followed up from previous lessons.

T – I am holding two pipes (image of the pipes) that are made of what material?

P1- Of plastic.

T- Both pipes are made of plastic nevertheless the one is bent and the other is upright, why?

P2- This pipe has kinds of rings so it is flexible.

T – So actually here we have a model without planning it at all. I took it from a pump which we have here in the storeroom. What is this a model of?

P3- Of the breathing tube.

T – No no, I mean a model that exemplifies a principle for us. What principle can this model exemplify? Yes? What principle can this model exemplify?

P4- That it is flexible.

T – But what is the principle?

P5- That the rings are simply more flexible (gestures with his hands).

T – Good, if I have a pipe of a hard material

P5- But this one is also hard.

T – Okay. Both are hard, both are of the same plastic material. What gives this one flexibility is simply that its structure has been changed into rings. So here we see a model which exemplifies a principle of adaptation of a structure to its function. I see that you didn't understand the issue so well so therefore I am showing you a model. You see that it is possible to use everyday things as a model.

Figure 5. Excerpt of the First Protocol Format (translation)

Organization of independent work, exploration and experimentation in small groups according to the type of topic explored framed in the topic "sound" in class 2.

Existing technological developments utilizing sound waves	No' of pupils	Construction of models of innovative technological developments utilizing sound waves	No' of pupils
Ultrasound	4	String instruments	6
Cane for the blind	3	Rattles	4
Electric guitar	4	Alternative door-bell	2
Acoustic developments	2	Alternative public address system	2
Radio	2		
Sonar systems	2		

Figure 6. Sample of the Second Protocol Format (translation)

In each text format described I noted the time frame of segments or episodes of a lesson and the time frame of each performance in a session of presentation events, the focus of the lesson, the type of activities pupils were engaged in, and the kind of materials, objects and equipment made available to pupils. I made the protocols during the observations in an attempt to phrase as concretely as possible what I absorbed, and what Goetz and LeCompte (1984) termed as "low inference description". The protocols provided raw data for reflection, interpretation and clarification of further steps in research. It also enabled the enhancement of the analysis of pupils' texts and presentation events in the course of and following the fieldwork.

Description

One way of trying to answer the research questions of this thesis is to use description as a research tool. I used the method of description to construct a detailed account of the resources made available to and deployed by pupils in the production of texts and in the rhetorical process of presentation events. Description is a significant research method in a study like this, which attempts to trace the transformational resources pupils deployed in the production of texts and in the rhetorical process of presentation events. Nonetheless, it would be a non-realistic endeavour to attempt to describe in detail every act of meaning in a communicative event such as a presentation. Description serves in this research as an instrument to derive multi-levels of interpretation and analysis. Therefore, I present a summary description of the resources made available to and deployed by pupils in the production of texts in response to the teacher's lesson

(chapter 4); and I present in each case study example a descriptive summary of the rhetorical process of the presentation events (chapter 5). Detailed description provided the basis for analysis of the meanings and functions of pupils' semiotic and rhetorical choices and their role in communicating scientific knowledge; it allowed me to reveal the resources pupils drew from presentation events and integrated into their revised exploration reports (chapter 6). The terms of description I used and the entities being described draw on theory, since description rests always on theory, explicitly and implicitly (Ochs, 1979).

Collection of Texts

I collected samples of a range of pupils' texts and related texts from textbooks, information books and worksheets provided by the teacher, which I photocopied. The criterion for the collection of pupils' texts was their production within the lessons in the science classroom. I decided not to include projects or other kinds of tasks performed as homework. My preference was to collect productions created within the classroom environment where I had access to the resources made available by the teacher. In many cases, I was able to closely observe the diverse conditions of the production of texts and the design of presentation events. I considered those factors as an aid in understanding the relationship between pupils' texts and the practices in which they were situated in the context of learning. This seemed to me to enhance the possibility of answering the research questions this thesis addresses. The collection of texts in the main data consists of the following forms of texts pupils produced: comics, mixed generic structures (i.e. journalistic writing and scientific report), flowcharts, exploration reports and experimental reports.

Recording Presentation Events

I used a home video camera to record pupils' presentation events (except for pupils' presentation whose parents opposed the method of video recording). The video data provides a form of text in itself and the videotexts were transcribed. Complying with the teacher's explicit restriction, the selective use of video recording as a method of data collection was used only in sessions of pupils' presentation events.

In light of the intensive and dynamic nature of the presentations as communicative events, the method of video recording was significant although I had observed and had made written protocols at the same time. This was important since during the presentation meaningful communicative actions are often executed at a speed which is

hard to take in through observation during the event. At the same time I could make notes of what the home video camera did not capture. For example, the entire picture of the class, how pupils were seated, the teacher, and the complexity of their responses as an audience was not captured by the camera, as the camera was fixed at the back of the class and focused on the pupil presenting.

A presentation, as any communicative event, can be described in terms of focus that includes a wide or narrow view, and/or in terms of a close up or a distant view (Goffman, 1974). I was interested in a close view of the individual presenter's communicative actions, thus I focused the video camera on the child presenting. Due to the ritual character of the presentation and due to practical reasons (space, and the electrical plug) I fixed the video camera positioned at the back of the class. Although the class and the teacher as an audience are in most cases visually not present on the videotexts their voices are audio recorded or partially recorded. Nonetheless, their significant role as an audience and their impact on rhetoric choices and orchestration of modes of communication is very evident across the videotexts.

The value of the method of video data is well documented (Cohen & Manion, 1989; Lomax & Casey, 1998) as well as the academic debate on the method. One of the points in the debate refers to the distorting affects this method might have on the phenomenon explored and on its validity, which can be restored and promoted by combining video data with other methods of data collection as was done in this research.

The use of the method of video recording has both advantages and disadvantages. In this research the "synoptic perspective" (Lemke 1995, p. 33) of the video data is a great advantage. The more I watched the video data, the more it allowed me to identify the function of communicative modes, which I did not notice as semiotically significant at the time. It also allowed me to identify rhetorical choices that I had not been aware of in real time. In addition to my written protocols the video data provided a resource for detailed description and analysis through a process of successive reviewing, transcription, interpretation and analysis.

A session of pupils' presentation events in its nature arouses excitement in class. At the beginning, my use of the video camera also aroused some excitement, but it seemed that pupils got used to it at an early stage.

Transcription

The way one interprets and analyses the data influences the transcription, which draws on theoretical perspectives and reflects the particular interests and hypothesis the

researcher is interested in examining (Ochs, 1979). The transcription in this study is focused on speech of the pupils and the teacher in the science classroom observed and the video data of pupils' presentation events.

To overcome the problem of how to transcribe the interwoven work of communicative actions realized through multiple modes, the process of transcription involved successive reviewing of the video recordings and three formats of transcription. The intention at each format of transcription was to develop descriptions capable of deriving levels of interpretation and analysis that can enhance the explication of the answer to the second research question of this thesis (i.e. what use do pupils make of resources to communicate scientific knowledge in the rhetorical process of presentation events?)

The process of transcription of the video data enabled me to identify the meaning function of communicative actions, which seemed to be transparent, as having a significant rhetoric and semiotic function such as the use of a gaze, position, a gesture or the manner of manipulating objects. The first level of transcription was in the format of a running text written as a descriptive account in prose style in as concrete detail as possible of the staging of the presentation and the performer's communicative actions in temporal order of the unfolding event.

The second format of transcription involved analysis of the rhetorical process of the event. Each sample of the descriptive accounts was classified into gross analytical units of rhetorical frames in temporal order of the event. The format of this level of transcription is a descriptive account described above, classified into units of rhetorical framings, which were marked by separating lines and labels. I have labelled each of the rhetorical framings of an event according to epistemological characteristics.

The third level of transcription is in a table format involving a multimodal transcription in integration with a rhetorical analysis. It is based on the previous forms of transcription in combination with reviewing the video data and the protocols involving refinement of the dimensions of analysis. The analytical units of the rhetorical framings of the event were further classified according to the rhetorical devices used and the interplay of communicative modes as highlighted in relevant research literature (reviewed in the previous chapter), and derived from the nature of the data. The rhetorical devices were classified according to two categories, the semiotic objects of action used as rhetorical means and the rhetorical strategies. The communicative modes were catalogued according to speech, and the visual and actional mode. The process of cataloguing included noting the performer's use of modes in each of the rhetorical framings which

comprised the event. It also included recording the specific enacted semiotic actions, which were identified as semantically and rhetorically significant.

I used the following devices of the written language in the transcription in order to create a "written" version of speech:

- Full stops (.) and in the version translated into English also capitalizing initial letters of new sentences.
- Question marks (?) at the end of an utterance or after a word indicate the speaker's intonation.
- Commas (,) indicate places where I could sense a pause, or where there was an audible pause.
- Underline (_) indicates stressed words.

Translation

As commented in chapter one, the collection of data for this study was carried out in science classes in Israel, hence all the samples and excerpts subject to analysis throughout this thesis were translated from Hebrew into English. The focus of the research questions and the nature of the analysis and discussion of the data in the frame of this thesis do not require a discussion, from an epistemological point of view, about the distinctive nature of the two languages, Hebrew and English. The guiding principle was to be as accurate as possible in my translations to ensure that the meanings, which are an issue in the texts/events considered in this thesis are accurately re-presented. For example, I made the effort to re-present in the translations, as accurate as possible, the representation of agency, which is essential in scientific texts. That is, how the pupils represented themselves as agents, how they addressed the reader/ audience, how they described and explained phenomena at issue, in the active or passive voice, or as causal processes. The punctuation appearing in pupils' original texts is intentionally not changed in the translation, in order to remain as close to the original text as possible at the same level as the pupils' writing.

THE FRAMEWORK FOR ANALYSIS OF DATA

Multimodal Analysis

In the process of re-viewing and re-interpreting data it became evident that a structured framework and detailed analysis of pupils' texts and presentation events was necessary. It is true that existing frameworks such as that suggested by Fairclough (1989,

1992, 1993), could be a model for an analytic approach to textual analysis. However, since his focus is uniquely on linguistic dimensions of analysis it could not provide a conceptual framework to account for the multimodal nature of pupils' texts and presentation events. Therefore, a broad view beyond the boundaries of the concept of text or event as a linguistic construct was necessary. The multimodal and social semiotic theoretical framework discussed in the previous chapter provides this view. It opens up possibilities to include dimensions of analysis, which attend to a range of resources deployed to realize expressions of scientific knowledge in signs/texts/events pupils produce. Accordingly, the framework for the analysis of pupils' texts and presentation events is a multimodal analysis.

The framework consists of three parts as follows:

1. Multimodal textual analysis of pupils' texts.
2. Multimodal and rhetorical analysis of pupils' presentation events.
3. Textual analysis of pupils' exploration reports in conjunction with multimodal analysis of related communicative events comprising the overall presentation.

Dimensions for Multimodal Textual Analysis

The first part of the framework considers data with respect to the first research question this thesis addresses. The production of texts in the science classroom is embedded within the broad rhetorical framing of a shared topic, which takes on a particular form in class. In the process of production of texts pupils are engaged in a complex of choices, within possibilities and constraints of available resources. These choices include how to transform and materially represent scientific knowledge constructed through the multimodal experience of the teacher's lesson and the multimodal experiences of the pupils' activity into a two dimensional text. They have to choose what to draw on from the range of resources made available in the science classroom. They not only have to choose what content from the teacher's lesson and other available materials to represent in texts they were asked to produce but also to decide how to organize that content in generic structures to integrate scientific knowledge and through what mode. They need to choose how to address the reader (i.e. directly/indirectly, personally/ impersonally) and whether to appear or efface themselves as authors, how to position the reader in relation to phenomena described, as well as how to structure the layout and organize the overall visual space of the text. They need to decide which materialities and tools available in the science classroom will best serve their purposes, what Kress & van

Leeuwen (1996) and van Leeuwen (1998) call "materiality" of texts (i.e. the word processor, paper and pencil, colour).

One way to understand pupils' subjective choices involved in representation and communication of scientific knowledge is to trace the range of resources they deployed and transformed into new signs/texts. In light of the discussion above, the framework for analysis considers how the pupils organised scientific content in texts they produced in response to the teacher's lesson according to the following dimensions: genre, mode, the physical material aspect of text, and the process of production. In other words, the framework for multimodal textual analysis examines variation in pupils' texts according to the following facets:

a. The choice of content, the sources of content (i.e. the teacher's lesson, worksheet, textbook, experiment, other lessons) and transformations of content.
b. The choice and use of generic conventions as a resource to package scientific content.
c. The use of visual and language resources to realize expressions of scientific knowledge (i.e. how agency was expressed visually and linguistically); the relationship between meanings in the visual and the written mode.
d. The spatial arrangement of text on the "visual space" (Kress & van Leeuwen, 1996).
e. The materiality and tools employed.
f. The process of production (in case it was accessible).

The analysis of texts pupils produced in response to the teacher's lesson considers the similarities and differences between the texts across the above dimensions.

The framework draws on Kress' approach to the aspect of genre discussed in detail in chapter two. Accordingly the analysis does not examine the extent to which pupils' texts are structured according to formal text forms. It rather considers how pupils deploy visual and linguistic conventions in a variety of genres as resources to realize expressions of scientific knowledge influenced by their interest and the context of learning.

The framework considers how pupils used linguistic and visual resources in meta-functional terms to realise ideational, interpersonal and textual meanings in texts they produced. Drawing on notions from Hodge & Kress' theory (1993) the framework examines how pupils represent agency in the written mode. This is accomplished through syntactic analysis of the relations between entities in clauses appearing in pupils' texts, i.e. transactive and non-transactive clauses.

The framework draws on notions from Kress & van Leeuwen's framework for visual communication. With respect to representation of the experiential-ideational world the analysis considers whether, and if so, how, pupils used a "narrative structure" or a

"conceptual structure" to express scientific knowledge. In conceptual structures such as a diagram or a flowchart the analysis examines how the process, that is, the relation between the participants is realized visually. For example the relation between participants represented by a linking arrow, may signify one partaker as the origin, or actor and the other as the recipient or goal. The analysis considers how social relationships were realized in pupils' texts in the visual mode. For example, how the reader is addressed in a text is examined by visual features such as the use of vectorial relations to directly address the reader by means of the gaze of depicted participants; or how they represent and relate to participants by the use or absence of agency, reduced or absence of details, colour, shading or background.

The analysis considers the coherence of the arrangement of the text on a page, on an overhead or any other surface in terms of a 'visual space' (Kress & van Leeuwen, 1996; Kress, Leite-Garcia & van Leeuwen, 1997; van Leeuwen, 1998). It examines the page of a text as a whole, its layout and composition, and the constituents, both visual and linguistic elements comprising the text. It considers the meanings and information values of the arrangement of elements of texts on the visual space according to their place along the vertical top-bottom structure and the horizontal given-new structure.

Multimodal and Rhetorical Analysis of Presentation Events

The second part of the framework concerns the rhetorical aspect in pupils' presentation events. In other words this part of the framework considers data with respect to the second research question this thesis addresses. The analysis of the presentation events is structured broadly according to the rhetorical process of the event and the orchestration of semiotic modes deployed, i.e. a multimodal and rhetorical analysis.

The framework draws on the notion of "rhetorical frame" suggested by Kress et al. (1998) as an analytical unit. The framework considers the presentation event as a whole, as a rhetorical unit of analysis that is comprised of analytical units of rhetorical framings. Classification of an event into analytical units neither suggests that pupils consciously rhetorically framed their presentation in that way, nor that the presentation was fragmented. In the analysis of the rhetorical process of presentation events rhetorical frames were interpreted by a configuration of a range of factors, which were identified as semantically and rhetorically significant including: the performers' position on the floor at the front of the class; body posture; the use of gaze; changes made in the given space organisation; spatial orientation towards the audience and to the semiotic objects of action; the starting point of the event or a unit; explicit statements regarding the next move, which I termed "transitional statements"; the choice of content; the choice of

mode; positioning in relation to knowledge; the objects of action used and how these were manipulated and positioned in relation to the performer and the audience; the style of interaction.

The shifts in the rhetorical framings throughout a presentation event were identified by textual meanings. Shifts in the rhetorical framing in the process of the unfolding event were realized by reframing or changes in one or a number of the interwoven compound of factors mentioned, or by introduction of new factors such as: introduction of new information; introduction of a new object of action; a shift in the foreground mode; a shift in epistemology; a change in the style of interaction; or the use of a new rhetorical strategy.

Each sample of the presentations has been classified into analytical units of rhetorical frames in temporal order of the unfolding event under three interwoven categories: rhetorical means, rhetorical strategies and semiotic modes, as presented in table 2. In addition, the rhetorical frame heading and the rhetorical frame time has been noted to position the reader in relation to scientific knowledge established on the topic and the temporal boundaries of the event as a whole and the different discrete units comprising the event. The detailed description of the rhetorical process and intensive analysis of the case study examples (presented in chapter 5) may elicit the impression that a presentation event or certain parts of it stretched over much more time than in actuality. Noting the time frame elucidates the proportion of the dimension of time in which the event transpired in actuality.

The framework for analysis of the presentations comprises three related parts in each case study example in the following order:

1. A descriptive summary account of the presentation rhetorically framed in temporal order of the unfolding event.
2. An analysis of the rhetorical process of the presentation organized in temporal order under three interwoven categories: rhetorical means, rhetorical strategies and semiotic modes summarized in a table format.
3. An intensive multimodal and rhetorical analysis and discussion based on the first two parts.

Table 2. Format for the analysis of the rhetorical process of presentation events

Rhetorical Frame		Rhetorical Means	Rhetorical Strategies	Modes
Rhetorical frame time	Rhetorical Frame heading and No.			
Example:				
2.00	2. Classification of the xylophone	Model/image xylophone	-Classification -Explanation	Visual + speech + gesture + audio

The table format (consider table 2) provides the possibility to attain an entire overview of the range of factors involved in the rhetorical process of a presentation. The table format enables a view along the vertical axis according to the linear time of the unfolding event along each of the categories. It also provides a view along the horizontal axis according to the simultaneously interwoven co-occurring communicative modes and rhetorical devices used at the level of rhetorical frames. Additionally, it makes it possible to focus on a specific element presented in a cell-segment in the table. Each view offers a different angle of vision in relation to the communicated scientific knowledge, the rhetorical process and the rhetorical orchestration of the modal ensemble throughout the event.

The Categories for Analysis of the Rhetorical Process of Presentation Events

The three categories: rhetorical means, rhetorical strategies and modes are in actuality interwoven in communicative events such as presentations and could be placed under one broad category of semiotic resources deployed for rhetorical purposes. Nevertheless, I have classified the resources into three analytical categories for the purpose of analysis. This helps to analytically examine the variation in the use pupils made of the affordances of resources, possibilities and constraints and the manner in which these were deployed in the rhetorical process of presentation events. As discussed in the previous chapter I adopt the notions of "rhetorical devices" and "rhetorical strategies" used by Kress et al., (1998, p. 2) to describe the teacher's rhetorical action in the science classroom for the analysis of rhetorical action from the pupil's perspective. Although Kress et al. do not define the distinction between these two notions, for the requirements of my data, I have classified rhetorical means and rhetorical strategies into two separate categories as considered in the following section.

Rhetorical Means and Rhetorical Strategies

I use the term rhetorical means to refer to the different types of the material objects of action used by pupils for rhetorical purposes, whereas I refer the term rhetorical strategies to the principles of semiotic and rhetoric action taken up by pupils in the course of the presentation. The distinction between the two categories, rhetorical means and rhetorical strategies, helps to illuminate the use pupils made of the semiotic affordances of the semiotic matter which constitutes the objects of action and the rhetorical strategies used to mediate meanings surrounding the objects. The type of objects used and the material resources that constitute these objects influence the construal and representation and the communication of meanings. Hence considering these as a separate category for the purpose of analysis enhances the possibility to better understand pupils' choices and thereby explicate the answer to the second research question.

In contrast to semiotic objects used as rhetorical means, rhetorical strategies are not perceived as having a physical material existence. Take for example, the act of posing a question to create diversity and then constructing an explanation by demonstrating the function of the oesophagus by means of the model (consider observation 5 in chapter 1). Although those communicative actions (i.e. posing a question, demonstrating and explaining) are materially constituted they do not have, and probably are not intended to have, the same level of material existence as the oesophagus model does. Hence, creating a difference by means of a question and constructing an explanation through demonstration are considered in this framework as rhetorical strategies, whereas the material semiotic object, i.e. the model itself, is referred to as a rhetorical means.

The analysis considers the use pupils made of the semiotic potentials and limitations of the resources, which constitute the objects of action used by pupils for rhetoric purposes. The considerations concern the constitution of semiotic objects on a symbolic and material level. The material features of objects are significant in representational and communicational practices. These characteristics are what Ormerod and Ivanic call "physical features" (2000, p. 91) of material semiotic objects. They are features that contribute in different ways to the meaning of objects as signs, constituting semiotic objects, which reflect practices associated with the habitus of school science.

Pupils presenting used a range of rhetorical strategies to communicate scientific knowledge and to ensure the class' interest and communicative engagement. For example, the strategy of demonstration was used to make a commonly invisible phenomenon visible; i.e. demonstration of the function of the lungs or the oesophagus by means of a model. Pupils also used rhetorical strategies in an attempt to construct

convincing explanations on the phenomena explored. For that purpose they used different rhetorical strategies, which created an "explanatory context" (Ogborn et al., 1996) that provides the resources for an explanation. They used rhetorical strategies to create a gap between what they know on the topic and the class presumably does not, which invited the use of rhetorical strategies to bridge that gap. For that purpose pupils used rhetorical strategies such as creating differences by naming the topic of exploration, initiating questions, providing definitions or construction of new terms and entities.

Modes

The category mode enables an overview of pupils' rhetorical orchestration of modes, which were in interplay in each of the units comprising the rhetorical process of a presentation and/or the foreground mode used. In addition it helps to illuminate the functional specialisation of modes in the rhetorical process of a presentation event. In meta-functional terms, it helps to highlight what mode was used to realize ideational, interpersonal and textual meanings. As mentioned above the operating modes in presentation events were catalogued according to speech, the visual and the action mode as highlighted in research literature and as deriving from the nature of data. The analysis of the complexity of the mode of action as enacted in presentation events draws on Kress et al.'s (1998) approach to action as a mode in the rhetoric of teaching and learning science. The framework considers a number of dimensions of action including the performer's position on the floor, body posture, gaze and direction of gaze, spatial orientation, manipulation of objects (i.e. pointing and tracing a map), the orientation to objects and the audience, hand and arm gestures, movement with the whole body and movement in the classroom space. The analysis attends to the interplay of the three kinds of meanings, ideational, interpersonal and textual, realised within and across modes throughout the rhetorical process of the presentation event.

Textual Analysis Linked to Multimodal Analysis of Communicative Events

The final part of the framework concerns textual analysis of pupils' exploration reports connected with a multimodal analysis of communicative events comprising the overall presentation. I call related communicative events as "the overall presentation", which includes a pupil's presentation event and related events following the presentation such as class discussions lead by the teacher and/or the pupil presenting.

This part of the framework considers data with respect to the third research question. This part of the framework constitutes three inter-related stages. The first stage

of the analysis examines the exploration reports pupils produced prior to the presentation in comparison to the revised exploration reports produced following the overall presentation according to the following dimensions: mode, genre and organization of content with respect to the task framework set by the teacher. The analysis considers the similarities and differences between the two versions of the report across those dimensions.

The second stage concerns the analysis of the meaning functions of modes (speech, action and the visual mode) in operation in the overall presentation event. This is done by multimodal analysis of sample excerpts of episodes from the overall presentation focused on realisation of ideational meanings. That is, the analysis examines how expressions of scientific knowledge were realized through speech, action and the visual mode in sample episodes from the overall presentation event.

The third stage considers the possible relations between the meaning function of modes in operation in episodes from the overall presentation and the written reports. This is accomplished by examining what elements from the overall presentation may have been transformed into the revised text, in terms of organization and structure of the text and in terms of ideational meanings, that is, expressions of scientific knowledge.

In summary, having outlined the methodology applied in the course of this research does not suggest that the replication of the research design in a similar setting and conditions would not be difficult. The replication of research even in natural science is not always a straightforward process (Hammerseley, 1990). However I would expect that the findings of this research regarding the use pupils' make of affordances of resources for the expression of learning in the science classroom could recur at the principle level. That is, I would expect that the characteristics of how pupils deploy and transform available resources into texts, integrating visual and language resources to convey scientific knowledge in a variety of genres, would recur. I would also expect that the characteristics, which govern the rhetorical process of pupils' presentations and the potential contribution of modes in operation in communicative events to pupils' writing resources, would recur, if the methodology and research design established in this research would be used in a similar setting and under comparable conditions. In addition, since the issue of this thesis is the semiotic resources made available to and deployed by pupils in science learning practices in the regular setting and environment of the science classroom, the multimodal framework applied can exemplify how it can be used as a tool to trace evidence of learning as semiosis from the pupil's perspective as illustrated by the case study examples in the following three chapters.

CHAPTER 4
PUPILS' TEXTS PRODUCED IN RESPONSE TO THE TEACHER'S LESSON

> Any learning a child encounters in school always has a previous history.
>
> (Vygotsky, 1978, p. 84.)

INTRODUCTION

The purpose of this chapter is to explore the practice of text production in the science classroom from the pupil's perspective. It is exemplified by a multimodal analysis of samples of texts that pupils produced in response to the teacher's lesson and a writing task she gave them. In other words this chapter takes up the first sub-question of the research questions in this thesis: what use do pupils make of resources made available to them in the science classroom to realise expressions of scientific knowledge in texts they produce? The framework of analysis and the theoretical notions and concepts I draw on were presented in the previous chapters.

This chapter is comprised of three sections. In the first section, I will consider the resources the teacher made available for pupils in the lesson. In the second section, I shall analyse and discuss samples of the texts that pupils produced in response to the lesson. In this section I will also consider the practice of text production from a pedagogical point of view. Finally, in the conclusion section I will consider the production of texts in the science classroom from the aspects of mode, genre and assessment from the pupil's perspective.

Kress (1997) has pointed out that the resources meaning makers deploy in the production of signs also provide the evidence through which the reader of the sign can attempt to reconstruct the sign maker's interest marked in the sign. In the light of this view, I will first present a summary description of the teacher's lesson and other resources she made available for pupils in order to better trace the resources deployed and the ways pupils made use of them to express scientific knowledge in their texts.

A SUMMARY DESCRIPTION OF THE TEACHER'S LESSON

The lesson under discussion is the fifth lesson in a sequence of seven lessons on the topic "the respiratory system", framed in the topic "systems in the human body" which was framed in the broader topic "health". The lesson concerned the function of muscles, the diaphragm and inter-rib muscles, with emphasis on the function of the diaphragm, in

the process of inhaling and exhaling. In order to explain the role of the muscles in the breathing process the teacher deployed a number of semiotic objects and semiotic modes in integration.

First she used the motion of her body in an exaggerated manner (chest and abdomen) to demonstrate the motion of muscles as we take in and let out air in the act of inhaling and exhaling. Then she directed the class to also do so and to sense the movement of their body, when taking air in and letting it out by the act of inhaling and exhaling. Then she manipulated the model of the torso. She took relevant organs out of the model, classified and named them, and she introduced the diaphragm as a muscle. Then she used a coloured map diagram representing the inner structure of the breathing organs and the diaphragm. She correlated between the organs she introduced through the 3D model and the two dimensional diagram of the organs. Then she provided the pupils a worksheet showing schematic images of the contraction and expansion position of the diaphragm and of the inter-rib muscles presented in figure 7.

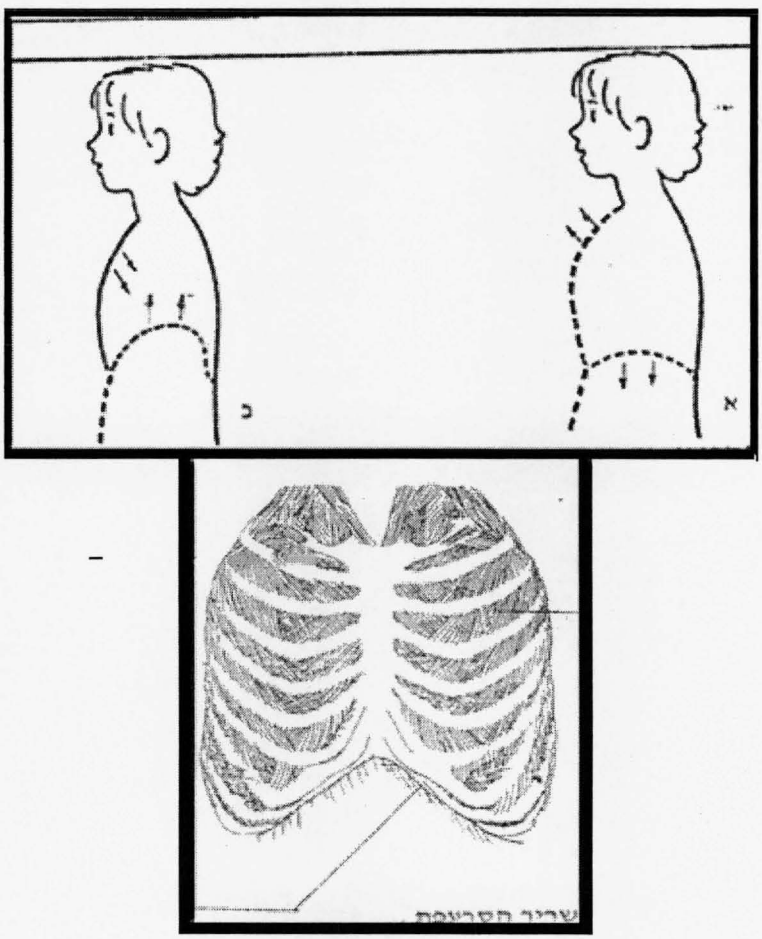


Figure 7. Worksheet images of the diaphragm and inter-rib muscles

On the basis of these images she demonstrated the function of the diaphragm by means of the torso model in integration with gestures of her hand and speech. She animated dynamic motion of the diaphragm, the contraction and expansion position, as represented in the worksheet, since the model represents only the expansion position. Then she stood behind the skeleton model embracing it while inhaling and exhaling to animate the motion of the chest by the inter-rib muscles. Then she shifted to a large coloured image of the human body, naturalistic in design, providing a map of muscles in the body. She pointed out the location of the relevant muscles in proportion to the body as a whole. She directed the class to consider again the schematic images on the worksheet showing the image of the diaphragm and the inter-rib muscles. She suggested that they imagine how the muscles work in the act of inhaling and exhaling. Finally she connected all the elements she referred to concerning the process of inhaling and exhaling, by describing in a narrative style the "route" of air through the "stations"- the breathing organs and the work of the muscles as a cyclic process.

The key players were the air, the diaphragm and the muscles between the ribs. In her narration she commented on the function of each organ in preparing the air for respiration and the change in the volume of the chest until the process of exchange of oxygen and CO_2 occurs. She termed the function of the muscles in the process of inhaling and exhaling as *the mechanism of breathing.*

The integrated work of the different semiotic objects and modes of communication, which the teacher combined in the lesson, provided different representational and communicational possibilities and constraints. At times she gave prominence to one of the modes. For example at one point the action mode was in the foreground at the opening episode of the lesson and speech served as the foreground in the last two episodes of her lesson. Consider the teacher's multimodal communication in the lesson presented in table 3 below. At times co-occurring modes operated in integration in the orchestration of meanings, as in episode 3 and 5. In these episodes action, speech and gesture worked in integration.

The teacher shaped the lesson rhetorically by moving on a continuum from the outwardly, visible, and concrete experience of the process of inhaling and exhaling (i.e. by means of the body), towards a deeper, inner and more analytic view of the body (i.e. by means of the models, images, schematic diagrams), which led to a more abstract level of representation. Each level of representation required different cognitive interpretative work from the pupils. Finally, by speech she connected all the elements into what she termed *the mechanism of breathing* in a narrative style. Following that part of the lesson

(about 25 minutes), she set a writing task, to be accomplished in pairs or individually. The task was to answer the following question: *How does the inhaling and exhaling process work?*

Table 3. Co-occurring semiotic objects and modes in the teacher's lesson

Episode heading and no.	Semiotic objects	Modes
1. Demonstrating inhaling exhaling	The body	**Action** + speech
2. Directing class to sense the body		**Speech** + action
3. Classifying organs	The torso model	**Action + speech + gesture**
4. The diaphragm	Diagrams + schematic image	**Visual** + speech
5. The function of diaphragm	Model + body	**Action + speech + gesture**
6. Function of inter rib muscles	Skeleton model + body	**Action** + speech + gesture
7. The location of the muscles in the body as a whole	Map of muscles + schematic images	**Visual** + speech + gesture
8. Narrative-the route of air in the breathing organs	Models + diagrams	**Speech** + action + gesture
9. Task framework		**Speech** + gesture

The **bold font** marks the modes that were given prominence across episodes in the lesson.

To accomplish the writing assignment, the teacher proposed to the pupils during independent work to select and utilise any of the following resources: the torso model, the skeleton model, the map of muscles in the human body, the map of the breathing organs, a dynamic interactive model exemplifying the function of the diaphragm and its affect on the lungs, relevant passages in three textbooks of different levels, information books and two worksheets. One worksheet used in the lesson, showed the schematic diagrams of the expansion and contraction of the muscles in the breathing process. A second worksheet included a written text, under the heading "Information sheet: on the diaphragm and chest". This text is a report common in worksheets the teacher often provided. The text describes and explains what inhaling and exhaling is while stressing the function of the muscles in the process. In addition the text deals with the notion of inhaling and exhaling as involuntary actions and the extent to which we can control the process for different activities.

The question she set as a writing task outlined the task with respect to content. In what form should the anticipated answer be constructed as a text was not discussed in class. In addition, the teacher probably anticipated as self-evident that the pupils would draw on her part of the lesson and would respond to the focus of that specific lesson to be expressed in their texts. However she did not explicitly express that anticipation.

The Variation of Texts

Though the pupils participated in the same lesson, and were given the same task, offered the same semiotic material, their response to the lesson and the task resulted in a variation of textual productions. Nevertheless, an overview of the texts produced in the lesson revealed that pupils integrate scientific knowledge in a small number of existing genre types, some structured as mixed genres. The collection of pupils' texts in this lesson can be classified as follows: flowcharts, comics, diagrams illustrated by writing, reports and narrative structures. Within and across each form, the texts varied remarkably. The framework for multimodal textual analysis examines variation in pupils' choices of resources to realize expressions of scientific knowledge. The analysis examines pupils' choices and organization of content in texts according to the following dimensions: mode, genre, the physical material aspect and conditions of production (in case it was accessible).

The analysis is not intended to exhaust representative samples of the variety of all the forms of texts produced within that specific lesson. Intensive analysis of a number of samples is sufficient to demonstrate the multimodal approach as a tool for tracing science learning as semiosis from the pupil's perspective, to elucidate the answer to the first research question taken up in this chapter, and to consider the practice of text production in the science classroom from a pedagogical point of view.

CASE STUDY EXAMPLES

ANALYSIS AND DISCUSSION OF SAMPLE TEXTS

In this section I will consider samples of two types of texts pupils produced in the lesson under discussion. One type of text I termed as unexpected (i.e. by the teacher) in science class and the second type as expected (i.e. by the teacher) in science class based on the teacher's responses to the pupils' texts. First the analysis considers three samples of the unexpected type of texts, using visual and linguistic resources and mixed generic markers in different narrative structures. This is followed by an analysis of four samples of the second type of texts, namely expected texts in the science classroom, in the form of flowcharts. Though the dimensions of analysis, introduced earlier, are in actuality interwoven, for the purpose of analysis I will consider them separately in the breakdown of the first three sample texts. In contrast, the dimensions of analysis of the flowcharts will be considered in integration.

TEXT ONE – "THE DIAPHRAGM"

The text production, materiality and layout

The text, presented in figure 8, is a co-production. First, Matti made the drawing with a pencil on an A3 size paper. It included 6 frames marked by numbers from left to right. Afterwards Ron produced the speech bubbles according to the placement of the narrator represented by a face image (frame 1) and the image of a rocket (frames 2-6). The orientation of the frames marked by numbers from left to right in the opposite direction of the written language in Hebrew may have confused Ron, thus by mistake linking frames 2 and 4 instead of frames 2 and 3 in accordance with the speech bubbles.

Content

The text concerns the route of air through the breathing organs and the relation between the inner structure of the organs and their function in cleaning the air for breathing. The text represents the inhaling process; the process of exhaling is inexplicitly referred to in a small bubble in the last frame as follows: *the process goes all the way around back.* The inner structure of the breathing organs is represented in schematic images in the following order of the frames from left to right: 1 – the openings of the nose; 2 – the hair and mucous in the nose; 3 – the pharynx; 4 – the breathing tube; 5 – the bronchi; 6 – the alveoli.

The content in this text draws from elements in the teacher's lesson. It is evident in the heading "the diaphragm", in the point of departure i.e. *the air goes in and out,* in the sequence of the organs and the account of their function in cleaning the air for breathing in the speech bubbles. The text represents the organs in the same sequence as narrated by the teacher by means of semiotic objects (body, model, diagrams) in the lesson. The air and the muscles, which were the key players throughout the teacher's lesson, are the key players in this text.

Genre

The text is structured as a guided tour in the medium of comics used to convey scientific knowledge, for example: *Let's enter the nose in the nose we'll find a lot of hair that clean the air of dust and germs and so does the mucous...* My suggestion is that the pupils used representational possibilities of the medium of comics in integration with generic conventions of a guided tour to transform elements from the teacher's multimodal

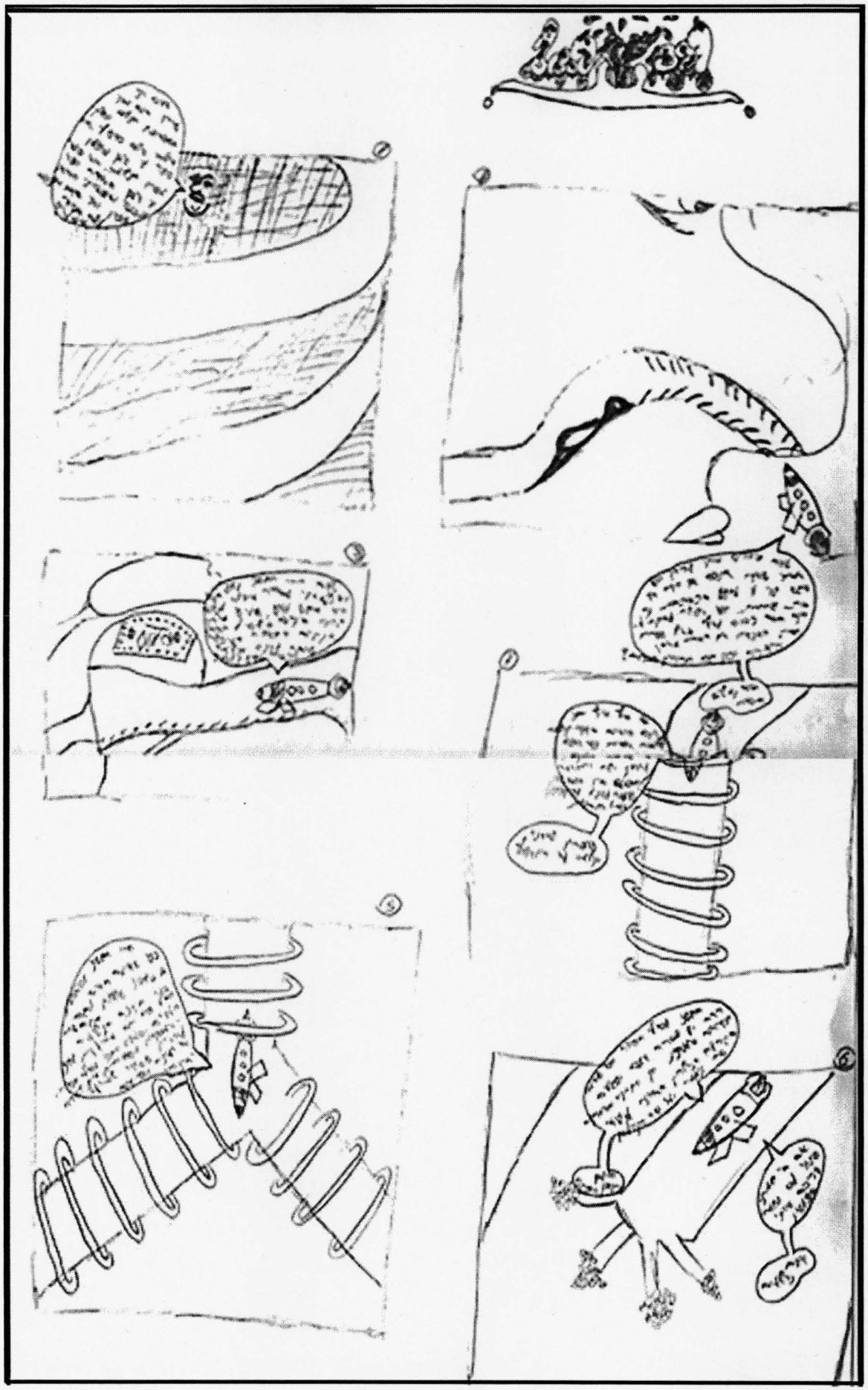


Figure 8. (a) Text one "The diaphragm" (b) Translation of the original text

Text one – "The diaphragm"

(The numbers refer to the numbers of bubbles in each frame)

Frame 1
Hi I am muscle man. Today I flow through the breathing system and I met someone by the name of the diaphragm man who told me how the breathing system works. He told me how the air goes in and out and how he makes the lungs move and I'll take you there on a wonderful tour!

Frame 2
Hi remember me I'm muscle man great I said I'd take you and I will hang on a moment while I start the engine brr…brr…brr…wonderful we can begin. Let's enter the nose in the nose we'll find a lot of hair that clean the air from dust and germs so is the mucous got it!

Frame 3
Hi here we are in the pharynx you know as you can see as the air is cleaned for breathing it enters the pharynx the pharynx is only a midway station for the moving air in the meantime the cleaned air enters the breathing tube I can't wait to get there!

Frame 4
1. Let's go on with our tour
2. Oh finally we are here as you can see through the breathing tube the clean air moves and soon you'll see some rings these are cartilage rings that assist the breathing tube to stay upright and the elastic stuff between the rings assist the tube to bend flexibly but the rings
3. keep the tube upright.

Frame 5
Hi we arrived at the bronchi as you can see the bronchi are also made of rings like the breathing tube but they are divided into two parts. We are almost at the end of our tour. The bronchi transfer the air to the lungs now to the left or to the right okay okay to the right!

Frame 6
1.We are arriving at the end of our tour as you can see these are tiny round things called bronchi* they are the last station in the process of cleaning the air for breathing here the air run out again the process
2. goes all the way around back
3. Okay bye I have heard that you are short in air I'm needed between the ribs
4. You are breathing

*By mistake he named the alveoli bronchi.

(b)

communication into a two-dimensional text. They transformed the teacher's narrative and metaphor of the "route" of air, and her analogy of the breathing organs to "stations" into a "narrative structure" (Kress & van Leeuwen, 1996, p. 79) of a guided tour.

The text in the speech bubbles moves between tenses, past, present and future, which is outside the conventions of scientific writing, for example: *I said I'd take you and I will... soon you'll see some rings these are cartilage rings that assist the breathing tube...* The interaction between the different tenses used derives from the tension between generic requirements of a guided tour and forms of expressing objective scientific information.

Agency

Generic conventions of a guided tour require a sequenced structure with a clear beginning and ending leading to a target. The pupils used that generic structure to represent the agentive role of the organs in the process of cleaning the air for breathing in a direction and sequence consistent with the route of air in the respiratory system. The process is described as a causal process; it is evident in the way they relate entities in transactive forms of clauses throughout the text. In Hebrew, like in English, the linear direction of the word order is a conventional representation of the causal relations between entities. For example: *He* (the diaphragm) *makes the lungs move...hair clean the air of dust and germs... cartilage rings assist the breathing tube...the bronchi transfer the air to the lungs.*

The genre of a guided tour also requires an active agent – a guide, addressing an audience, and a means to move from place to place. This may explain the pupils' decision to personify the key players, the inter-rib muscles, the diaphragm, and to use the image of a rocket as a vehicle. An image in frame 1 is the face of a personified muscle that represents itself in the speech bubble as a muscle man, being the narrator and the guide of the tour in the respiratory system. *Hi, I am muscle man. Today I flow through the breathing system...and I'll take you there on a wonderful tour!*

That is, the pupils represent themselves as agents through the narrator-guide who speaks on behalf of them. In the last speech balloon (frame 6) it turns out that the muscle man is a muscle from between the ribs that left his position to guide the tour. The goal of the tour is expressed in a general statement in the final bubble in frame 6: *you are breathing.* The diaphragm, though being the heading of the text is indirectly introduced by muscle man and he is given the role of actor that affects the lungs: *I met someone by*

the name of diaphragm man that told me how the breathing system works... how he makes the lungs move...

Personification of the muscles also incorporates their feature of action and motion. The readers are directly addressed in the speech bubbles i.e. *here we are in the pharynx you know, as you can see...* and through the gaze of the image's face in frame 1. The direct and personal address of the reader is outside the conventions of scientific texts but derive from the genre conventions.

Relationship between the visual and written elements in the text

In contrast to the interpersonal meanings realized through the gaze of the image's face and direct address of the reader in the written mode, the images of the organs (frames 2-6) are impersonal. The images show the breathing organs as isolated and schematic, with minimal lines in black and white. This kind of image is referred to as an "offer" (Kress & van Leeuwen, 1996, p.124). It impersonally offers objective information. That is, the structure of the organs is represented close to conventions of scientific drawings (i.e. the hair and mucous in frame 2-3, the breathing tube, the bronchi and alveoli in frames 4-6), which the pupils may have drawn from worksheets provided by the teacher such as the one presented in figure 9. Unlike the image in the worksheet, which shows the breathing system as linked organs in the body, the pupil's drawings show the organs in isolation. Each frame visually represents one participant organ – a "station" in the tour. In frame 3, the pupil explicitly used the term station in which the pharynx is defined as a *midway station for the moving air*. Unlike the narrative structure of the speech bubbles the structure of the visual elements in the frames is a "conceptual structure" (Kress & van Leeuwen, 1996, p. 79). It represents a schematic and analytic view of the inner structure of the organs.

The pupils used the medium of comics, which opens up representational possibilities and is at the same time constraining. In comics every line has a meaning. On the one hand, this characteristic of the medium of comics opened up the possibility of representing the structure of the organs in objective schematic images. On the other hand, the format of comics might be constraining. Comics structure both time and space into a sequence of frames (Eisner, 1992). The format of comics requires a particular sort of division of space and layout. This may explain why the pupils designed the breathing organs in isolated images so as to fit in the frames, not providing the picture of the breathing system as a whole.

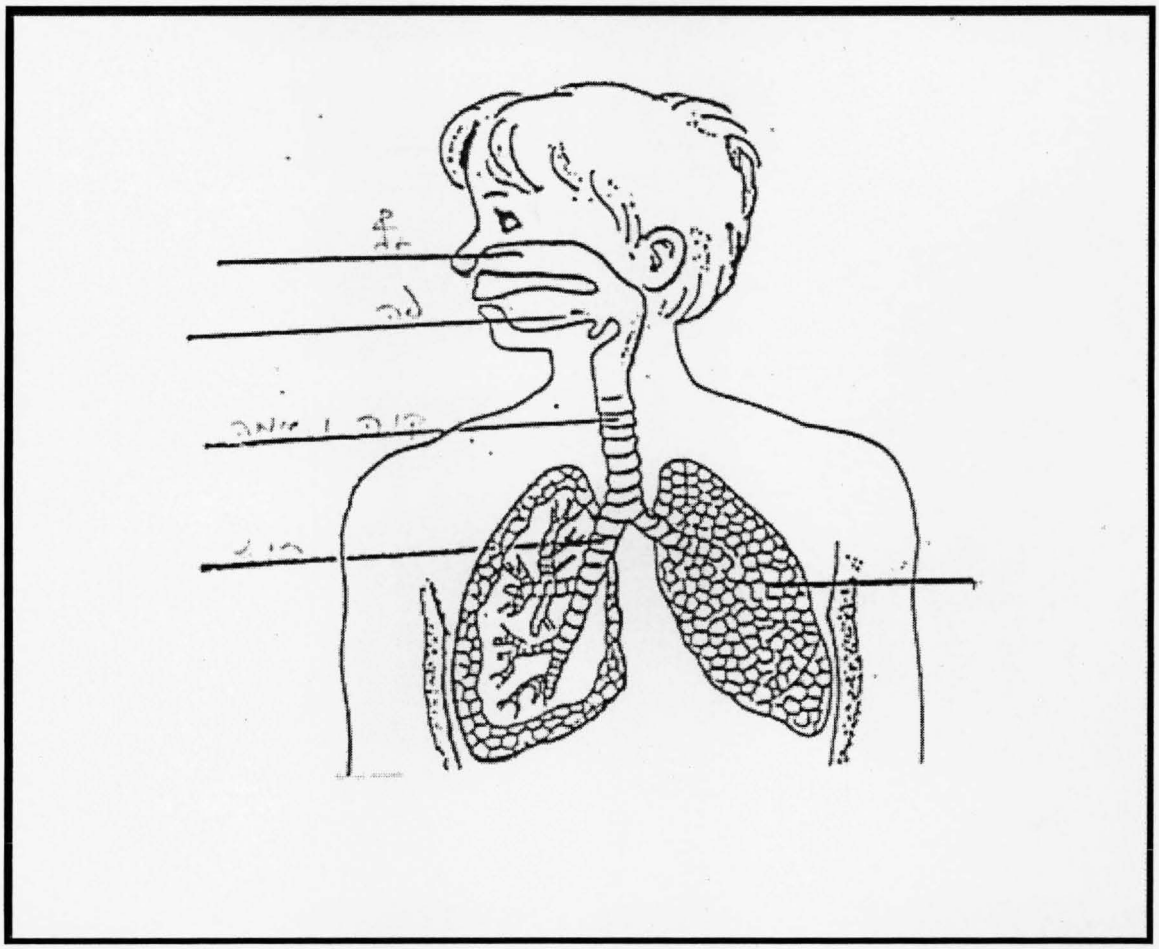


Figure 9. Worksheet image of breathing organs

The division in a sequence of frames does not suggest that the reader cannot capture the whole picture. It is the human mind's ability to observe the parts and perceive the whole, by connecting between the frames and filling in the gaps between frames by applying the ability of closure (McCloud, 1994; Purves, 1998).

The medium of comics also enabled the pupils to cope with a representational problem of how to depict the entity "motion", a criterial characteristic of muscles, which were the key players in the lesson and in the worksheet text. The teacher solved this problem through multimodal communicative actions using multiple modes and a number of objects and strategies in the lesson (i.e. demonstration of the motion of the body, animation of the function of the muscles by integration of the models, the body and gestures, and by the metaphor of the "route" of air).

The medium of comics provides representational possibilities which enabled the transformation of the multimodal experience of the entity of motion into the two dimensional comic texts. The pupils visually solved the problem of depiction of motion, even though drawings are static in nature. In frame 1, they used shading lines, which created blank spaces in a form of a route, creating the illusion of air in motion, which is in

actuality motion of invisible matter in space. In the following frames there are markings of the route within the organs by different lines. They also depicted motion by the image of the rocket, which symbolically represents motion. The rocket is designed in a form similar to the shape of an arrow, marking the direction of movement.

In summary, although this type of text is unexpected by the teacher in the science classroom (consider the discussion in the section below under the heading "a pedagogical point of view) the pupils gave scientific content a shape corresponding to the requirements of the medium of comics and the generic structure of a guided tour using the interplay between the visual-spatial mode and the written mode for the expression of scientific knowledge within generic constraints. They used the medium of comics and the genre of a guided tour to transform elements from the teacher's multimodal communication in the lesson into a two dimensional text.

TEXT TWO – "THE JOURNEY INSIDE US"

The text under the heading "The journey inside us", depicted in figure 10, is also structured as a guided tour. However, this text is remarkably different from text one. In this case the text integrates genre markers of a guided tour and a scientific report.

The text production, materiality and tools

This text is comprised of written and visual elements. The text was produced in cooperation at the computer. Elisa was working on the keyboard and Dina was more active in talking and drawing. While Elisa worked on the final written text Dina produced a diagram showing the breathing tube and the lungs in one image, which she transformed into a map of the tour. She worked with pencil on a separate and distinct A3 size poster paper. In my observation I noticed that they termed their text as a story.

Content

The text concerns structural features of organs in the respiratory system. Towards the end of the text the function of the lungs, mainly the function of the alveoli in transferring oxygen to the body is considered. The following organs are included in the route as stations in the guided tour: the breathing tube, the bronchi, the bronchial tree, the lobes, the alveoli, and the diaphragm. Each station/organ comprises a section in the text, marked orthographically by a subheading *First station, second station* and so on in bold

The Journey Inside Us

From outside we are fresh and beautiful, we try to look as good as we can, but what about our inside? What is happening there? In the lungs? What do they look like? Let's go on a magical and wonderful journey, the journey to our lungs the journey inside us.

First station! The driver announces.
And the lecturer explains: the first station is the breathing tube which is at the continuation of the throat it is a pipe slightly flattened at the back. Its length is 10-12 cm. Its sides are strengthened by 16-20 incomplete cartilage rings, in which their free edges turn to the back. So the lecturer concluded and drove on.

Second station! The driver announces.
And the lecturer explains: the second station is the bronchi. The breathing tube splits into two bronchi in which each one enters into one lung. The bronchi are called the main bronchi.
We go on there are four more stations the driver says and drives on.

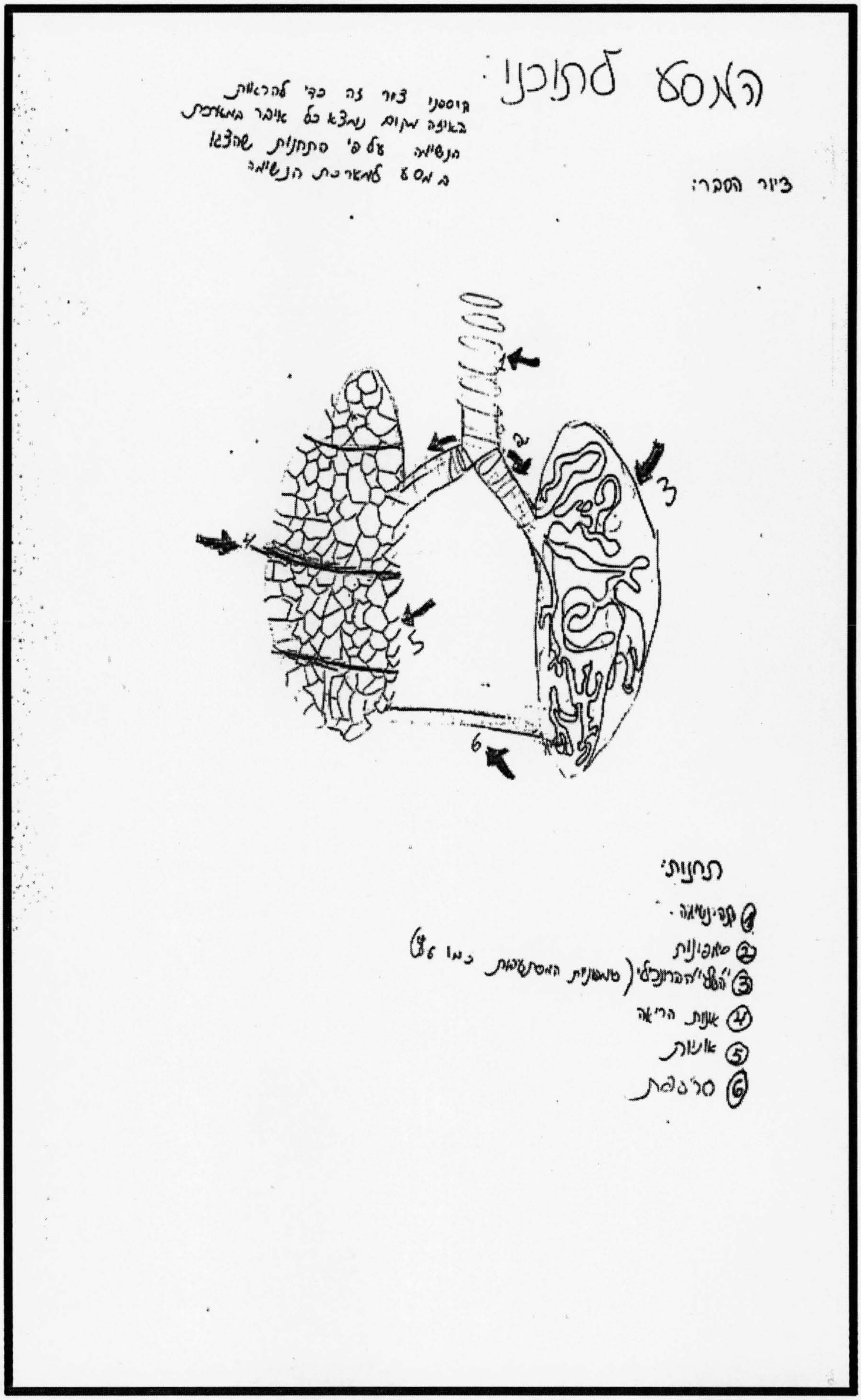
Third station! The driver announces
And the lecturer explains: the third station is the bronchial "tree", the bronchioles are thin and narrow pipes which branch off from the bronchi resembling the form of a tree. The lecturer concluded and the driver starts the vehicle.

Fourth station! The driver announces
And the lecturer explains: the fourth station is the lobes, each lung has lobes, the right has 3 and the left 2. Let's go on to the next station.

Fifth station! The driver announces
And the lecturer explains: the fifth station is the bronchioles each lobe is divided into many bronchioles by a linking tissue which lies between them. The bronchioles are comprised of alveoli. The number of alveoli in the human body are millions, the lungs are comprised of alveoli and of bronchi which transfer the air. We have mentioned that the breathing tube branches off into two bronchi which transfer air to both lungs. The alveoli are very tiny in the form of a bubble, the diameter of an alveolus is .0.1 mil. Hundreds of them will total 1 cm only. Because they are so tiny and much of the oxygen moves to the alveoli which are wrapped in capillaries and so the oxygen moves into the blood. Because they are so many this process is done with speed and quickness, and the oxygen arrives at each of the body parts.
Following five minutes the last station.

Sixth station! And the last the driver announces
And the lecturer explains: the sixth station is the diaphragm which is a muscle beneath the chest which contracts and expands the abdomen in the acts of inhaling and exhaling.
That's all children our journey has come to an end.
Good bye.

Figure10. (a) Text two "The journey inside us" – translation of the original text; (b) Map diagram; (c) Translation of the map diagram

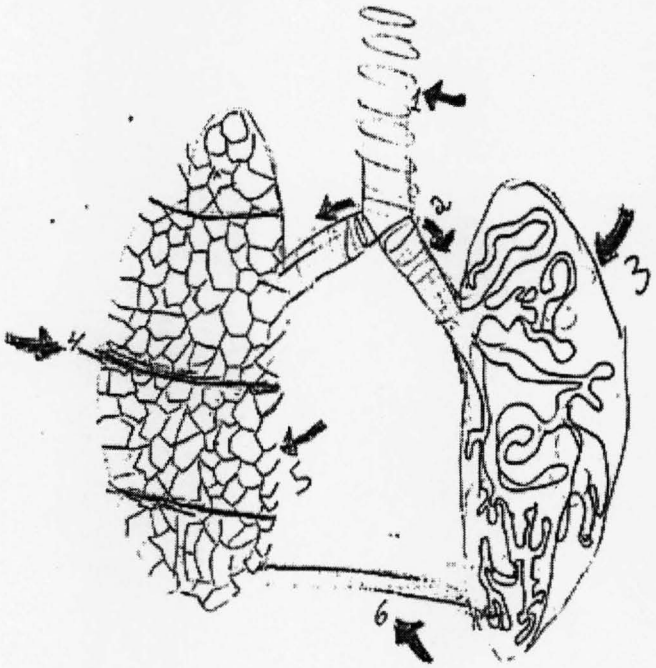


(b)

The journey inside us

Explanation of the drawing:

We did add this drawing to show each organ in the breathing system according to the stations on the journey in the breathing system



The stations:

1) The breathing tube
2) The bronchi
3) The bronchial "tree"
4) The lobes
5) The alveoli
6)The diaphragm

(c)

and a larger font size than for other parts of the text. The diagram – map, which accompanies the written part of the text, represents the introduced organs. A legend accompanies the map.

Unlike the content of text one, which drew on the teacher's lesson, the content of this text indicates that the pupils drew mainly on texts from two different textbooks. In one textbook they focused on a section under the title "What are the lungs and what is happening inside them". In the second textbook, which is a high level textbook, they focused on a section under the title "The lungs" particularly on the diagrams illustrating the text. This can be derived from their focusing on the lungs, rather than on the role of the muscles in the process of inhaling and exhaling stressed by the teacher in the lesson. On the one hand they did not include a number of organs comprising the breathing system, e.g. the mouth, the nose and the pharynx, introduced by the teacher as involved in the process. On the other hand, influenced by the texts they drew on, they extended the technical information beyond what the teacher introduced in the lesson. They integrated specialised terms such as *the bronchial tree* and measurements and numerical details, which the teacher did not introduce in the lesson. For example: *...the diameter of an alveolus is .0.1 mil. Hundreds of them will total 1 cm. only...*

Genre

Similar to the first sample text discussed, it seems that the producers of this text also transformed the teacher's narrative and her metaphor and analogy on the route of air in the breathing organs, into a guided tour. Similar to the producers of text one they also used some generic conventions of a guided tour, but in this case they used the genre of a guided tour to provide scientific information on the breathing organs as being topographical sites in the tour. For example:

The first station is the breathing tube which is at the continuation of the throat it is a pipe slightly flattened at the back. Its length is 10-12 cm. Its sides are strengthened by 16-20 incomplete cartilage rings...

The generic structure is mixed and unfolds as follows:

Journalistic introduction > scientific report (framed in 6 sections of "stations" of the tour) > journalistic closure > scientific diagram – map.

The introduction section is written in a journalistic and current advertisements style of suggested guided tours. My suggestion is that the pupils transformed the title in the textbook, elaborated and adjusted it to the requirements of the genre they chose. As

mentioned the following is the title in the textbook: "What are the lungs and what is happening inside them". Their transformed introduction is as follows:

From outside we are fresh and beautiful we try to look as good as we can, but what about our inside? What is happening there? In the lungs? What do they look like? Let's go on a magical and wonderful journey, the journey inside us.

The closure directly addresses the children although produced as a task for the teacher: *that's all children; our journey has come to an end. Goodbye!*

In contrast to the journalistic writing in the introduction and the closure of the text, the six sections, comprising the stations on the tour, and the map diagram provide objective and scientific information, though framed by generic constraints of the guided tour. For example: *Fifth station! The driver announces... the fifth station is the bronchioles each lobe is divided into many bronchioles by a linking tissue which lies between them...*

The diagram of the organs is transformed into a map by marking lines, arrows and numbers that specify the organs as stations appropriated to the genre of a guided tour. In this case the numbers are marked from the right to the left side of the diagram consistent with the direction of writing in Hebrew.

Agency

The agentive role is given to two different agents. First, is a driver, his role is to announce each station: *First station...Second station...*and so on. The second agent is a lecturer who speaks on behalf of the producers of the text. The role is not given to a guide-narrator, as in text one but to a "lecturer", who has the "legitimatization" to provide information loaded with specialised terms, as conventional in high-level scientific reports. Although the lecturer appears as the agent directly addressing the imaginary audience, he uses neutral, objective and formal language. Thus the schematic map diagram is also agentless like a conventional drawing in scientific texts. Unlike the lecturer in text two, the guide narrator in text one has the "legitimatization" not to use specialized terms, for example, instead of the term "cartilage" he used everyday terms: *the elastic stuff between the rings.*

Text two mainly represents structural features of organs rather than the causal relations between the organs in the process of breathing. It is evident in the relational structure of clauses, comprising the majority of the text, for example: *The breathing tube...is a pipe slightly flattened at the back... the bronchioles are thin and narrow pipes...the bronchioles are comprised of alveoli... alveoli are very tiny in the form of a*

bubble... Only towards the end of the text the description shifts to causal relations between entities. Here the oxygen, alveoli and the diaphragm are the agents of action: *the oxygen moves to the alveoli which are wrapped in capillaries and so the oxygen moves into the blood... The diaphragm which is a muscle beneath the chest contracts and expands the abdomen in the acts of inhaling and exhaling.* However, the process of inhaling/exhaling as a whole is not clearly represented as a causal process, since the point of departure and the agentive role of the organs described earlier in the text (i.e. who is acting on whom) is not represented.

Comparison between text two and text one on the dimension of agency reveals that text one, a comic text, more transparently represents the direction of causality in the process of breathing than text two does. Nonetheless, on the surface text two seems to provide a higher level of scientific information on the topic as it is loaded with technical terms.

Relationship between the visual and written text

The map diagram accompanied the written element of the text as an illustration on a distinct, separate and larger size page (A3) than the written text (A4). However the map diagram was given the same title as the written text "the journey inside us". This indicates that the pupils view the map as comprising the text though not integrated in it. They did add a written note on the top of the page of the map, which they defined as an *explanation of the drawing. We did add this drawing to show where each organ in the breathing system is according to the stations on the journey in the breathing system.*

The note is significant in terms of the research question this chapter attempts to answer. It indicates the producers' understanding, consciously or unconsciously, that there are scientific meanings that can be better represented through visual resources than through linguistic resources. In my view the pupils' note also indicates tension between their interests and the teacher's interests and anticipations. Their note reflects their attempt to ensure that the teacher will accept the diagram which they transformed into a map of the tour, which is outside the conventions of scientific diagrams at school.

TEXT THREE – "THE DIAPHRAGM"

This text, in figure 11, is also a comic text under the same heading as text one. Unlike text one, the sequence of images in this text represents a narrative of an everyday event whereas the written text in the speech bubbles is structured according to conventions of scientific writing in school.

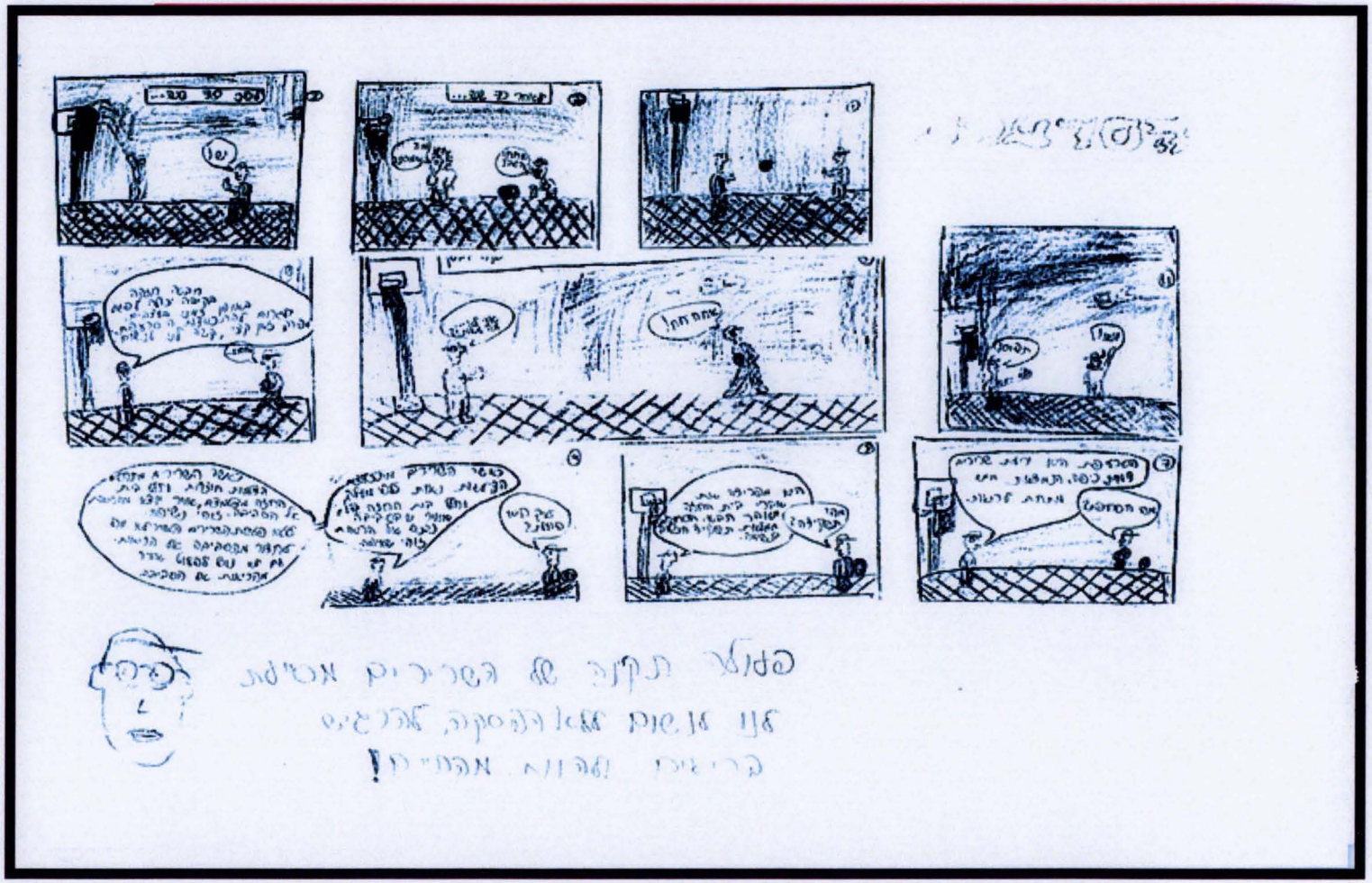


Figure 11. (a) Text three "The diaphragm"; (b) Translation of the original text

Text three – "The Diaphragm"

(The numbers refer to the number of bubbles in each frame)

Frame 2
The heading: After 70 years…
1. Ohhh….my back!
2. What did you say?

Frame 3
The heading: 70 years before…
1.Yes!

Frame 4
1. Catch!
2. Wow!

Frame 5
The heading: in the moment he turned, the ball hit him hard in the abdomen.
1.Ohhhh!
2. Oh no… what have I done?

Frame 6
1.Ohhhh…
2.A hard hit to the abdomen can temporarily damage the nerves and cause the diaphragm to contract for a short moment it is difficult for us to breath.

Frame 7
1.What is the diaphragm?
2.The diaphragm is a cap like sheet of muscle which is located right under the lungs.

Frame 8
1.What is it's function?
2.It separates the chest organs from the abdomen organs. The diaphragm performs a very important function in breathing.

Frame 9
1.How does it work?
2.When the muscles contract the ribs move up and the volume of the chest increases, the air in the environment enters into the lungs, this is inhaling.
3.When the muscles relax, the ribs go back and the volume of the chest decreases, air goes out from the lungs to the environment. This is exhaling. Without the muscles' work the air could not move from the environment to the lungs. We also could not let out the air from the lungs to the environment.

General conclusion at the bottom of the page
Normal operation of the muscles helps us breath continuously, feel healthy and enjoy life!

(b)

Text production and layout

This text is also a co-production. First Raz made drawings on size A3 paper, which included 9 frames marked by numbers from right to left. Unlike text one he marked the numbers from right to left, in the direction of Hebrew writing. Afterwards Jonathon produced the speech bubbles. Frames 2, 3, and 5 also have written headings and at the bottom of the page there is a general conclusion written on the contribution of muscles to our health taken from the worksheet text: *Normal operation of the muscles helps us breath continuously, feel healthy and enjoy life.*

Content

The text concerns the function of the muscles particularly the diaphragm in the process of inhaling and exhaling. The written text in the speech bubbles integrates elements from the teacher's lesson and the text in the worksheet she provided under the heading "on the diaphragm and chest", mentioned above. However, the pupils transformed only those parts in the worksheet text which concerned the key players in the process of inhaling and exhaling, namely the muscles and the air, as introduced also by the teacher.

Genre

The images in the sequence of frames have a narrative structure. The images show episodes in a basketball game between two participants. At a certain moment (frame 5) by accident one hits the other hard with the ball in his abdomen. The play is interrupted, which generates talk between the two participants and a scientific explanation for the breathing problem caused by the accident: *A hard hit to the abdomen can temporarily damage the nerves and cause the diaphragm to contract for a short moment it is difficult for us to breathe...* (frame 6). The interaction between the participants unfolds in the form of questions and answers. The participant hit was given the role of asking the questions and the participant that caused the accident provided the answers, for example:

What is the diaphragm?
The diaphragm is a cap like sheet of muscle...
What is its function?
It separates the chest from the abdomen organs...
How does it work?
When the muscle contracts the ribs move up and the volume of the chest increases...

In this manner they specifically addressed the question, which was set as a writing task. My suggestion is that the use of a narrative structure in the medium of comics opened up representational possibilities to express the tension between two levels of knowledge, the level of everyday knowledge and scientific knowledge. It can be viewed as a transformation of the strategy the teacher employed in the lesson. This she did by moving from the everyday experience of sensing the body in the act of inhaling and exhaling to abstract scientific terms and knowledge regarding the process of inhaling and exhaling. The pupils employed the medium of comics to represent the move between the two levels of knowledge by the interplay between the narrative structure of the images and the scientific knowledge and explanation provided in the written text in the speech bubbles. The turning point in the narrative event (frame 5) invited the scientific explanation.

Agency

The represented participants in the images speak on behalf of the producers. Although the speech in the bubbles is structured as questions and answers it is not structured as a natural conversation. It is rather general, formal and detached from the particular event represented in the images, as expected in scientific texts.

The process of inhaling and exhaling is described in the active voice as a sequential causal process. The muscles are given the role of agents affecting the volume of the chest, which affects the entrance of air in and out of the lungs. This is evident in the causal relations between entities in the form of transactive clauses in the speech bubbles. The pupils also explicitly state the essential role of the muscles' work:

> *When the muscles contract the ribs move up and the volume of the chest increases, the air in the environment enters into the lungs this is inhaling. When the muscles relax, the ribs go back and the volume of the chest decreases. This is exhaling. Without the muscles work the air could not move from the environment to the lungs. We also could not breathe out the air from the lungs to the environment.*

Comparison between text one, two and three on the dimension of agency shows that text three represents the direction of causality in the process of inhaling and exhaling as presented by the teacher in the lesson, it also responds specifically to the question she set.

Relationship between the visual and the written mode

Although visual and linguistic resources are integrated in the sequence of frames as is common in comics, the visual and the written elements do not express meanings in parallel throughout the text. The images have a narrative structure representing an everyday event focused on interpersonal meanings between the represented participants. By contrast, the speech bubbles (frames 6-9) focus on ideational meanings, providing objective scientific information impersonally and detached from the particular event in the images, as is conventional in scientific texts. This is in contrast to text one, also a comic text, in which the images have a conceptual structure and the speech bubbles a narrative structure.

SUMMARY OF TEXTS ONE - THREE ANALYSES

With respect to the first research question considered in this chapter the analysis shows that the three texts vary significantly in the use pupils made of available resources to realise expression of scientific knowledge. The variation is evident across the dimensions of analysis as discussed below and summarised in table 4a.

In relation to content the texts vary significantly. The variation in pupils' differential focus on content suggests that they felt free to select different aspects, key concepts, key players, points of departure and other elements from the teacher's lesson (i.e. narrative, metaphor) and from other available materials, which they transformed into texts. Text one focuses on the function of organs in cleaning the air for breathing. The text draws elements from the teacher's lesson. Text two focuses on structural features of breathing organs and the function of alveoli in transferring oxygen to the body. The text draws elements mainly from two textbooks. Text three focuses on the affect of the muscles on the acts of inhaling and exhaling. The text draws elements from the teacher's lesson and a worksheet text.

With respect to genre, each transformation deployed different merged generic conventions to integrate different aspects of scientific knowledge. The choice of generic conventions can be seen as the pupils' attempt to integrate their interests in the production of the texts. The fact that the texts were structured in merged genres did not weaken their coherence. The producers of text one used generic conventions of a guided tour to present the function of the breathing organs in cleaning the air for breathing as a causal process. Unlike text one, the producers of text two used genre markers of a guided tour to frame a scientific report, introducing structural features of breathing organs as being topographical sites on the tour. The producers of text three used a narrative structure in

the medium of comics to frame a scientific report providing an explanation on inhaling and exhaling as a causal process. That is, the pupils deployed genre markers as resources differentially even within the same genre (i.e. the guided tour, text one and two) and medium (i.e. comics, text one and three).

Table 4a. Summary of the dimensions of analysis of texts one-three

Textual dimensions	**Text one**	**Text two**	**Text three**
Heading, content specific/other	"The diaphragm", content specific	"The journey inside us", content specific	"The diaphragm", content specific
Content	Structure and function of the organs in cleaning the air for breathing	Classification of organs and the function of the lungs	The role of the muscles in the acts of inhaling/exhaling
Content draws on	The teacher's lesson	2 Textbooks	The teacher's lesson+ worksheet text
Genre	Comics narrative-guided tour integrating scientific information	Journalistic narrative-guided tour merged with scientific report	Comics everyday narrative used for scientific explanation
Relationship between visual and written elements	Integrated	Distinct and separate, image as illustration	Integrated
Agency	Breathing is a unified causal process	Agentless classification of organs + causal goal of transferring oxygen	Inhaling/exhaling a unified causal process
Actor Goal	Air + muscles breathing	– Transferring oxygen	Muscles Inhaling/exhaling
Metafunctional meanings in visuals	Ideational-schematic analytic images of organs	Ideational-schematic map-diagram	Interpersonal + textual - images representing narrative
Metafunctional meanings in writing	Interpersonal, ideational, textual in narrative structure	Interpersonal, ideational, textual, narrative used for scientific report	Ideational, textual, Scientific explanation
Materiality and tools	Pencil, A3 paper	Computer printed A4 paper, drawing- pencil, A3paper	Pencil , A3 paper

The variation in the use of specific genre markers in integration suggests that pupils may have employed genre markers as a resource for transformation of elements of

the teacher's multimodal lesson into a two dimensional multimodal text. Three examples illustrate this point: the depiction of the route of air and the 'motion' entity through the medium of comics and the genre of a guided tour in text one; the sense of action and motion in the guided tour in the lungs in text two; and the sense of action in the narrative structure in the comics in text three.

With respect to mode, though the task was clearly set as a writing task, the pupils felt free to use visual and linguistic resources to realise expressions of scientific knowledge. The relation between the visual and the linguistic elements shows that the meanings realised through the different modes are not expressed in parallel in each case. This is salient in the two comic texts. In text one the schematic images represent ideational meanings close to conventions of scientific drawing, whereas the written elements integrate interpersonal and ideational meanings. In text three, the images represent a narrative focused on interpersonal meanings, whereas the written elements focus on ideational meanings written according to conventions of scientific writing. The variation in the ways pupils relate entities in clauses within and across the written elements in the texts indicates how they represent agency; how they differentially conceptualise inhaling and exhaling, as a unified causal process with a clear point of departure and goal (text three); as a goal oriented process (text two) in which the point of departure and sequential direction of causality in the process of inhaling/exhaling is not clearly represented; or as a unified causal process focused on the function of organs in cleaning the air for inhaling (text one).

The texts vary in the way the imaginary audience/reader is addressed. The variation in pupils' choice of personal or impersonal, direct or indirect address, within each text and across the texts, derives from generic constraints and the focus on different dimensions of meaning. When focused on ideational meanings the text is impersonal or formal. When focused on interpersonal meanings, both the visual and the written elements in the text are personal. Take for example text two, which directly and personally addresses the reader in the journalistic narrative elements of the text. There is direct address but formal in the integrated scientific report sections, and an agentless and impersonal address in the accompanied map diagram. However, even when directly addressing the reader, this is accomplished through a narrator, represented visually or in the written text, (i.e. a guide, lecturer, represented participant) who speaks and provides scientific knowledge on behalf of the producers of the text. Considering that the reader of the texts was in fact the teacher, addressing children explicitly in text two and inexplicitly in text one, is interesting. Perhaps it stems from the genre constraints employed.

The co-operative work in each text transpired so that one pupil focused on the production of the visuals and the other on the written elements in the text; a process, which responded perhaps to individual preferences involved. However, in the medium of comics the visual representation preceded the writing. In each of the samples the pupils conceived and introduced the text as equally produced. The pupils used a larger size paper (A3) for the integration of visual and written elements (text one and text three) or for the drawing work as an illustration of the written text (text two). The variation in the size of the material surface suggests that pupils need more action space for the creation of visual representation of knowledge.

A Pedagogical Point of View

Referring to the pedagogical point of view, I would like to make note of an anecdotal account about the teacher's responses to the texts discussed thus far. These responses were accessible to me by my observations in the lesson a week later. In response to text one, the teacher commented: *You have chosen a very original and creative way to express your knowledge although you have not summarized the material as an answer to the question.* Since this comment instantiates the teacher's responses towards unexpected texts, in particular towards image dominated texts, my interpretation is that she considered the text in terms of creative expression rather than a serious means of communicating scientific knowledge. In this case her response was perhaps a reaction to the medium of comics. Since images are the most significant element in comics it is usually not accepted as serious matter. The ease of reading comics gives it a reputation as being restricted to low and limited intellectual accomplishment (Hornblower, 1993; Eisner, 1994). However, Eisner suggested that comics are an adequate teaching tool to cope with subject matter of substantial sophistication. Although the images of the breathing organs in text one were designed close to conventions of scientific drawing the teacher did not comment on it.

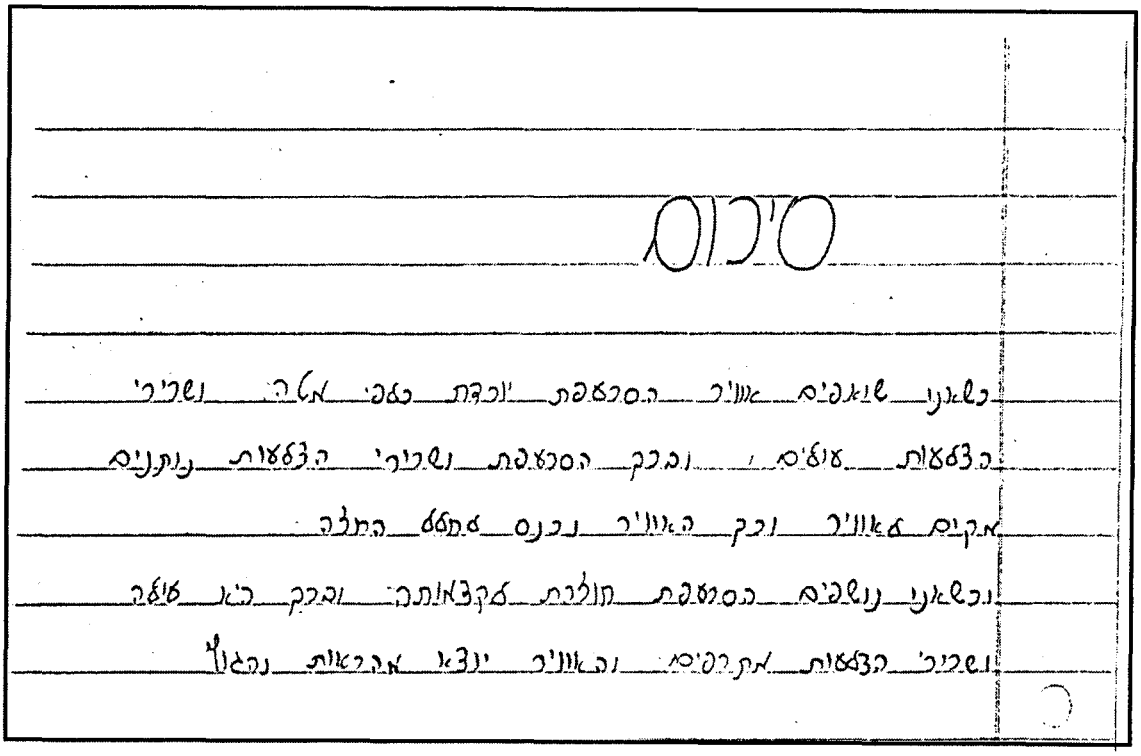
In the case of text two the teacher responded similarly and yet different by suggesting the pupils re-produce their text as follows: G*irls. You have chosen a very original and creative way to express your knowledge. But it would be advisable to organise the material as a summary.* The term "summary" commonly refers in Israeli education context to a general "neutral" non-disciplinary form of text. For illustration purposes consider a sample text presented in figure 12 that includes the heading "summary" produced in response to the lesson under discussion in this chapter, which can be read as a factual report. This form of texts was accepted and did not receive any

specific comments from the teacher, unless the language or the factual information was incorrect.

Turning to the teacher's response to text two, only following the accomplishment of the writing task she realised that it was not the form of text she would have anticipated in the science classroom. Though the map diagram was designed according to conventions of a scientific drawing it did not receive any specific comment from the teacher. However, in response to the teacher's comment and suggestion the pupils produced a second and different text. They drew on a canonical text as a model in the same high-level textbook which they used for the creation of the map diagram in their first version of text. Their second text was constructed close to the model text, loaded with technical information and phrases taken from the textbook, under the heading "the lungs" adopted from the source text. The text in the textbook is constructed as a canonical report, which is common in older high-level science textbooks. Considering the teacher's response to their new version of text, a loaded text with technical information was clearly not the text she wished them to produce: *Do you understand all the words you have written? You should not use words you don't understand.* That is to say, the teacher responded to their text from a linguistic point of view.

In the case of text three, a comic text, the teacher responded similarly and yet different: *You have chosen a very creative way to express your knowledge*. In this case the teacher did not add a critical comment as in the case of text one or suggest to re-produce the text in a different form as in the case of text two. Although the written elements in text three were written according to conventions of scientific writing and could be considered as a complete and correct answer to the question set as the writing task, they did not receive any comment from the teacher.

In summary, although the three sample texts discussed are not the type of texts expected by the teacher in science class they do provide evidence of the transformational resources involved in the expressions of scientific knowledge. That is, they afford an indication of the visual and linguistic resources in a variety of genres pupils bring to practice in text production as resources to realise expressions of scientific knowledge based on their interests. In the cases discussed, the pupils' interests seemed to compete with the teacher's interests and anticipations, however at the initial stage of disciplinary learning in the science classroom.



(a)

Summary

As we inhale air the diaphragm moves down and the inter-rib muscles move up and thereby the diaphragm and the inter-rib muscles make room for the air and so the air enters into the cavity of the chest

And as we exhale the diaphragm returns to its initial position and thereby it moves up and the inter-rib muscles relax and the air leaves the lungs and the body

(b)

Figure 12. (a) Sample text "summary" (b) Translation of the original text

FLOWCHARTS

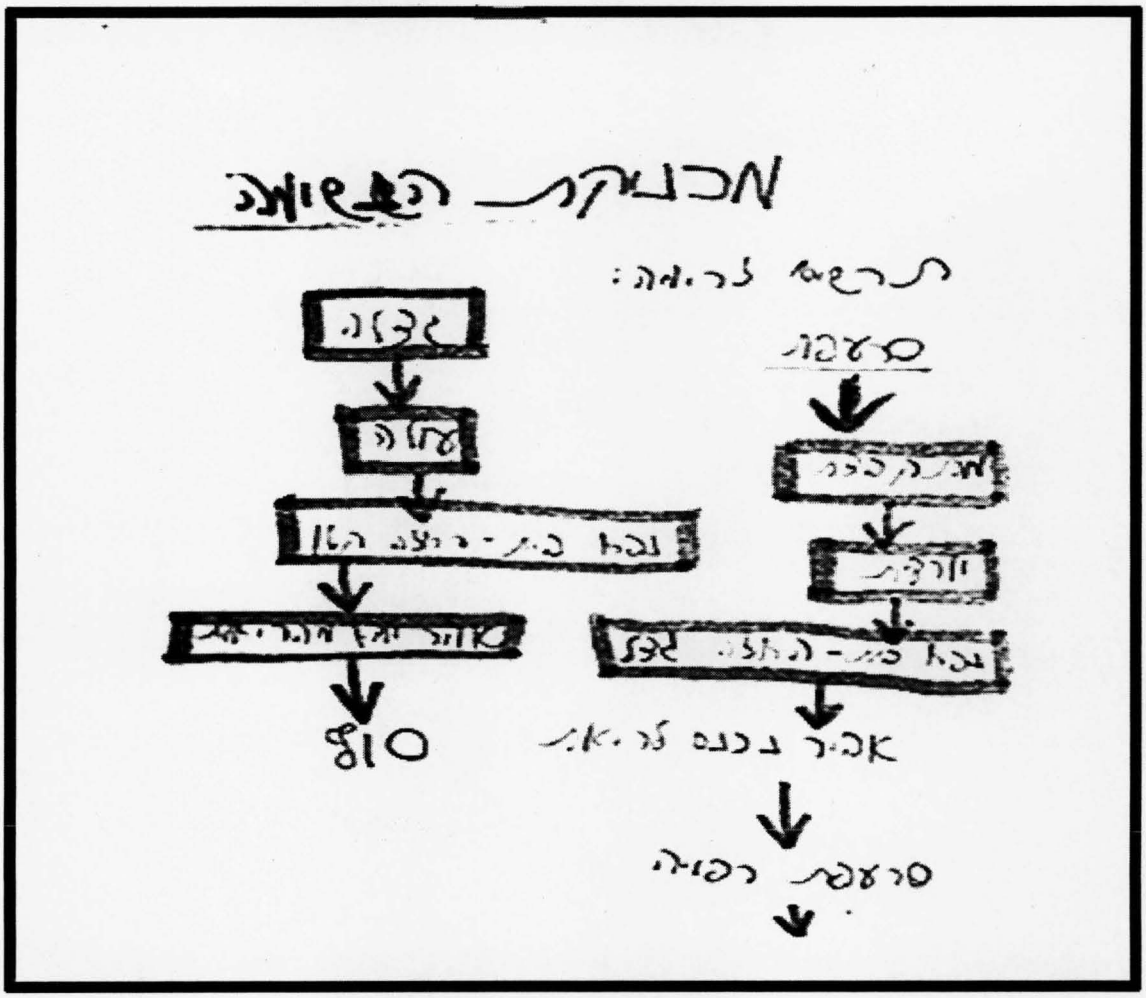
Flowcharts are used as a tool to spatially and visually represent phenomena having the nature of sequential progression, with a clear beginning, direction and end. The direction of progression is usually marked by a line, namely, a vector, commonly with an arrowhead. The information is usually organised in a sequence of abstract graphic form of boxes, which serve to represent concepts, words, and usually the noun elements of the information linked by lines and/or arrows in the direction of the process or goal. The participant from whom the arrow starts out is termed as the Actor and the participant to whom the vector is aimed at is termed as the Goal (Van Leeuwen, 1996; Kress & van Leeuwen, 1996). The design of the visual spatial structure carries meaning. That is, the meanings are realised by integration of linguistic units and visual graphic elements organised in spatial arrangement. Hence the dimensions of analysis regarding pupils' flowcharts will be considered in integration. The following four flowcharts were individually produced.

TEXT FOUR – "THE BREATHING MECHANISM"

The text, in figure 13, was produced on an A4 size blank page with a pen and Indian ink, which is used to mark prominence or salience. The flowchart is vertical, spatially arranged as a sequence of elements from the top to the bottom at the right side of the page, continuing also from the top centre to the bottom, most obviously, because of the limitations of the page, in order to include it in one sequence.

The text concerns the function and affect of the diaphragm on the entrance of air in and out of the lungs. Although the terms inhaling and exhaling were not explicitly used the content responds to the specific question set by the teacher. The headline is content specific. In contrast to the content specific headline, the sub-headline is the general term "flowchart" declaring explicitly the form of the text. It is marked as less prominent than the headline, by it's placement beneath the headline at the right side of the page, by being written in a regular pen and not in bold Indian ink as the headline and in a smaller font size. The subheading is followed by a colon, taking the function of detailing, by referring to the sequence of participants represented vertically.

The content of this text draws on the teacher's lesson. This is indicated by a number of components including: the headline, the point of departure, the sequence of participants, the key players and the direction of the process from the Actor to the Goal.



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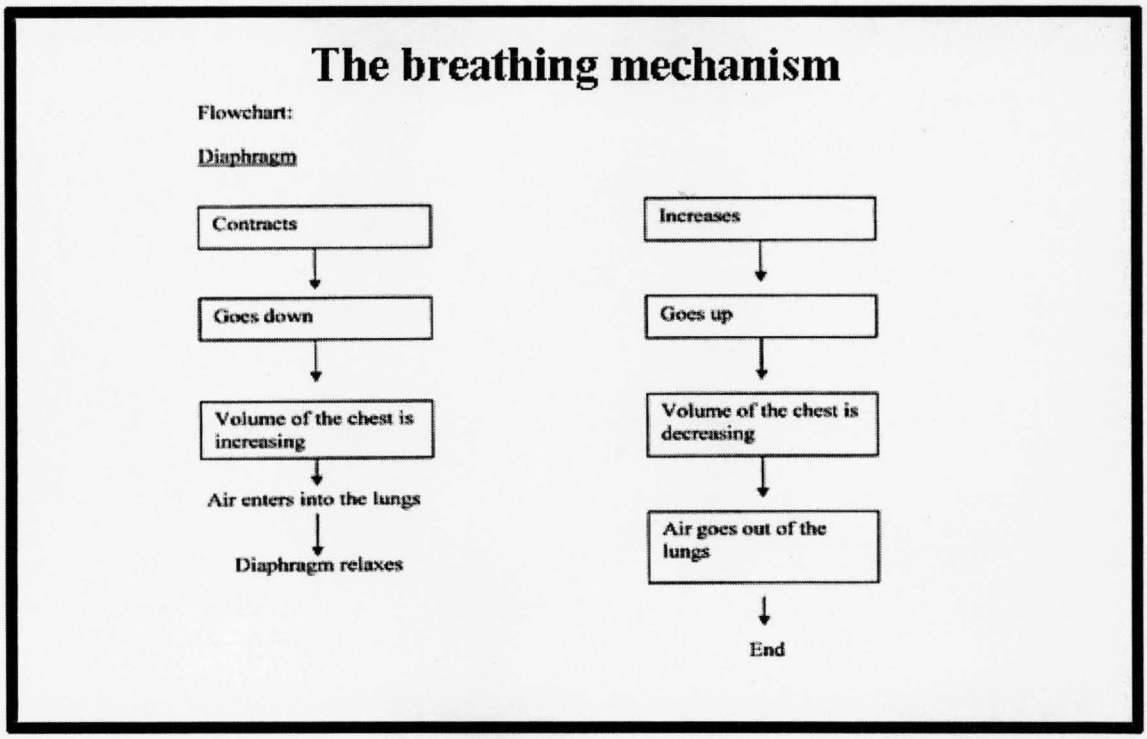


Figure 13. (a) Text four "The breathing mechanism"; (b) Translation of the original text

The pupil adopted the headline "the mechanism of breathing" from the last episode in the teacher's lesson. It reflects the core of the topic of the lesson. He used generic conventions of a flowchart to visually represent both the participants and the direction of causality in the process of inhaling and exhaling, which was multimodally introduced by the teacher as a narrative process. He arranged the selected key participants in a sequence corresponding to that process. As conventional in flowcharts he linked the linguistic elements by visual elements. The heterogeneous elements of words and boxes were connected by arrows marking the direction of the process. The arrangement itself of the elements of a text on the visual surface also produces meaning. The arrangement of this text is clearly along the top-bottom vertical axis. In this case the position of information at the top of the structure indicates its significance. In this flowchart the position of the participant "diaphragm" at the top indicates its prominent role. That is, the diaphragm was given the agentive role of the Actor that affects the volume of the chest. This was the teacher's point of departure, stressing the role of the diaphragm as affecting the volume of the chest, hence the entrance of air in and out. Thus the pupil positioned the air as the Goal of the process. In addition the prominence of the diaphragm is marked orthographically by being stressed in Indian marker ink, written in an enlarged font size and the single underlined participant in the sequence, similar to the underlined headline and by not being framed in a box as most other participants in the sequence.

The represented sequence along one vertical axis (although divided because of spatial limitations of the page) indicates that the pupil referred to inhaling and exhaling as a causal and unified process. All the arrows are in bold Indian-ink. They indicate the direction of the causal process by connecting the participants starting out from the first participant and so on, along the sequence. The end is signified by the word "end" as common in young children's narrative texts. The nominal participants and process participants are not distinctively located and marked in this flowchart, as is conventional in flowcharts. A quick overview of the participants shows that the producer effaces himself as author/agent; that the information is focused on ideational meanings, using impersonal language, in the present tense commonly used to signify objective information, as is conventional in scientific texts.

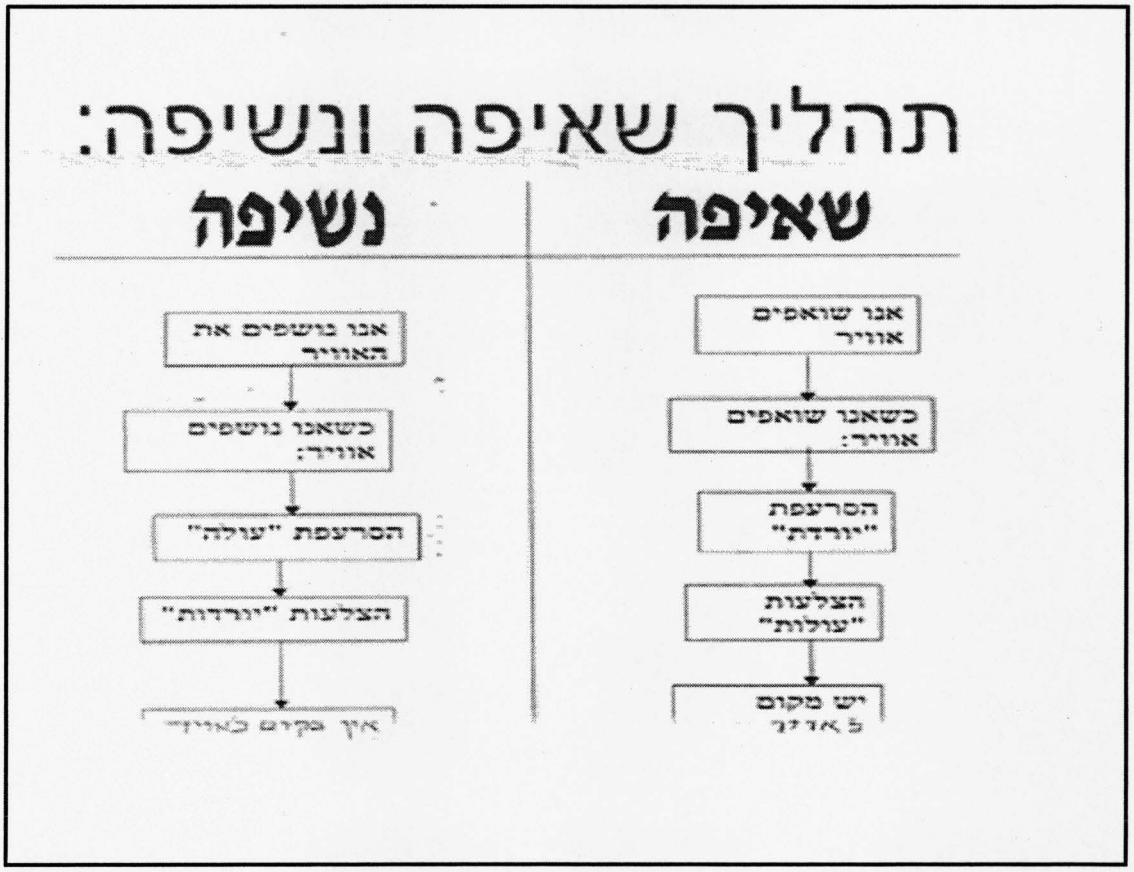
TEXT FIVE – "PROCESS OF INHALING AND EXHALING"

This flowchart, in figure 14, was produced on the word processor. The headline is content specific and responds to the formulation of the question by the teacher. Its location at the top of the page and orthographic elements, the enlarged and different font

type indicate its prominence. Under the same headline the pupil arranged the flowchart in a table like form, containing two parts, marked by crossed lines. One part at the right is under the subheading inhaling and the second part on the left is under the subheading exhaling. In each part of this table-like structure there is a vertical flowchart comprised of boxes linked by arrows. The bold and different font types signify their significance. These are the participants, all arranged in boxes, under the heading of inhaling (which I mark with numbers for convenience sake): 1. we inhale air 2. as we inhale air: 3. the diaphragm "goes down" 4. the ribs "go up" 5. there is space for air. And these are the participants of the exhaling unit: 1. we exhale air 2. as we exhale air: 3. the diaphragm "goes up" 4. the ribs "go down" 5. there is no space for air.

The heading *process of inhaling and exhaling* explicitly defines inhaling and exhaling as a process. The colon following the heading indicates that although the pupil separated inhaling and exhaling, the process includes both parts. And yet, compared to the previous flowchart represented in one sequence, here the division of the process into inhaling and exhaling is clearly visually spatially marked. The first participant in each part of the flowchart is a general statement *we inhale air; we exhale air.* These statements are considered given information, which is indicated by a number of factors. First, the linguistic form of the general *we* in integration with the grammatical form of the verb in plural and in the present tense (the Hebrew "stami") is the characteristic form in Hebrew to express a common and given general "truth". Second, the next participant in each part of the flowchart is the process which draws on given information that is followed by a colon *as we inhale air: as we exhale air:*. This indicates that the agents of action in the process of breathing are the human beings in general terms that affect the muscles. The act of inhaling and exhaling affects the function of the diaphragm, which affects the motion of the ribs. Hence she placed the diaphragm and the ribs in the third and fourth positions in the structure of the flowchart. That is, the point of departure in this flowchart is remarkably different from the previous flowchart discussed.

It seems that the producer of this text draws on the teacher's demonstration and the pupils' experience of physically sensing the body in the act of inhaling and exhaling in the opening episode of the lesson. It was indeed the point of departure of the teacher at the start of the lesson, which the producer of the flowchart transformed into a general statement. She represents the process based on that given general fact in the structure of the flowchart. In this case it seems that the separate representation of inhaling and exhaling draws on the teacher's demonstration by means of her body, the torso model and



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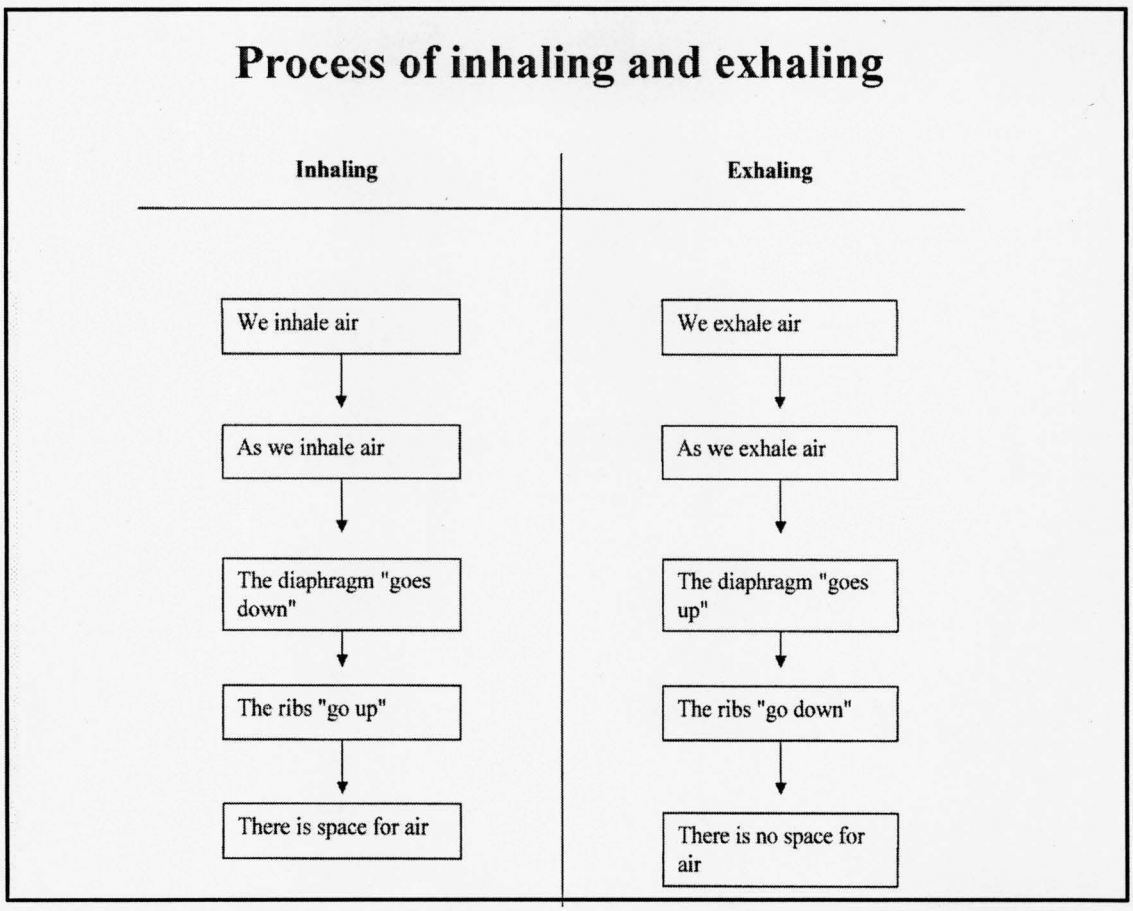
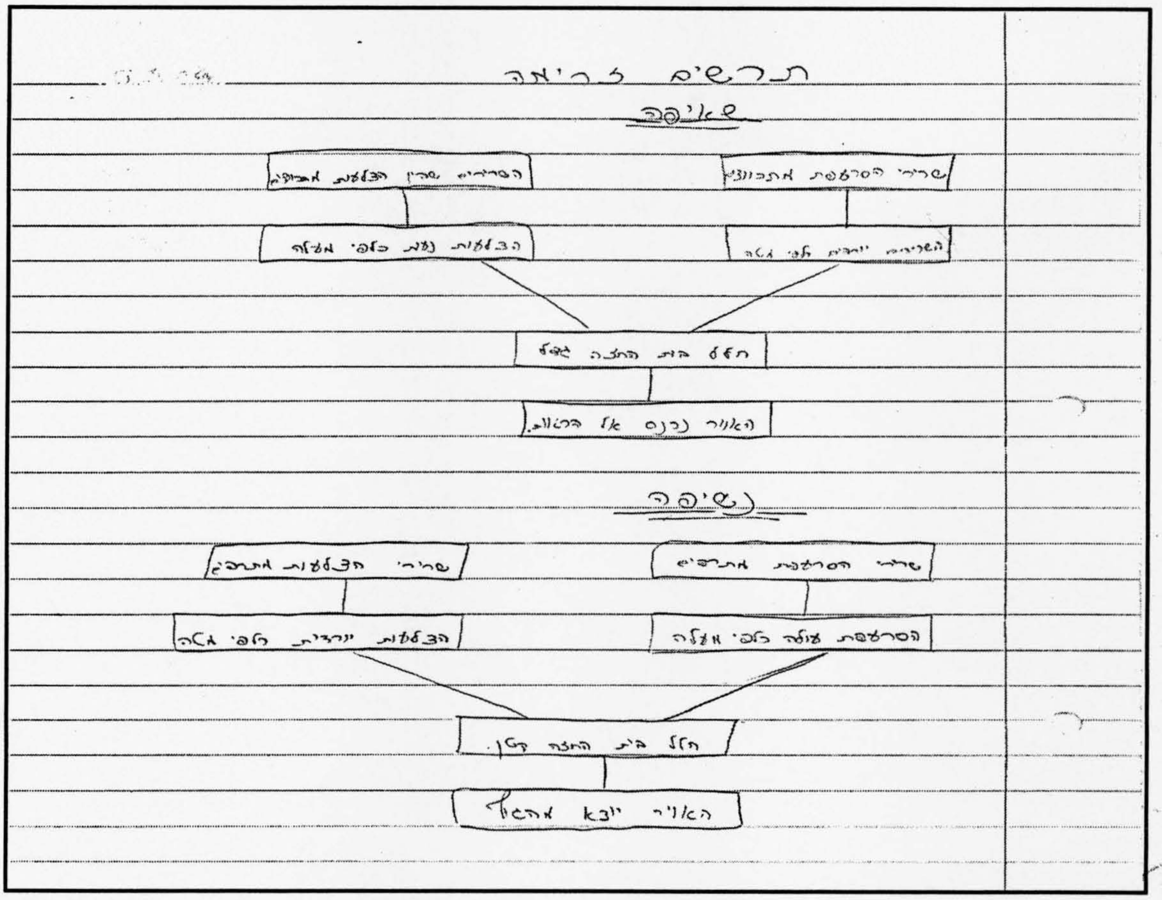


Figure 14. (a) Text five "Process of inhaling and exhaling" (b) Translation of the original text

the schematic images. As described, the teacher focused on the two different positions of the diaphragm, contraction and expansion, and its differing affect on the movement of the chest and its volume in the act of inhaling and exhaling. In addition the pupil's drawing on the physical experience of the act of inhaling and exhaling might explain why she used everyday expressions "goes down", "goes up", which she put in quotation marks, rather than the scientific terms of contraction and expansion used by the others. The use of quotation marks indicates that she understands that expressing the function of organs in the body is as if it is being viewed by the naked eye. The representation of inhaling and exhaling in two separate structures in the flowchart is also the form of the following text, though they differ remarkably.

TEXT SIX – "FLOWCHART"

This text, appearing in figure 15, was produced with a pen and paper. It has a general term of the form of the text "flowchart" as the heading, at the top centre of the page, not referring to the specific content of the text. The absence of a heading, not positioning the reader in relation to the topic of the text gives a sense of a context bound text. Two separate structures are represented under the heading, inhaling and exhaling. The unit of inhaling takes the top of the page, under the subheading inhaling which is underlined. The unit of exhaling takes the bottom of the page, and the subheading exhaling is also underlined. As discussed in the previous examples, the visual spatial arrangement carries meaning and therefore it is important to describe it in more detail. Each of the structures of the flowchart is comprised of six rectangular boxes of the same size, in which a vertical line, without an arrowhead, links each two boxes. The arrangement of boxes under the subheading of inhaling is as follows: on the right, two separate boxes one beneath the other, are linked by a vertical line, as well as two boxes on the left side of the page which in turn are linked each by a diagonal line to two boxes beneath at the centre of the page. That unit includes the following participants: 1. the muscles of the diaphragm contract 2. the muscles move down 3. the inter-rib muscles contract 4. the ribs move up 5. the volume of the chest increases 6. the air enters the lungs. The unit on exhaling has exactly the same identical visual spatial arrangement, which is separately positioned on the page beneath the unit of inhaling. This unit includes the following participants: 1. the muscles of the diaphragm expand 2. the diaphragm moves up 3. the inter-rib muscles expand 4. the ribs move down 5. the volume of the chest decreases 6. the air leaves the body.



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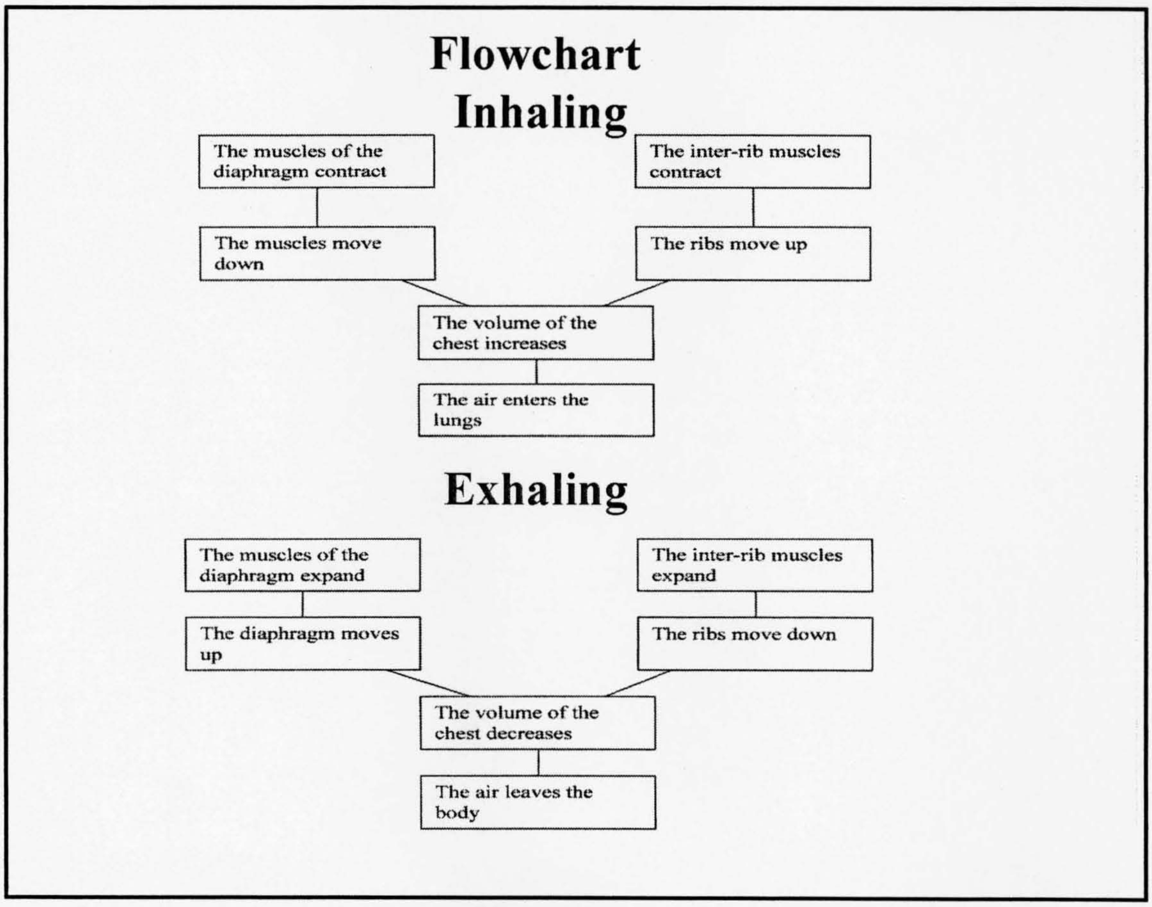


Figure 15. (a) Text six "Flowchart"; (b) Translation of the original text

The written elements are structured in non-transactive clauses; nevertheless the causal relations between the participants and direction of causality are indicated by visual spatial resources, that is, by the position of the participants and the linking lines. The written elements use the present tense, which is the common form to represent given general objective facts. They are focused on ideational meanings and textuality is realised through visual spatial resources.

The pupil used a page with lines. This may derive from her concern for neatness and symmetry as reflected in the symmetric, identical and balanced structure within and across both structures. The sense of symmetry and balance is also achieved by deploying the same tool and visual resources. She used the same pen and cursive font size for the production of all the elements in the text. The heading and subheadings are in a slightly enlarged font.

The visual spatial symmetrical balanced structure carries meaning. It awards the same position and role to the key players, the muscles, in the process of inhaling and exhaling. Both the diaphragm and the inter-rib muscles are at the same hierarchical position. In other words, both the diaphragm and the inter-rib muscles are represented as the actors affecting the volume of the chest at the same time, hence the process of inhaling and exhaling. The diagonal line, linking both muscles to the third participant visually indicates their affect on the volume of the chest. The muscles, the diaphragm and inter-rib muscles are in themselves not linked symbolically in the flowchart, but they are linked to a common goal. Namely, the goal is to increase the volume of the chest in order to enable the air into and out of the body.

In this case the pupil's point of departure is different from that of the teacher in the lesson and from the previous flowcharts discussed. It seems that she drew on the text in the worksheet under the title "on the diaphragm and chest", mentioned above. The text deals with the role of each of the muscles in the process of inhaling and exhaling in two separate paragraphs. In addition the term inhaling and exhaling is underlined within each paragraph and in the flowchart.

Drawing on the worksheet text, the pupil's flowchart can be seen as a transformation of the structure of the written source text into a visual representation in two separate structures of the flowchart. In my opinion, the pupil's visual spatial arrangement gives a clearer sense of the direction of causality in the process of inhaling/exhaling than the written source text. In this case it exemplifies how the two media, the written language and the visual mode are distinctly organised. In this flowchart, as in the previous flowcharts, the pupil includes both the nouns and the related

processes in the boxes. The linking lines indicate the direction of causality in the process towards the Goal. Kress and van Leeuwen (1996) have pointed out that it is difficult to interpret the kind of action vectors represent in abstract forms of texts. This is because the meaning of vectors in general is abstract. They can represent different processes, which in speech or writing may be lexicalized as distinct, and in the visual mode may not be represented as distinct. This can explain why pupils contain objects/nouns with action/processes in the boxes to avoid ambiguity. Unlike the three vertical flowcharts discussed thus far, the following text was produced in a cyclic structure.

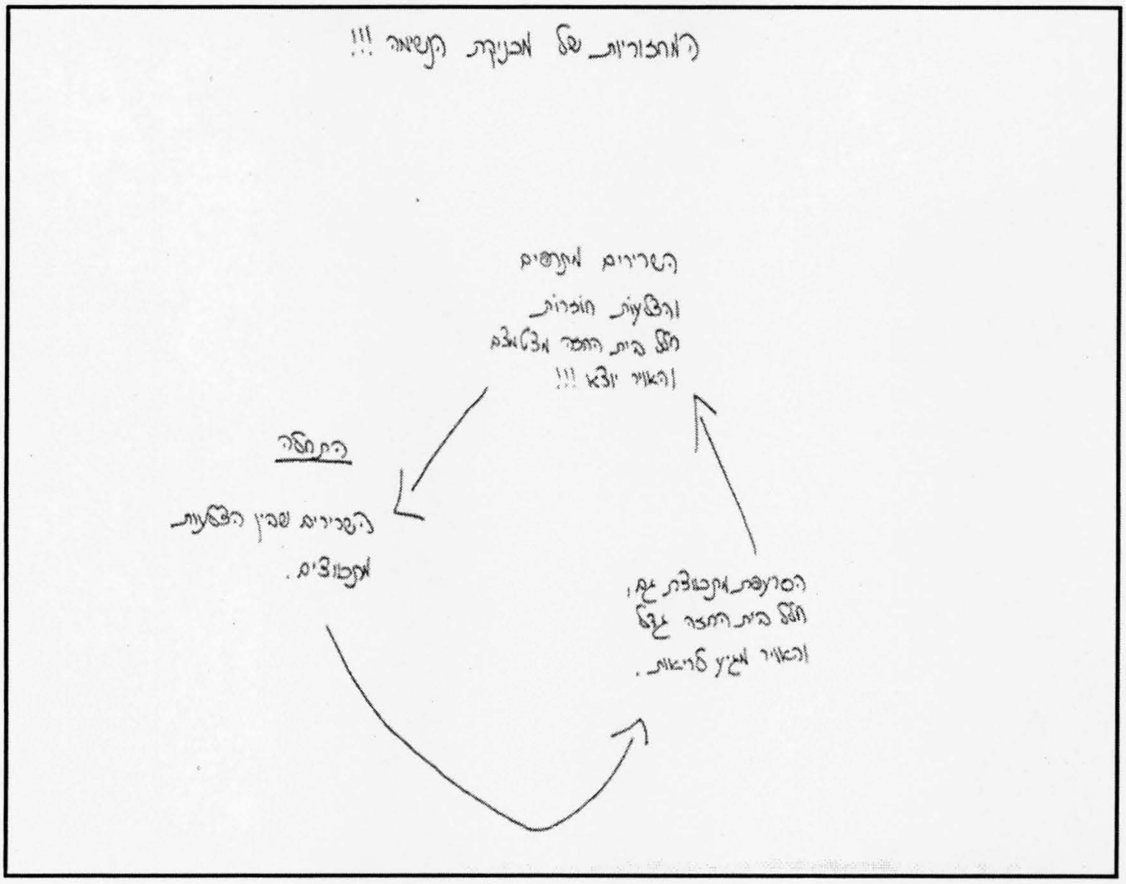
TEXT SEVEN – "THE CYCLIC MECHANISM OF BREATHING!!!"

This text, presented in figure 16, was produced by pen on paper. The pupil explicitly referred to the cyclic nature of the mechanism of breathing in the heading, using three exclamation marks, to stress that notion, which is outside the conventions of scientific writing. She also used exclamation marks after the last participant in the structure, probably to mark the end and to stress the Goal of the process. She gave expression to the cyclic nature of breathing visually, through the circle like arrangement of participants, and the linking arrows. The round structure starts from the left to the right, which is uncommon in the Hebrew language but may be influenced from materials in the media, new technologies, or from translated and imported materials from semiotic systems oriented from the left to the right.

The starting point is stated explicitly by the underlined word, "*beginning*", which indicates that the producer of the text implicitly takes into account the reader, though not addressing the reader directly. The flowchart contains the three following propositions not enclosed in boxes, which I marked here by numbers for the convenience of the reader: 1. beginning (underlined) the muscles between the ribs contract. 2. the diaphragm contracts also, the volume of the chest increases and the air arrives at the lungs. 3. the muscles expand and the ribs move back the volume of the chest decreases and the air leaves!!!

As in the previous flowcharts, the author is effaced and the reader is not directly addressed. Also, the written elements use the present tense, the common form to express general objective facts. The flowchart is focused on ideational meanings and textuality is achieved through visual spatial resources.

The pupil made the decision not to enclose the words in boxes, although the words are arranged in a group similar to being enclosed in a box. Using a square or rectangular shape might have been in contrast to the sense of the cyclic nature she intended to express. In this text the inter-rib muscles are the first participant in the process that has



(a)

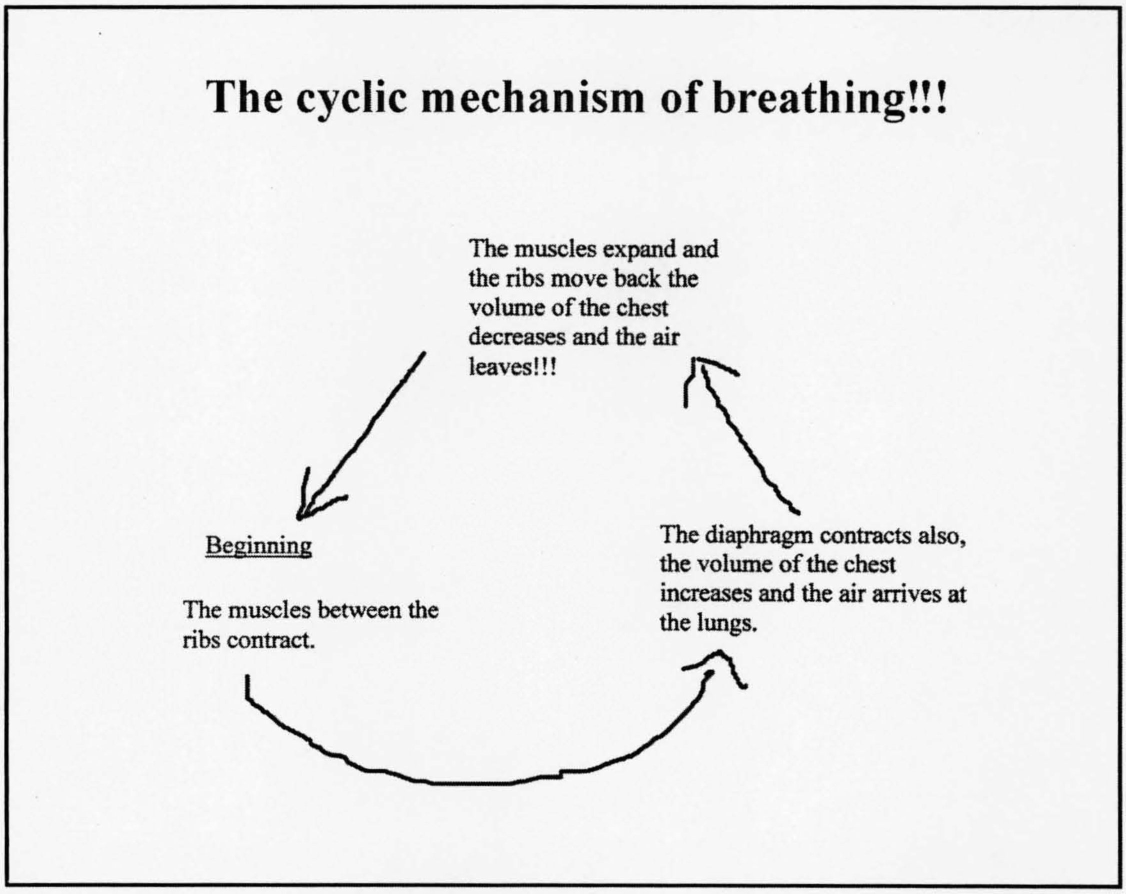


Figure 16. (a) Text seven "The cyclic mechanism of breathing!!!" (b) Translation of the original text

the role of the Actor. A curved arrow points counter clockwise, from left to right. It links the first opening participant in the text to the next one. A diagonal arrow links the following participants creating the illusion of a circle.

The structure represents breathing as a causal cyclic process. The terms inhaling/exhaling were not explicitly used; instead she described the process as follows: *the air arrives at the lungs, and the air leaves*. It seems that the producer of this flowchart selected an aspect from the end of the teacher's lesson. It was at this point that she referred to the cyclic nature of the process of inhaling and exhaling, an aspect which most of the pupils in class did not express in their texts.

SUMMARY OF TEXTS FOUR – SEVEN ANALYSES

The analysis of texts four – seven contributes to explicate the answer to the first research question by illuminating additional semiotic and pedagogical facets to those discussed surrounding texts one – three. It shows that though each of the pupils used generic conventions of flowcharts, an expected type of text in science class (i.e. the use of impersonal language, the organisation of linguistic elements in a visual spatial structure), the texts vary across the dimensions of analysis as summarised in table 4b (though the dimensions of analysis are identical to those concerning texts one – three summarised in table 4a, for the convenience of the reader I present the summary of the dimensions of analysis of the flowcharts in a separate table).

Each text integrates visual and linguistic resources in a different structure to organise selected participants and key players in the process of inhaling and exhaling. The variation in the design and structure of the flowcharts may reflect how pupils' differentially visualise inhaling and exhaling as a unified integrated process (text four), as a distinct yet unified process (text five), as a distinct separate process (text six) or as a cyclic and unified process (text seven). The choice of content draws on elements from the teacher's lesson (text four five and seven) and/or on the worksheet material (text six).

The variation in the point of departure leading to the goal shows pupils' differential understanding of agency of whom or what activates the process of inhaling and exhaling. In text four it is the diaphragm, in text five "we" human beings, in text six both the diaphragm and inter-rib muscles and in text seven the inter-rib muscles. The variation in pupils' choice of the various elements (including the concepts, propositions, the number of linguistic and visual elements, the spatial organisation of elements, the visual forms marking the elements, the kind of relationships between linguistic and visual elements, the use of orthographic resources and the material substance used to convey

meaning) suggests that despite pupils' differential understanding of key elements in the topic of the lesson, they understand that form and meaning are inseparable in the process of making meaning, whether consciously or unconsciously made. Differential representational and compositional choices suggest that the variation is a result of pupils' differential response and understanding of the topic in the lesson based on their differing interests.

Table 4b. Summary of the dimensions of analysis of texts four-seven

Dimensions of analysis	**Text four**	**Text five**	**Text six**	**Text seven**
Heading, content specific/ Other	"The breathing mechanism", content specific	"Process of inhaling and exhaling", content specific	"Flowchart', general term	"The cyclic mechanism of breathing", content specific
Content	The function of the diaphragm in breathing	Affect of inhaling/exhaling on the muscles	Function of diaphragm and inter-rib muscles	The function of muscles in the process of breathing
Content draws on	Teacher's lesson	Teacher's lesson	Worksheet text	Teacher's lesson+ worksheet
Genre	Flowchart, vertical, top to bottom	Flowchart, table form - two vertical parts top to bottom	Flowchart, two separate structures, two sided balanced units	Flowchart, circle structure
Agency	Air in and out is a causal unified process	Inhaling/exhaling a distinct yet unified causal process	Inhaling and exhaling, each a distinct, separate causal balanced process	Breathing is a unified causal cyclic process
Actor Goal	Diaphragm Air	General we Space (for air)	Diaphragm+ inter-rib muscles Air	Inter-rib muscles Air
Relationship between visual and written elements	Integrated: boxes linked by arrows Words + propositions	Integrated: boxes linked by arrows Propositions	Integrated: boxes linked by lines Propositions	Integrated: text units linked by arrows Propositions
Metafunctional meanings in visuals	Ideational + textual	Ideational + textual	Ideational + textual	Ideational + textual
Metafunctional meanings in writing	Ideational + interpersonal	Ideational	Ideational	Ideational + interpersonal
Materiality, tools	Blank paper, pen, Indian Ink	Computer printed	Lined paper, pen	Blank paper, pen

A Pedagogical Point of View

The pupils' choice of the form of flowcharts did not receive any specific comments from the teacher. They were accepted and recorded as a "correct" accomplishment of the writing task. That is, flowcharts were considered as one of the text forms expected inexplicitly by the teacher in the science classroom.

CONCLUSIONS

This chapter exemplified the application of a multimodal framework as a tool to trace evidence of science learning through multimodal textual analysis from the pupil's perspective. In particular this includes the different ways in which grade five pupils transform resources made available to them in the science classroom to realise expressions of scientific knowledge in texts they produce.

The analysis shows that in the production of texts in response to the teacher's lesson pupils are in fact engaged in the transformation of elements from the teacher's multimodal lesson, from textbooks and handout materials she makes available, into two dimensional texts. They transform aspects of content presented in one form of text into a different form (i.e. the process of inhaling and exhaling presented in the worksheet text in the form of a report transformed into a flowchart). They transform aspects of content represented in one mode (i.e. speech) into a different mode (i.e. the written mode), for example transformation of the spoken idea of "the breathing mechanism" into a written text (text four); they transform meanings represented in a combination of modes (i.e. action and speech) into a different combination of modes (i.e. image and writing).

Although the teacher clearly frames the production of texts as a written assignment, pupils feel free to use visual and linguistic resources to convey scientific knowledge, nonetheless at the beginning stage of disciplinary learning in the science classroom. This they accomplish by using representational possibilities of the interplay between visual and linguistic elements in the text to solve representational problems (i.e. the depiction of the "motion" entity or representing the tension between everyday knowledge and scientific knowledge). In addition, it seems that the integration of visual and linguistic resources is often constrained by generic conventions (i.e. comic texts).

Although the pupils are apprenticed to the generic structure of the written experimental report they are commonly engaged in the production of texts that are framed in terms of content, whereas the form of the texts to be produced are usually not framed and discussed in class. However, in the production of texts pupils do deploy generic conventions or mixed generic markers available to them, to give scientific knowledge an outward material structure and shape.

So from where do pupils import generic conventions used as a resource to integrate scientific knowledge in texts they produce? According to Feldman-Fleisher & Kalmar (1996) a genre may become "a cognitive model or a framework for construal" (p. 438) that guides interpretation and production. Cognitive models may emerge through a process of exposure to various genres and discourse types i.e. through reading texts at school or outside school, classroom discourse, or other subjects at school (e.g. the "summary" or flowcharts discussed), which may become a part of the individual's generic tool kit.

Although the form of texts to be produced usually remains open to pupils' choice, in the science classroom they do not create new genre types, as no individual can create (Kress, 1982). They use existing genre types differentially even within the possibilities and the constraints of generic conventions of the same genre type (i.e. flowcharts). At times they choose characteristics of existing genre types expected and conventional in the subject of science (i.e. text four – text seven). At times they mix conventional with non-conventional generic structures, and a mixture of conventions of scientific writing and drawing with realisation of meanings visually and linguistically outside the conventions of science (i.e. text one – text three). This does not suggest that pupils' texts are not innovative but that they are within the constraints of existing genre types.

The teacher's responses to the texts pupils produce reveal her inexplicit expectations. They also reveal that she views the new signs/texts from a linguistic perspective and image dominated texts are viewed as creative expression rather than a serious means of communication. In addition the teacher did not comment on the images integrated in or illustrating the written elements in unexpected forms of text even when designed close to scientific drawing. Accordingly she also did not comment on written elements in unexpected types of texts, in particular image dominated texts, even when constructed according to key conventions of scientific writing (text three).

That is, if the text form did or did not meet the teacher's expectations of a scientific text structure, the pupils were not informed of what in the text makes it appropriate or inappropriate to the topic and the subject of science. In addition, the teacher's comments, particularly on image dominated texts, as being creative expressions and her effort to make the production closer to scientific texts (consider the discussion on text two), with what Feldam & Kalmar call a "neutral or frameless frame" (p. 455), did not make the process easier, from the pupil's perspective.

From a pedagogical point of view, a multimodal analysis of pupils' texts as exemplified in this chapter can provide the teacher a basis for interpreting pupils' differential rhetorical orchestration of modal ensembles in communicative events in the science classroom from the pupil's perspective. This will be exemplified in the next chapter by a multimodal and rhetorical analysis of pupils' presentation events.

CHAPTER 5
RHETORIC IN THE SCIENCE CLASSROOM FROM THE PUPIL'S PERSPECTIVE

> Educational practices widely assume that knowledge-telling is entirely unproblematic, as if any who knows something can also communicate it.
>
> (De Beaugrande, 1997, p. 425)

INTRODUCTION

This chapter considers the practice of staging presentation events in the science classroom from the rhetorical aspect of the pupil's perspective. In other words, this chapter takes up the second research question of this thesis: what use do pupils make of resources to communicate scientific knowledge in the rhetorical process of presentation events?

To exemplify how grade five pupils use available resources to communicate a topic explored presented to the class as the audience I will describe, analyse and discuss the rhetorical process of five case study examples of presentation events. In each case I provide a summary description of the rhetorical process of the presentation, an analysis of the rhetorical process in temporal order of the event summarized in a table format, an overview of the categories of analysis (i.e. rhetorical means, rhetorical strategies and semiotic modes) and a discussion of their function in the rhetorical process of the presentation event. The framework for analysis was discussed in detail in chapter three, the methodology chapter.

This chapter is organised into two parts. The first part considers three case study examples of presentation events that concern pupils' explorations, experimental in nature. The second part considers two case study examples that concern pupils' explorations, theoretical in nature. Finally, the conclusion section considers characteristics of the rhetorical process of presentation events from the pupil's perspective and the practice of presentation from a pedagogical point of view.

CASE STUDY EXAMPLES OF PUPILS' PRESENTATION EVENTS

PART I

INTRODUCTION

The three case study examples considered in this part were framed in the topic "sound" studied in the 5th grade, termed as class 2 in this thesis. Two of the case studies concern pupils' simple experimentations regarding the relation between vibration of objects and the pitch level of notes they produce. Pupils could select an experiment from a set of experiments proposed by the teacher. The teacher assigned two related tasks: to produce a written experimental report to be handed in for her review and to report on the experiment in a presentation before the class. The procedure of experimenting was clearly framed by the teacher as a sequence of steps to be followed. The structure of the written experimental report was also clearly framed (it was to include a research question consisting of the relation between two variables, the procedure of the experiment, the results, the conclusion and a scientific explanation of the specific phenomenon explored), whereas the task of presentation remained open to pupils' interpretation and design.

The third case study example concerns pupils' suggested "model/invention" of a technological development utilising the phenomenon of sound waves. The pupils could explore an existing technological development or propose an innovative technological development in any unprocessed idea and form. In this case pupils were also asked to complete a written assignment to be handed over to the teacher and in addition to perform a presentation for the class.

The pupils embarked on independent experimentation on the foundation of a basis of knowledge established by the teacher in class including key entities concerning the topic of sound (i.e. vibration, frequency, and sound waves), and the explanation of central ideas in scientific terms (i.e. the travelling of sound through air, the relation between the frequency of the vibration of objects and the pitch level of notes, the relation between the length of vibrating air columns in objects and pitches produced).

PRESENTATION ONE – "HIGH NOTES AND LOW NOTES"

From a pedagogical point of view Naama's (pseudonym) response to the very task of presentation caught my attention. She was the single pupil who explicitly opposed the task of presentation: *I am not willing to stand at the front of the class.* However she changed her mind in the course of experimentation, and performed the presentation. She

selected one of the experiments suggested by the teacher. She filled soft drink bottles with different quantities of water, and by means of a mallet she experimented on the production of notes.

A Descriptive Summary of Presentation One Rhetorically Framed

Frame 0 – preliminary actions

On the desk at the front of the class Naama displays two bottles made of slightly dark brown glass and two overhead transparencies. She holds a mallet in her hand. She takes the teacher's usual position. There is some unrest in class. She waits for a moment, makes a serious facial expression and direct eye contact with the class.

Shift - She moves closer to the class as the audience.

Frame 1 – recounting the experiment

Naama: *The experiment I conducted was I filled bottles with different quantities of water. Then, I took bottles with different quantities of water and I hit them with a mallet.*

Shift – She lifts a bottle for a better view for the class.

Frame 2 – concrete constituents in the experiment

She exhibits the bottle: *here is a really small quantity of water.* She gestures with the thumb and index finger. She hits the bottle in a slow manner with the mallet the sound is dull, she smiles embarrassed. The teacher whispers: *put the bottle back on the desk.* She hits the bottle again in a slow manner it makes a clear note. She turns her head slightly, listening, she says: *the sound produced is a low note.* She exhibits the second bottle: *here is much more water.* At the same time with her fingers she traces the quantity of water on the bottle. She hits the second bottle: *here the note is higher.* She repeats the demonstration in succession in a slow manner: *okay, this is a high note this is a low note.*

Shift – She directs her gaze to the class: *now, the explanation is like this*. Smiling she says: *ehh, no, first of all I posed a research question.*

Frame 3 – relations between constituents

Naama: *what are the relationships between the quantity of water and the quantity of air in the bottles and the pitch of the notes produced? Now, the explanation is like this.* She repeats the demonstration and explains at the same time; consider the transcript in figure 17.

Action	Speech
She lifts the bottle with the small quantity of water. She hits the bottle in a slow manner. It makes a sound. She speedily opens and closes her fingers. She repeats the same gesture three times. She traces an imaginary line on the part with the air on the side of the bottle.	*When I hit the side of each bottle with the mallet it produces vibrations. Now, vibrations do not occur in the water but only in the air in the bottle. The air column vibrates. When the bottle is filled with a real small quantity of water then there is more space for air and the vibrating air column is long so a low pitch sound is produced.*
Action	**Speech**
She hits the second bottle. She listens to the sound. She waits awhile. She represents the quantity of water with both hands.	*When there is more water there is less air, there is less space so the air column is shorter and a high pitch sound is produced.*

Figure 17. Experiment Demonstration

Shift - Naama moves to the overhead projector, displays a transparency, smiling she says: *I am not Picasso but ehh, this is what you get.*

Frame 4 – constituents involved in more abstract form of representation

Positioned at the right of the white board she points at the projected text:

> *Well here there is a bottle with a lot of water and less air and the mallet is hitting and the vibrations I drew happen only in the air and there are fewer frequencies. Ehh, no, in fact there is more water and less air so the note is high because short air columns vibrate more rapidly than long air columns. The quantity of water determines the number of vibrations (changes an overhead, points at the projected text on the whiteboard) and here there is more air and less water there is more space for air so a lower note is produced because large air spaces vibrate slower than small air spaces.*

Frame 5 – end

She lifts her arms, directs her gaze to the class smiling: *that's it I am done.*

An Overview of the Categories of Analysis (consider Table 5)

Rhetorical means

The resources, which constitute the objects of action used as rhetorical means, provide different semiotic and rhetorical potentials and limitations. Thus, I will consider the resources which constitute the rhetorical means and their function in the rhetorical process of the presentation event. Naama staged her presentation around two rhetorical

means: the objects of experimentation and two overhead transparencies (OT) she produced.

Table 5. Analysis of the rhetorical process of presentation one – "high notes and low notes"

Rhetorical frame		Rhetorical means	Rhetorical strategies	Modes
Min.	**Heading & no'**			
	0 Preliminary actions	- 3D objects, transparencies		Action: handling objects, position, gaze,
	Shift			Action: shift in position
0.20	**1** Introduction of the experiment		Recounting empirical actions	Speech
	Shift	3D objects: bottles		Action: movement, position
1.00	**2** Concrete constituents	3D objects-bottles	- Demonstration - Introducing key players - Repetition of demonstration	Action + speech + gesture
	Shift		Transition statements	Speech
2.00	**3** Unobservable constituents	3D objects-bottles	- Creating difference by research question - Repetition of demonstration - Explanation	Action + speech + gesture
	Shift	Overhead projections	- Transition statements	Action + speech
3.30	**4** Relations between constituents	Overhead projections	- Mediation of text, - Extension of explanation	Visual + speech + gesture
	5 – End		Closure statement	Speech + gesture + facial expression

The objects of experimentation

Naama used everyday 3D objects, two soft drink bottles filled with different quantities of water and a mallet, to demonstrate her experiment – the production of notes by means of vibrating objects. In the process of interaction and experimentation the soft drink bottles acquired a new meaning; they became suitable scientific objects of experimentation in the context of science class. The objects played a significant role in

the construction of a scientific explanation. The explanation concerned the relation between the quantity of water and the vibrating air column in the bottles and the pitch level of notes produced.

The overhead transparencies

The two OTs are comprised each of a large image of a bottle in the top centre and a brief written text beneath it, presented in figure 18. The images are realistic, what Hegarty, Carpenter & Just (1991) would classify as iconic diagrams in scientific texts. Naama signified the different constituents involved in the experiment by different diagrammatic lines and Indian ink colours. Straight lines in brown colour represent the contour lines of the bottles; slightly wavy lines in blue represent the water; the empty uncoloured space in the image represents the air in the bottles; and a broken line in red colour outside the contour lines of the air part in the bottle, represents the vibrations. In addition she placed the written labels "air" and "water", inside the image. An arrow beneath the image points to the brief written text, which is organized as a visual unit in each of the two overheads:

1. *Less water*	2. *More water*
More air	*Less air*
Less vibrations	*More vibrations*
Low note!	*High note!*

The relationship between the salient image at the top centre of the transparency and the brief written element at the bottom indicates the prominence attributed to the meanings in the visual mode (Kress & van Leeuwen, 1996; van Leeuwen, 1998).

The medium of the OT provides flexibility. It enables the use of a range of semiotic resources in the design of the text. In addition the possibility to enlarge the projection of the represented meanings flexibly, makes it an efficient rhetorical means and easy to handle in presentations. The enlarged projected text functions as a visual scenery of the stage on which the performer can ground her communicative actions and the audience can receive the mediated meanings. The design and overall arrangement of the text on the visual space shows that Naama understands how to use the medium of OT for rhetoric purposes (i.e. the big images, the different lines and colours, sparse written elements and the layout).

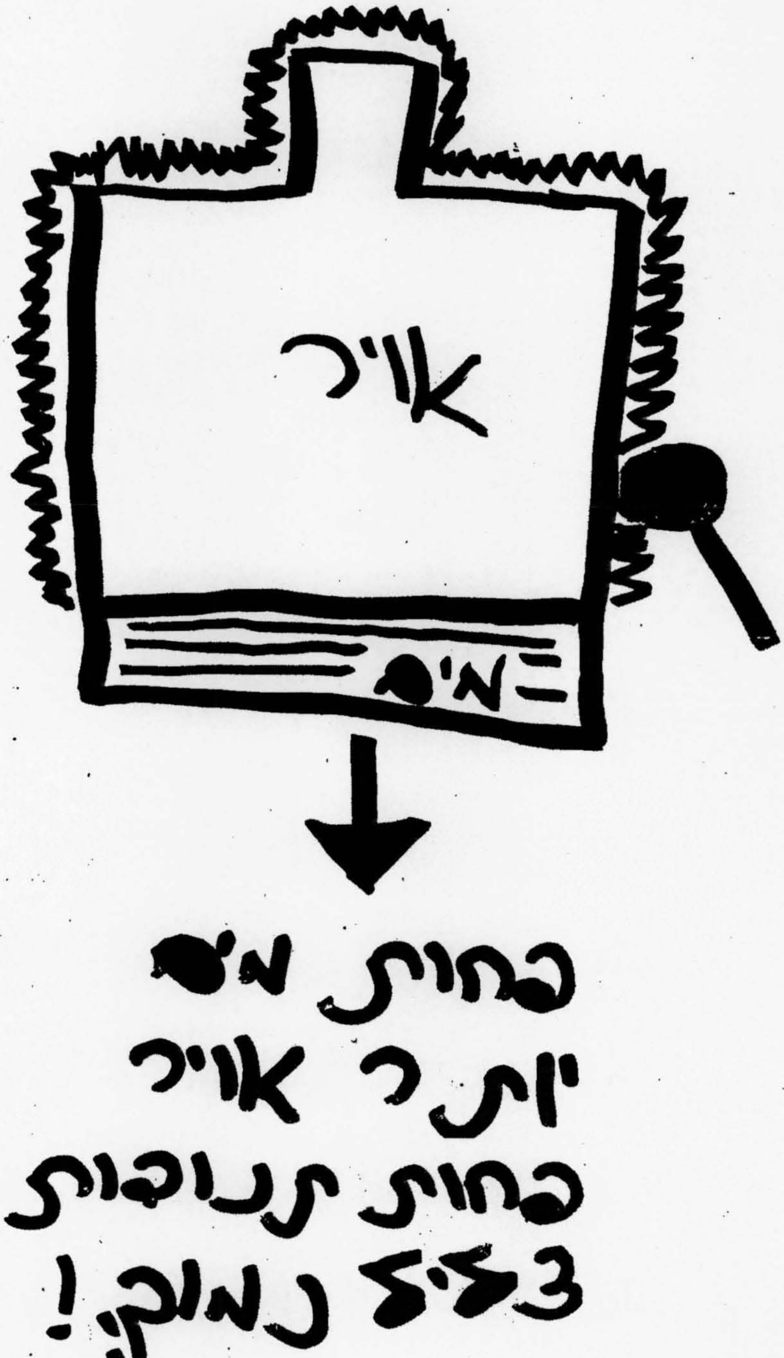
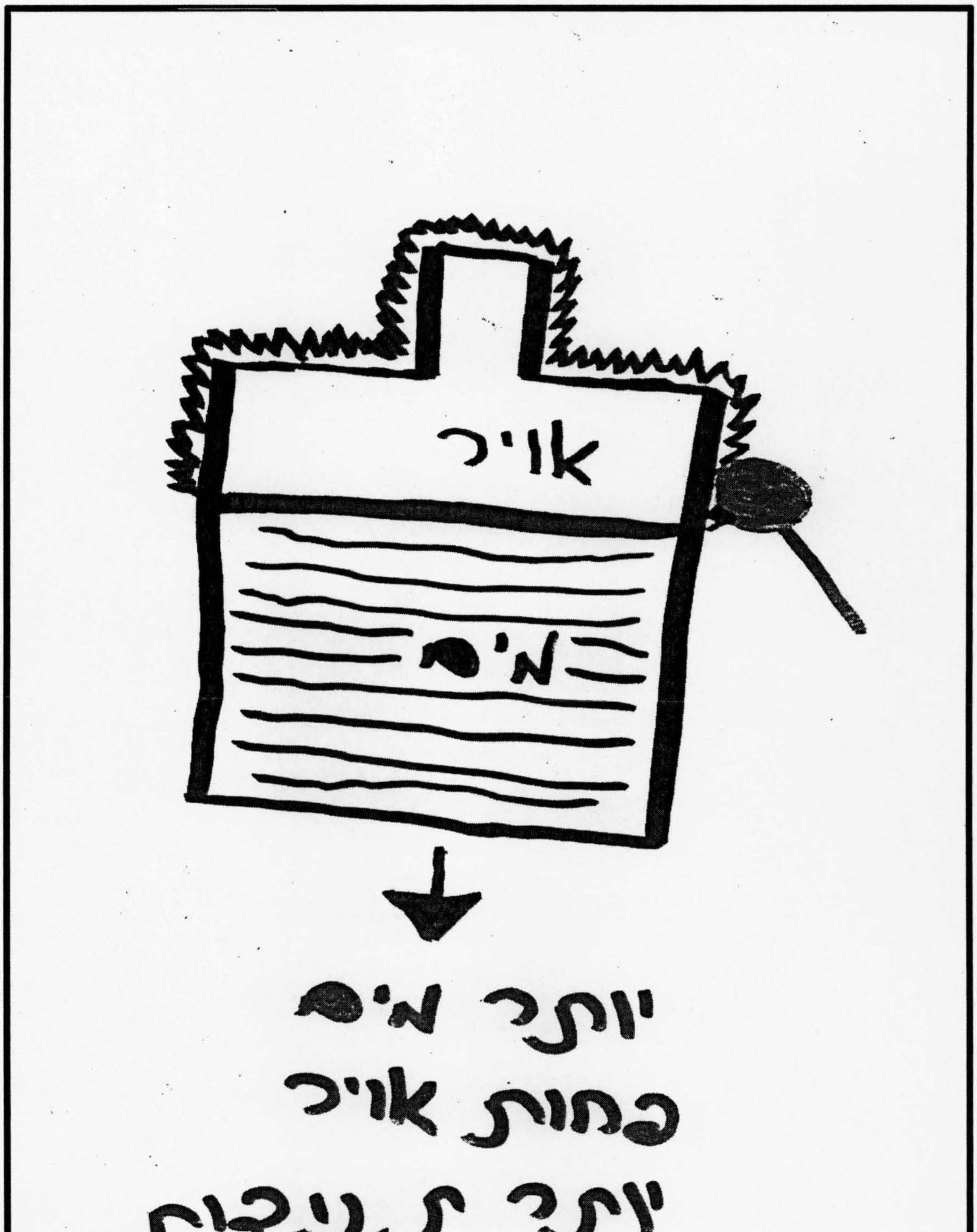


Figure 18. Texts of overhead transparencies (a)



(b)

Rhetorical strategies

Naama used a number of rhetorical strategies to introduce her experiment including: empirical recounting, demonstration and description, repetition of demonstration, providing transition statements (i.e. statements that mark the transition to the next move in the rhetorical process of the event and/or an issue under discussion), presenting the research question, repetition of demonstration, explanation, mediation of texts on the OT, extension of explanations and providing a closure statement. To illustrate the function of rhetorical strategies I focus on two cells in table 5 under the category rhetorical strategies in frames 2 and 3 including the shift unit.

Naama introduced her experiment by the rhetoric of demonstration. This enabled pupils to see for themselves the concrete key players involved in the process of production of notes. First, she introduced the concrete and observable key players in everyday terms: *here is a really small quantity of water... here is much more water... this is a high note this is a low note* (frame 2). Following the demonstration she created difference by presenting her research question (frame 3) exactly as it was formulated in her written experimental report; although the actual written report was not at hand in the event: *What are the relationships between the quantity of water and the quantity of air in the bottles and the pitch of the notes produced?*

By presenting the research question she also introduced the specific phenomenon explored as framed by the teacher, namely exploring the relation between two variables. Then she repeated the demonstration (frame 3) to introduce in scientific terms the unobservable key players involved in the process (i.e. vibrations, vibrating air column, long air column, and short air column): *When I hit the side of each bottle with the mallet it produces vibrations. Now, vibrations do not occur in the water but only in the air in the bottle. The air column vibrates.* Naama did not construct these entities. She presumed them as given established knowledge in class. She used them as resources to explain in scientific terms the relations between the two variables, namely the quantity of water and air and the pitch level of notes:

> *When the bottle is filled with a real small quantity of water then there is more space for air and the vibrating air column is long so a low pitch sound is produced. When there is more water there is less air, there is less space so the air column is shorter and a high pitch sound is produced.*

Actually at this point Naama could have ended the presentation since she provided a scientific explanation explicating the answer to the specific research question she posed.

Yet she continued the performance surrounding the OT she produced (frame 4). The question arose of what is the function of the OT in the rhetorical process of the event? This will be considered in an integrated manner in the section below: "The rhetorical orchestration of the modal ensemble".

The specific order in which Naama used the rhetorical means and rhetorical strategies in the process of presentation point backwards to the process of planning and design. It also projects the procedure of experimentation and work framed by the teacher in class, namely, the move from empirical experimentation and everyday terms of description to relatively more abstract forms of representation and scientific explanation of the phenomenon explored.

Modes

Naama's presentation is a multimodal event in which action, speech and the visual mode worked in different ways in the rhetorical task of introducing and explaining the phenomenon she explored. In metafunctional terms the co-operating modes worked to realise ideational, interpersonal and textual meanings simultaneously. However, the relative emphasis on one of the three kinds of meanings is related to the position of a unit in the rhetorical process of the event. In units comprising the core of the event from the aspect of scientific knowledge (frames 1 – 4) the relative emphasis is on ideational meanings.

To illustrate this process I focus on one unit in the rhetorical process of her presentation, taking a view along the horizontal axis in table 5 rhetorical frame 3. In this unit the relative emphasis is on ideational meanings realized by action and speech, where each mode performed a different function. By action she manipulated the objects of experimentation to generate the material process of the pitch level of notes. Through metaphorical gestures (McNeil, 1992) she represented the dynamic property of the vibrations by speedily opening and closing her fingers, a property, which she did not mediate by speech; and by speech she connected all the constituents involved in the process pf generating notes through description and explanation. However, in this case, the rhetorical power lies in the integrated work of the modes being used. She represented the dynamic property of the vibrations more efficiently by gesture than by verbal description. That is, speech and gesture have different functional specialisations.

The relative emphasis on interpersonal and textual meanings is in the boundaries of the event and/or in the shift units between rhetorical frames of the presentation. Interpersonal and textual meanings are realized by integrated modes or by foreground

modes. For example, speech and action worked in integration to realize textual meanings in the shift unit between frame 3 and 4. Naama established a kind of "pedagogically authoritative" interpersonal relationship with the audience from the start of the performance (frame 0 - 1). This was achieved by the contrast between her use of spatial resources and time and bodily resources. Although she took a close position to the audience, which could mark intentions for close relationships, this was in contrast to her upright posture, her silence and for a moment suspending the start of the performance, the direct gaze she used as a means to control the class and the framing of the event. The kind of relationships she established was consistent with her monologic style of interaction throughout the event.

The Rhetorical Orchestration of the Modal Ensemble

To illustrate Naama's simultaneous rhetorical orchestration of the modal ensemble I take a view along the horizontal axis in table 5, frame 4, focusing on one unit in the rhetorical process of the event. Apparently, it seems that in this unit using the OT Naama repeated the scientific explanation she already communicated thus far through demonstration with the objects of experimentation but fashioned them in a different form and in a different medium. In this case questions arose: Do the meanings she transformed from medium to medium indeed say the same thing? And what is the rhetorical function of repetition of the scientific explanation?

It seems that Naama transformed meanings she realized through the mode of action into the visual mode as a rhetorical means to cope with the problem of how to provide evidence of the major constituent in the process, namely the vibrations, unobservable and dynamic by nature. Although she already dealt with that issue by repeating gestures representing the vibrations (frame 3), it did not resolve the problem. To resolve the problem she used the red colour broken line to signify the vibrations' dynamic property and its prominence in the process of making sound. Though unconventional, as sound waves are conventionally represented by wavy lines and not by broken lines i.e. in science textbooks, she signified its prominence and dynamic nature. In a sense the visual durable material representation brings the vibrations into existence and shows more explicitly than gestures, what thinking might have been.

That is, the visual mode and action as a mode operate and deal differently with representational issues. Images do not simply serve to translate finished thoughts into visual representations (Arnheim, 1969). Images, as any process of representation in any semiotic mode, are an aid in the process of working out solutions of problems. The visual

mode, though static in nature, can provide some resources, which have the potential to complement, at least partially, some limitations of the mode of action. In addition, by means of the OT she did not just repeat the same explanation she rather extended the scientific explanation by adding significant information: *large air spaces vibrate slower than small air spaces.* That is, the red broken line is an innovative sign expressing her subjective interest at the moment of production motivated by the context in science class.

Naama's semiotic and rhetorical decisions are not arbitrary. Her transformation of the constituents involved in the process of making the pitch levels of notes from the mode of action into two dimensional texts convey meanings differently and can be subject to further mediation, discussion and contemplation.

PRESENTATION TWO - "A XYLOPHONE'S HIGH AND LOW NOTES"

Hila and peers' presentation varies significantly from Naama's presentation from a rhetorical aspect, which will be discussed below. From a pedagogical point of view I was interested in the diverse ways the pupils conveyed what being scientific in the science classroom means to them. Although Hila cooperated in a small group I call it her presentation in light of her dominant role in the design, production of artefacts and overall staging of the presentation.

A Descriptive Summary of Presentation Two Rhetorically Framed

Frame 0 – preliminary actions

The small group gets organised on the floor. Hila displays a model/image of the xylophone and a poster on the desk. Dana takes a position behind the mobile board, a mallet and a xylophone in her hands; she cannot be seen by the audience. Ronnie holds a folder with the experimental report; she takes a position at the side on the floor.

Shift – Hila shifts to the centre of the floor.

Frame one – the pitch of notes on the xylophone keys

Ronnie reads: *We explored the pitch of notes on the xylophone keys. We prepared the assignment on the pitch of notes, on low and high notes and the frequency of vibrations.*

Shift – Hila orientates herself physically towards the model/image on the desk at the front of the class.

Frame two – classification of the xylophone as an instrument

She points at the model/image with the mallet, not directing her gaze and body to the audience. She speaks at a slow pace (she usually speaks fast): *This is the xylophone. These are the metal plates.* (The teacher positions the model on the desk in a different position for better view. Hila continues undisturbed.) *In the xylophone there must be at least one octave of metal plates. Anybody knows what an octave is?* (Not waiting for a response) *O.K. an octave is eight, eight notes, eight instruments, eight metal plates. The xylophone belongs to the family of percussion instruments. The metal plates of the xylophone must be equally thick but they must vary in length. For example the first plate is short and the last plate is very long (*pointing at the plates on the model by the mallet). *The long one has a lower note* (Dana makes the note, behind the scene, not in exact synchrony with Hila's speech) *because it is heavier there are fewer vibrations per second. Whereas the small and short metal plate is lighter so it has more vibrations per second and therefore it comes out a higher note.* (Dana makes the sound on the xylophone behind the scene).

Shift – Hila turns to the audience. She exhibits the poster flowchart: *I prepared this flowchart so that you can see it better.*

Frame three – relations between the xylophone keys' structure and pitch of notes

With the poster in her hands Hila points at the poster in an attempt to mediate it. The teacher attaches the poster to the white board. Dana leaves her position behind the scene. Hila points at the poster on the board with a mallet:

> *Here at the top you see it is the xylophone. The xylophone has a structure of metal plates and here I began to arrange it according to high and low. In the chart you can see that if the metal plate is shorter there are more vibrations. If we want to know whether a metal plate makes a high or low note you can see, if it is short it has more vibrations per second and also the note is higher.*

Shift – The group stands in a row at the front of the class in an upright posture. Ronnie hands the experimental report over to Dana. Dana: *we will explain the work we did in class.*

Frame four – relations between the keys structure and notes in general terms

Dana reads:

> *Conclusion. Whenever one hits a larger key the note becomes lower. And whenever one hits a smaller key the note becomes higher. An addition from the book. When one hits a larger key it is heavier thus it*

makes fewer vibrations in a second. (Dana hands the text over to Ronnie, she reads) *Scientific explanation. The more the number of vibrations in a second increase the more the note is higher.*

Frame 5 – end

Hila looks around the class and smiles saying: *I hope you enjoyed our talk.*

An Overview of the Categories of Analysis (consider Table 6)

Rhetorical means

Hila staged the presentation around three rhetorical means: the model/image xylophone, the poster-flowchart and the experimental report.

The model/image xylophone

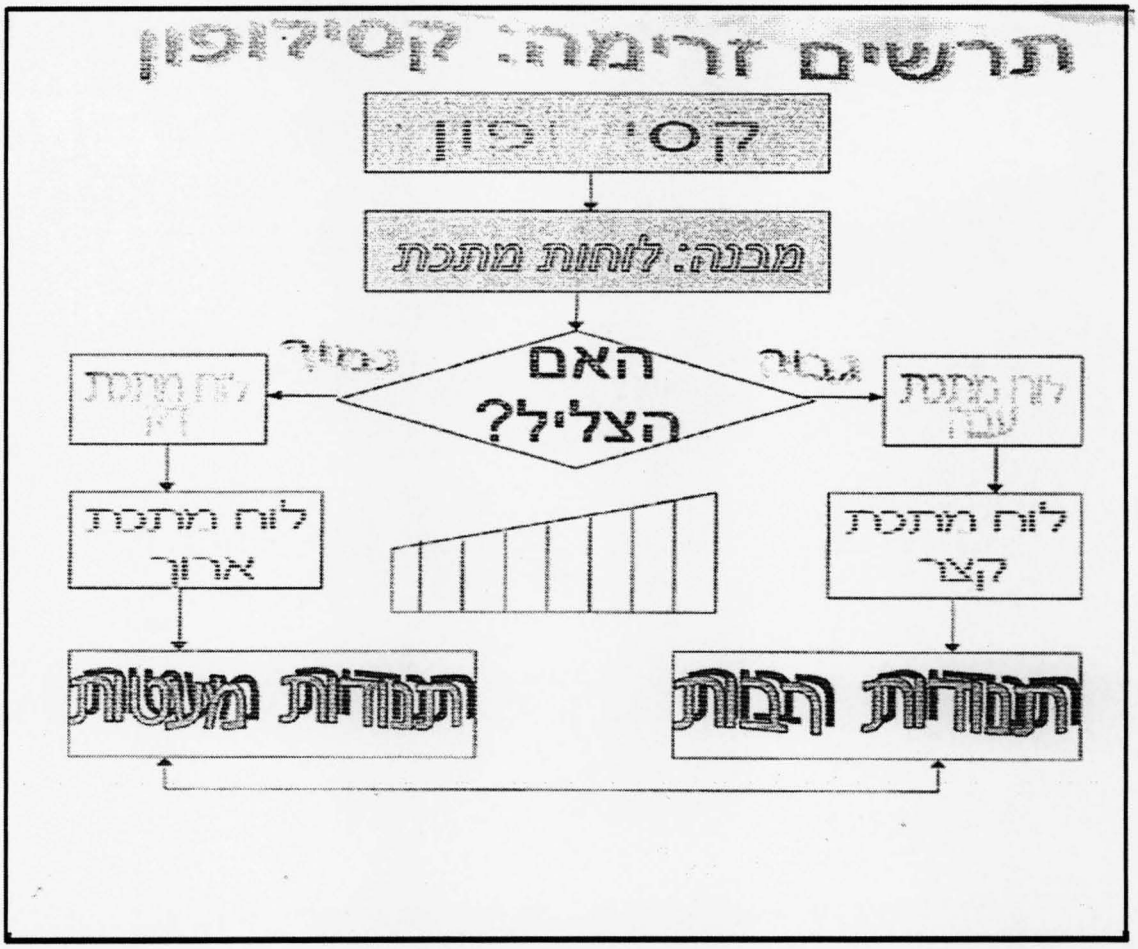
Hila produced a type of 3D model/image xylophone. She wrapped a shoebox with white paper. On one side of the box, on the large rectangular side, she drew the keys of the xylophone signifying the different keys through various colours and sizes. The function of the model/image as a rhetorical means will be discussed in the section below "the rhetorical orchestration of the modal ensemble".

The poster-flowchart

Hila produced a vertical linear flowchart on the computer, presented in figure 19. It represents the key players and the relations between them in the process of making contrasting notes on the xylophone. The function of the poster as a rhetorical means is projected in Hila's direct address to the audience: *I prepared this flowchart so that you can see it better... In the chart you can see that if the metal plate is shorter there are more vibrations. If we want to know whether a metal plate makes a high or low note you can see...* She transformed the experiment from the realm of action on a 3D object (i.e. the xylophone) into a two dimensional text. The poster provides the entire picture of the phenomenon explored, which the audience could see for themselves and quickly interpret. Similar to Naama's use of the OT (case study one) the poster is a durable material form of representation providing a kind of evidence of the participants and relations involved in the process of the phenomenon explored, subject to further mediation, discussion and contemplation.

The experimental report

The written experimental report included the following headings: the research question, conclusion, general conclusion and a scientific explanation. The generic structure of the written experimental report complies with the framework outlined by the



(a)

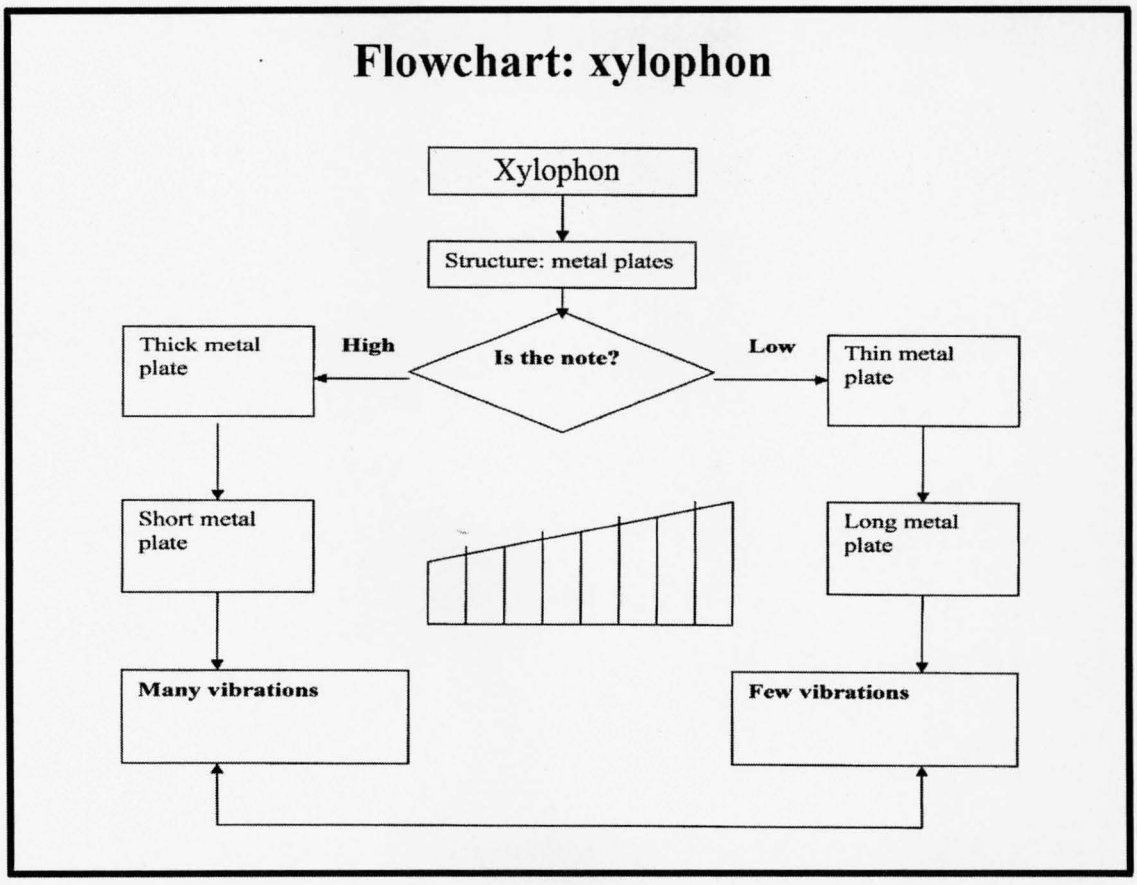


Figure 19. (a) Poster Flowchart; (b) Translation of the original text

teacher, though the procedure of experimentation as required by the task framework is not included. Presenting the report seems to have served the function of reframing their topic in the wider context in class. The strategy of reading aloud sections from the experimental report (frame 1 and frame 4) conveyed their doing the presentation task correctly. In view of the fact that the written experimental report was clearly framed in class in contrast to the task of presentation, which remained open to pupils' interpretation and design, presenting the written experimental report in a sense ensured they had done the presentation task right. In addition, the experimental report has a rhetorical function from an epistemological aspect. In the written report, though the scientific explanation is in a sense repeated, there is a move to a more general level of explanation: *Whenever one hits a larger key the note becomes lower... The more the number of vibrations in a second increases the more the note is higher.*

Table 6. Analysis of the rhetorical process of presentation two – "a xylophone's high and low notes"

Rhetorical frame		**Rhetorical Means**	**Rhetorical strategies**	**Modes**
Min.	**Heading & No'**			
	0 Preliminary actions	Model/ image+ poster/flowchart		Action: handling objects, position
	Shift			Action: shift in position, posture
0.20	**1** The pitch of notes on the xylophone keys	Text-experimental report	- Naming the phenomenon explored	Speech (reading from the text)
	Shift			Action: shift in orientation and posture
2.00	**2** Classification of the xylophone	Model/image xylophone	- Classification - Explanation	Visual + speech+ gesture + audio
	Shift	Poster-flowchart		Action + visual + speech
2.40	**3** Relations between constituents	Poster-flowchart	- Mediating text - Explanation	Speech + gesture + visual
	Shift	Text – experimental report	Transition statement	Action + speech
3.40	**4** Relations between structure and notes	Text – experimental report	- Repetition of explanation	Speech (reading from the text)
	5 – End		Closure statement	Speech + gesture

Rhetorical strategies

Hila and peers used a number of rhetorical strategies to introduce their experimentation and to explain the relation between the xylophone keys' structure and the pitch level of the notes produced. This included naming the phenomenon explored (reading from the report), classification of the xylophone, explanation, providing a transition statement, mediating the poster-flowchart and explanation, providing a transition statement, repetition of explanation (reading) and providing a closure statement. The function of rhetorical strategies will be exemplified in an integrated manner in the discussion in the section "the rhetorical orchestration of the modal ensemble" below.

Modes

On the surface it seemed that Hila and peers' drew heavily on language resources in the presentation (i.e. reading aloud sections from the written report, communication in a written style). An intensive multimodal look at their communicative actions revealed that they orchestrated resources from different modes, speech, action and the visual mode, to introduce the xylophone as an instrument and to explain in scientific terms the relation between the xylophone keys' structure and the pitch of notes. Action as a mode (i.e. frame 0 and shift unit to frame1) or speech (i.e. frame 1, 4 and 5) were foregrounded in the boundaries of the event and in shift units in the rhetorical process of the event. However, in the units comprising the core of the event from an epistemological aspect (frames 2 – 3), speech, action and the visual mode worked together to communicate scientific knowledge, as illustrated in the following section.

The rhetorical orchestration of the modal ensemble

To illustrate Hila's (and peers) simultaneous rhetorical and modal ensemble, that is, how she interwove rhetorical means, rhetorical strategies and modes, I take a view along the horizontal axis of two units in the rhetorical process of the presentation event, consider table 6, frame 2 and 3.

Hila introduced the xylophone as an instrument by means of the model/image xylophone while Dana made the notes on the actual xylophone behind the scene "hidden" from the audience. She used speech in integration with the visual mode (the model/image), action (gesture, pointing) and audio resources (the notes produced behind the scene). Hila pointed at the model and referred to it as the real instrument: *This is the xylophone. These are the metal plates... the first plate is short and the last plate is very long.*

The question of what is the reasoning for using the model/image xylophone before the audience instead of the actual instrument; and what is its function in the rhetorical process of the event emerged. It seems that Hila faced a difficulty that science teachers often face, of how to make what seems to be obvious into a case to be explained. Children know the xylophone from an early age. They are experienced with playing this instrument, though most of them in an amateurish manner. Unlike Naama's demonstration (presentation one) of the experiment with the bottles, which justified and invited a scientific explanation, demonstrating the making of notes with a xylophone would have been too obvious.

The use of the model instead of the real instrument is a rhetorical decision, consciously or unconsciously made. It distanced the presentation from the empirical experimentation to a relatively more abstract level of representation. Hence the use of the model/image as it can appear in written sources or multimedia texts (the notes produced were in the background). Therefore, she communicated in a written style in this unit. This is evident from the use of specialized terms and in the manner she classified the xylophone as an instrument: *The xylophone belongs to the family of percussion instruments; in the xylophone there must be at least one octave of metal plates...* Although she communicated orally it was in a formal written style. It is revealed not only in the information she provided but also in her use of intonation, and pace of speech. She stressed certain words and spoke in an un-naturally slow pace (she usually speaks fast), which intensified the sense of formality in her talk. This was consistent with her detached and impersonal relationships with the audience realized through bodily and spatial resources. This was articulated by her body orientation to the model/image, i.e. not directing her gaze to the class throughout that unit.

Rhetorically the function of the strategy of classification of the xylophone as an instrument is to open up a difference between what the performers know and the class presumably did not know. That is, exploring a phenomenon concerning the xylophone is not so obvious. This justified the scientific explanation, which followed: *The first plate is short and the last plate is very long. The long one has a lower note because it is heavier there are fewer vibrations per second. Whereas the small and short metal plate is lighter so it has more vibrations per second and therefore it comes out a higher note.*

In contrast to her detached and formal style of communication in frame 2, she realised close relationships in the next unit surrounding the poster/ flowchart (frame 3) using agency (i.e. *I prepared this flowchart so that you can see it better*), gaze, orientation

towards the class and direct address. It seemed that Hila moved between the teacher (frame 2) and the class (frame 3) as two different audiences.

In summary, the rhetorical means, rhetorical strategies and communicative modes interwoven in the rhetorical process of the event convey Hila's (and peers) stance to the experience of experimentation and what it means to them to be scientific in the science classroom. For Hila (and peers) being scientific means representing and communicating scientific knowledge distanced from the empirical experimentation moving towards relatively more abstract forms of representation (i.e. model/image, poster/flowchart, experimental report) not using the real xylophone at the front of the class throughout the event and complying with the writing task framework. In contrast, for Naama (presentation one) being scientific means constructing a scientific explanation of phenomena on the foundation of the empirical practical dimension of making science in the science classroom.

PRESENTATION THREE – "THE INVENTION OF A 'LIGHT-BELL' FOR THE DOOR"

From a pedagogical point of view this case interested me because of the division of work between two collaborating pupils Tal and Noah, and the translation of an idea into a model on the foundation of scientific principles. Tal suggested the idea of the invention, an alternative door-bell named "light-bell" for people with hearing problems. Tal was dominant in the development of the idea into a model. Noah played the dominant role in performing the presentation. In Kress and van Leeuwen's (2001) terms Tal is the designer of the presentation and Noah the performer.

A Descriptive Summary of Presentation Three Rhetorically Framed

Frame 0 – preliminary actions

Tal and Noah take positions on the floor. Noah holds the folder with the experimental report. Both make direct eye contact with the class.

Shift - Noah: *we have invented an invention.*

Frame one – introduction of hearing problems

Noah: *It is well known that there are many hearing problems of different kinds. Without entering now into details, there are many hearing problems. There is a significant difference between people who can hear and those who cannot. Tal and myself we have been thinking of hearing people in comparison to people with hearing problems in everyday regular life.*

Shift – Noah slightly changes her position: *We noticed it in our neighbourhood.*

Frame two – observation on a house with a deaf person

Noah: *At the entrance to a house in our neighbourhood when anyone wants to enter there is a bell or a knock on the door, which is based on hearing. There is a deaf person who went through treatments but he is deaf and he is living in the house. He lives a normal life though he cannot hear it. There is no device that can signal that somebody wants to enter the house. It is in fact based on hearing.*

Shift + Frame three – the idea of the invention like a bell

Noah: *So Tal thought of the idea of an invention like a bell, which we called "light-bell" for the door.* Some in the class ask: *how did you call it?* Noah responds smiling: *light-bell for the door.*

Shift – Both move to a desk at the side of the presentation floor. Noah leaves the folder with the report on the desk. They lift a container from beneath the desk (which I did not capture when it was brought there). There is some unrest in class. Teacher: *pay attention they are going to show their patent.*

Frame four – the components of the model construction

Both take out elements each in turn from the container. They exhibit each element. Noah: *It is constructed of battery housings, here we have two identical battery constructions each with three batteries, this is the wire, and this is the light bulb housing with a light bulb.* Tal: *this is the switch and this is the buzzer.*

Tal works on linking the elements. Noah: *in fact as we link all the components to an electric circuit, when we turn on the switch it should turn on the light bulb and the buzzer. But at the moment we have a problem, either the light goes on or the sound of the buzzer, but not both, we might need two circuits.*

Shift – Noah: *just a moment it will take us some time to link all the components.*

Both are working on the construction of the model as a whole.

Pupils: *how is it supposed to work?* The teacher moves to the white board. Teacher: *I will draw you the circuit they have built.*

Frame five – the function principle of the model

Noah and Tal hold the finished model construction while the teacher draws on the white board (consider the schematic image in figure 20 (b)).

Teacher: *they have built such a circuit. I am drawing each battery housing, at the continuation they did add the switch, then the buzzer, and by the way they had to review*

the subject matter from last year. At the continuation they did add the light bulb. Principally it is an electric closed circuit. The teacher leaves the floor.

Shift – Tal and Noah move back to the front of the class both hold the model construction in their hands on the background of the schematic image on the board.

Frame six – problem in the functioning of the model

In succession they demonstrate the functioning of the model again and again. The light bulb goes on and off. Noah: *well this is the circuit. It is a bit complicated. This is the switch, it closes the electric circuit, there is the buzzer now I turn on the switch, and you see the light bulb goes on, it should activate the buzzer but it does not.*

Frame seven – end, the aspiration to solve the problem

Both are holding the model. Noah: *At the moment we have a problem. We have checked the electric consumption of the buzzer and the light bulb and it should have worked. Our aspiration is that by turning on the switch we will be able to activate both at the same time, the sound together with the light.*

Teacher: *inventors sometimes have theoretical ideas, which need assistance in the practical technological aspect. Anyone who can assist should offer to help.*

An Overview of the Categories of Analysis (consider Table 7)

Rhetorical means

Tal and Noah used three objects for different rhetorical purposes: the experimental report, a container with the model's components and the model. In addition, though unplanned, the teacher drew a schematic image of the model on the white board, which had a function in the rhetorical process of the event.

The experimental report

From the start of the performance Noah held a folder with the written report, which she then left unused on the desk at the side of the floor (shift unit to frame 4). Unlike Hila and peers (case study two) Noah and Tal actually did not introduce their report during the event. In view of the fact that presentation events are well planned in advance the act of even just holding the written report at the front of the audience is not accidental. Noah may have had the intension to introduce parts of the report, which in the end she did not. It seems to me, however, that even the very act of holding the written report is a kind of an implicit statement that they had done the presentation task right.

Table 7. Analysis of the rhetorical process of presentation three – the invention of "light-bell" for the door

Rhetorical frame		Rhetorical means	Rhetorical strategies	Modes
Min.	**Heading & no.**			
	0 preliminary actions	Folder-exploration report		Action: position + gaze
	Shift		General statement	Action: shift in position + speech
1.00	**1** Introduction-hearing problems		- Creating difference by framing the problem	Speech
	Shift		Specific statement	Action: shift in position + speech
2.00	**2** Necessity of an alternative doorbell		Recounting an observation	Speech
2.30	**Shift + Frame 3** The idea of invention		Naming the invention	Speech
	Shift	Container	Transition statement (teacher)	Action: shift in position, handling object + speech
3.45	**4** Constituents of the model	Elements of the model	- Exhibition, - Demonstration - Naming the model constituents - Stating a function problem	Action: handling objects, gesture + speech
4.15	**Shift**	Model construction	1.Transition statement (pupil) 2. Transition statement (teacher)	Action: handling objects + speech
5.00	**5** Function principle of the model	Schematic image	Translation of 3D model into an image (by teacher)	Visual + action + speech
5.10	**Shift**	Model/ invention	Exhibition	Action: movement, handling object
6.10	**6** Function principle of the model	Model/ invention	-Demonstration + Explanation -Repetition	Action: manipulating object + speech
6.20	**7 End-** Function problem of the model	Model/ Invention	Stating problem and aspiration for further exploration	Speech + action

The container with the model's components

The decision to store the model components in a container "hidden" from the audience's view until to a certain point in the event (frame 3), i.e. not revealing the model as a finished construction is a planned rhetorical decision. It was used as a rhetorical means to introduce each of the components, its function in the model and to let the class see for themselves the actual process of construction. In addition, by not revealing the finished model to the public until a certain point in the event, they acted as scientific "inventors". This is reflected also in the teacher's statement: *pay attention they are going to show their patent.*

The model

The model/invention is constructed of two battery housings, each comprising three batteries, a wire, a light bulb, a buzzer and a switch; the switch should activate the light and buzzer at the same time. The demonstration of the functioning of the model, appearing in figure 20(a), was meant to make the class see for themselves how the suggested invention should work, though in a raw and incomplete form. The role of the electric circuit in the construction was explicitly considered. However, the utilisation of sound waves in the suggested model, which is relevant to the topic of "sound" studied in science class, was not explicitly referred to.

The schematic image

The image produced by the teacher on the white board was certainly unplanned. It was a transformation of the 3D model into a two dimensional abstract schematic image, presented in figure 20(b). The teacher drew the image in response to pupils' question: *how is it supposed to work?* She drew the image bit by bit on the white board accompanied by commentaries: *they have built such a circuit. I am drawing each battery housing; at the continuation they did add the switch, then the buzzer... At the continuation they did add the light bulb. Principally it is an electric closed circuit.*

The teacher transformed the 3D model into the visual mode to resolve a problem, which arose in class of how to clarify the construction of the model and its function principle as an electric closed circuit. The act of creating the schematic image as a means of clarifying a conceptual issue and giving thought shape is an example of how pupils' are brought into the habitus of school science, in a conscious or unconscious fashion. In an unplanned manner the image on the board functioned as a visual background while the performers on the floor held the model demonstrating and explaining its function

(a)

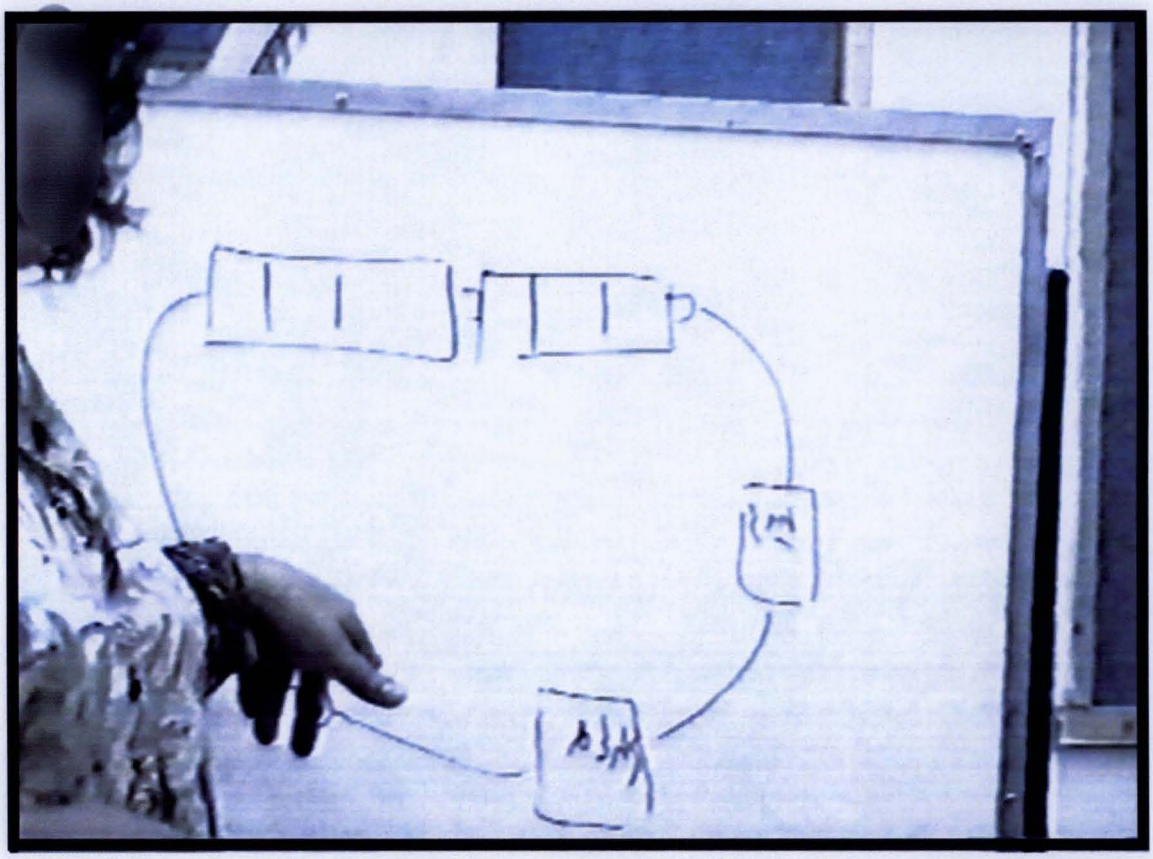


Figure 20. (a) Demonstration of the functioning of the model/invention; (b) Image of the model on the white board

principle. Thus the pupils' interpretative activity in class moved between the 3D model and the two dimensional schematic image on the board.

Rhetorical strategies

Noah and Tal used a number of rhetorical strategies including: a general statement, an introduction of the problem of hard of hearing, recounting a specific observation, naming the invention, providing transition statements, introducing the constituents of the model, stating a practical problem, translating the 3D model into a schematic image (by the teacher), demonstrating + explaining, specifying a problematic subject for aspiration and further exploration.

To illustrate the function of the rhetorical strategies used I take a view along the vertical axis under the category "rhetorical strategies" in table 7. The function of the general declaration at the start of the event: *we have invented an invention,* is to reframe the presentation in the task framework and to position the audience in relation to the issue of the presentation. However, Noah did not provide any additional information at that stage regarding the invention. She first talked of the general problem of hard of hearing:

> *It is well known that there are many hearing problems of different kinds. Without entering now into details...*

Then Noah moved to recounting a relevant particular observation before naming their model invention and introducing its components:

> *At the entrance to a house in our neighbourhood ...there is a deaf person ... There is no device that can signal that somebody wants to enter the house...*

Talking first about hearing problems, followed by recounting of a particular observation prior to the demonstration served to justify the necessity of the proposed model/invention. This also complied with the task framework, namely, to suggest a technological development utilizing sound waves for a real life problem. The strategy of basing their claim on an observation served to provide scientific power for their exploration and suggested invention. Nonetheless they did not include the particular observation in their written report. In the written report they justified their invention by noting generally on hearing problems in everyday life as follows:

This instrument can fulfil a significant function by helping people with hearing problems...when one wants to enter into the house of a person with hearing problems then he would not hear a knock on the door or the buzzing. Therefore we invented this instrument...

That is, they adjusted the content and form to the rhetoric situation of presentation. This is evident also in Noah's explicit refraining from entering into details about hearing problems: *without entering now into details*, which is meant to avoid loading too much information and technical terms on the audience during the presentation. In contrast, in the written assignment to be read ultimately by the teacher they extended the scientific information.

They clearly defined in scientific terms what a hearing problem is compared to "normal" hearing in terms of the measurement of sound in decibels (i.e. *a "normal" person can hear low sounds up to 15 decibels. One suffers from deafness when one cannot hear sounds beneath 60 decibels*). In the written text they also pointed out a range of causes of the prevalent kind of deafness (i.e. *1. A strange object 2. Earwax* 3. *Infection in the middle ear* 4. *Blockage in the Eustachian tube* 5. *Infection in the inner ear 6. Sclerosis of the ear*).

This shows the performers' understanding of the rhetorical situation of presentation, which sets different constraints and possibilities than the written report. The strategy of naming the invention *"light-bell"* for the door provided a cue as to the functional principle of the invention. This opened up a difference between what the performers know and the class presumably does not, which invited their explanation. Their move to handling the objects (the container + components) in combination with the transition statement provided by the teacher: *pay attention they are going to show their patent,* marked a shift (shift from frame 3 to 4) in the rhetorical framing, from talking about the invention to demonstration of the model/ invention itself.

Exhibiting and naming each of the elements comprising a model construct the resources for explanation of the principle function of the model as an electric circuit:

Here we have two identical battery constructions each with three batteries, this is the wire, this is the light bulb housing with a light bulb...this is the switch and this is the buzzer...in fact as we link all the components to an electric circuit...

Stating the state of affairs stressed that at this stage they still had a problem, which needed to be resolved:

At the moment we have a problem, either the light goes on or the sound of the buzzer, but not both... We have checked the electric consumption

of the buzzer and the light bulb and it should have worked... we might need two circuits.

This also led to the expression of their aspiration for further steps in the inquiry, which left the issue open for further exploration. The teacher's conclusion: *inventors sometimes have theoretical ideas, which need assistance in the practical technological aspect. Anyone who can assist should offer to help,* challenged the class to assist in solution of the problem, in a sense as a supporting "scientific community".

Modes

Noah and Tal deployed speech and action resources to introduce their model/invention and to demonstrate and explain its function principles. Each mode deployed performed a different function in realizing meanings. Speech was the foreground mode to realize ideational meanings in four units comprising the event (frames 1-3 and 7). Action and speech worked in integration to realize ideational meanings in one of the units (rhetorical frame 4) comprising the core of the event. In this unit they exhibited and introduced the model constituents at the same time. That is, in this unit, action and speech worked in integration to realize ideational meanings. Action was the foreground mode in one of the units (frame 6) where they demonstrated the functioning of the model. Speech was a secondary communicative mode used to label elements already introduced or for description of actions certainly seen by the audience, for example: *This is the switch...there is the buzzer, now I turn on the switch, the light bulb goes on, it should activate the buzzer but it does not...*

The relative emphasis throughout the event was on realisation of ideational meanings. Noah and Tal established close interpersonal relationships with the audience from the start of the event through speech, spatial and bodily resources, which influenced the construal and uptake of the ideas communicated. They took a physical close position to the class, made direct eye contact and realized agency by speech across the event: *we have invented an invention, Tal and myself we have been thinking... we noticed it in our neighbourhood... Tal thought of the idea, which we called... we, have a problem... our aspiration is...*

The relative emphasis on textual meanings is in the boundaries of the event and in the shift units between rhetorical frames, realized by speech, by action or by integration of action and speech. For example, the following statement: *just a moment it will take us some time to link all the components* realized textual meanings; it clearly marked a shift in the rhetorical framing of the event (shift to frame 5).

In summary, with respect to the research question the analysis presented in this chapter shows Noah and Tal's understanding of how to use available resources to communicate scientific knowledge in the rhetorical situation of a presentation. This is evident both in their deliberate design and in the actual performance, which sets different rhetorical requirements than the written assignment. It is evident in the way they deployed a range of resources, interweaving rhetorical means, rhetorical strategies and semiotic modes in coordination to mediate the function principle of their model/invention adjusted to a presentation to the class as an audience. At the same time they also attempted to comply with the task framework set by the teacher for the written experimental report. Unlike Hila and peers (case study two) but similar to Naama (case study one) Noah and Tal present themselves as science learners through the empirical experimental dimension in the process of learning science.

PART II

INTRODUCTION

This part of the chapter considers two case study examples of presentation events performed in the 5th grade class termed as class 1, framed in the topic "systems in the human body". The presentation events discussed in this part of the chapter were embedded in a distinct pedagogical framing of the topic and enquiry work than those discussed in the preceding part of the chapter. The presentations considered in this part of the chapter were the outcome of pupils' independent enquiry work theoretical in nature, which was loosely framed by the teacher. Although the teacher established a basis of knowledge on one system in the human body, the respiratory system, (considered in the observations in chapter one and chapter four) the pupils were to independently explore any other system in the human body, which was not yet studied at that time in class, according to general headings provided by the teacher. By contrast, the presentations discussed in the previous part of the chapter were the outcome of practical experimental work, clearly framed and shaped by the teacher as a sequence of steps to be followed, and based on a shared basis of knowledge established by the teacher in class on the topic sound. It seemed to me that from the pupil's perspective the distinctive pedagogical framing was influential on the use of rhetorical resources in presentation events and thus significant in terms of the research question this chapter attempts to answer; i.e. what use

do pupils make of resources to communicate scientific knowledge in the rhetorical process of presentation events?

PRESENTATION FOUR – "SKELETON AND MOTION"

From a pedagogical point of view Jordan's case interested me because she was relatively very quiet in class whereas in presenting at the front of the class she spoke up and performed quite confidently.

A Descriptive Summary of Presentation Four Rhetorically Framed

Frame 0 – preliminary actions

Jordan displays objects on the desk at the front of the class including: a poster-map of the skeleton, a copy of her written assignment, a simple model of two drinking straws and two transparencies.

Shift - She takes the teacher's usual position, the poster-map in her hands. She is slightly "invading" the audience's space. She makes direct eye contact.

Frame 1 – introduction of the skeleton structure

She exhibits the poster faced towards the class: *my topic is skeleton and motion.* "The skeleton and motion" is also the heading of the poster. She holds the poster close to her body and while attempting to point to elements she introduces: *This is the skull, which protects the brain. These are the neck vertebrae, which are called the axis and the atlas, this is shoulder band...* many in class complain: *we cannot see!* Jordan's voice is stifled.

Shift – The teacher takes a position near Jordan. The teacher takes the poster holding it faced towards the class. Jordan orientates herself to the poster her back to the audience.

Frame 2 – introduction of the skeleton structure (second attempt)

Jordan points at the map. She attempts to introduce the skeleton structure. Again many pupils complain that they cannot view what she is pointing at. Jordan is for a moment confused. The teacher silences the class, attaches the poster on the board and suggests that Jordan move on with her presentation and that they will discuss the matter of the poster following her performance.

Shift - Jordan picks up her written text, positions herself at the front of the class in an upright posture.

Frame 3 – structure and function of elements in the skeleton

Jordan reads. She is interrupted by pupils' comments to the first section in her text (it concerns the number of bones in the skeleton in a grown-up human body (206) in contrast to the number of bones in a newborn's body (300).

Pupils: *It is illogical!*

Jordan: *I also found it as amazing, but it is true! The baby's body entails much cartilage, and in the process of growth there is a process of ossification in which some bones become linked.* Jordan proceeds reading her text to the end; it concerns the function of the skeleton to protect sensitive organs.

Shift – Jordan is lifting the drinking straws. She turns to the teacher: *I have a model.*

Teacher: *Whatever you want to show, show it to the class, they are your audience.*

Frame 4 – structure and function of the spinal column

She approaches the class: *I have a riddle type question.* She is exhibiting the drinking straws and makes direct eye contact with the class. She manipulates one straw. She shows that it is sliced, flexible and can be bent. She shows the second whole and upright straw. She poses a question:

Which straw do you think is more like the spinal column? Explain your answer.

A number of pupils raise their hands they defend two opposite proposals. Jordan demonstrates the flexibility of the sliced straw and explains:

This is like the spinal column, the spinal column is comprised of vertebrae and therefore it enables motion. It is flexible like this (demonstrating with the sliced straw). *If it were one piece like this* (lifting the whole straw) *it could break when we make movements.*

Shift – Jordan takes the transparencies and declares: *I have another thing.* The teacher: *the floor is yours.* Jordan displays a transparency on the projector. There is a problem with the projector. A pupil assists in fixing the projector.

Frame 5 – the structure of bones and relations between systems

Positioned to the right of the board Jordan reads the headings of the projected transparency: "*skeleton and motion*" and the sub-heading "*cartilage, ligaments and tendons*". She points at a diagram: *this is the knee joint, this is the hipbone, this is the kneecap, this is the fibula, and this is the tibia, ligaments link the joint but allow free motion.* She points at the second diagram: *This is the front view of the knee joint, this is the hipbone, and this is the meniscus cartilage, ligaments, cartilage, the fibula and the*

tibia. She changes an overhead and reads the headings: *"skeleton and motion" "the structure of the bone"*. She introduces the diagram: *this is a sector of the hipbone, which shows its inner structure.* She points at the diagram and reads: *hard solid bone, spongy light bone, cartilage, marrow of the bone, blood vessels.* The class becomes restless. She reads: *an outward covering, which entails cells that assist to recover bones.* The class is restless and her voice is overheard. Jordan concludes: *In brief, the bone is comprised of living tissue rich with blood vessels.* The class is restless.

Frame 6 – end - Jordan: *that's it I am done.*

An Overview of the Categories of Analysis (consider Table 8)

Rhetorical means

Jordan staged her presentation around four rhetorical means: a poster-map, her written text, a simple model of drinking straws, and two overheads with schematic diagrams of bones.

The poster-map

The poster is a schematic map of the skeleton, which Jordan photocopied from a textbook in an enlarged form, to which she added the heading *skeleton and motion* and her written labels (i.e. *skull, the neck vertebrae, the shoulder band* and so on). By means of the map she attempted to introduce the skeleton's structure by naming its constituents: *This is the skull...these are the neck vertebrae, which are called the axis and the atlas...* .

Jordan's poster-map could have been a useful rhetorical means, yet, she was unsuccessful in mediating it; the pupils could not view the map's components, due to its small size. The teacher's reframing of the poster as she attached it to the board gave it a stable position, which could have been an efficient visual background had the size of the poster-map been in a larger format.

The written exploration report

The written text concerns structural features of the skeleton and the function of the skeleton to protect sensitive organs in the human body. Though short and incomplete (consider the text in figure 23 in chapter 6), in her written text Jordan attempted to adhere to the task framework set by the teacher. Thus, presenting the written text seems to have served the function of reframing her topic in the wider context in science class and to ensure she had done the presentation task correctly.

Table 8. Analysis of the rhetorical process of presentation four – "skeleton and motion"

Rhetorical frame		Rhetorical means	Rhetorical strategies	Modes
Min.	**Heading & No.**			
	0 Preliminary actions	Poster-map, text, model, overheads		Action: handling objects, movement
	Shift	Poster-map		Action: position
0.30	**1** Introduction of skeleton structure	Poster-map + body	Naming elements	Visual + speech + gesture + gaze
	Shift	Schematic map	Reframing the map	Visual + action: position, gaze
1.00	**2** Structure of skeleton	Schematic map + body	Constructing entity	Visual + speech + gesture + gaze
	Shift	Folder-text		Action
1.30	**3** Structure and function of skeleton	Exploration report	- Providing information - Explanation	Speech
	Shift	Simple model	-Exhibition -Transition statement	Action + speech + gesture
3.00	**4** Structure and function of the spinal column	Simple model	-Demonstration, -Creating difference, -Eliciting difference of opinions, -Explanation	Gaze + speech + Action
	Shift	Transparencies	Transition statement	Action + speech
6.00	**5** The bone structure and function	Schematic diagrams	- Naming elements, - Constructing entities	Visual + speech + Gesture
	6 End		Closure statement	Speech

The simple model of drinking straws

Jordan used everyday objects, e.g. two drinking straws as a model. She abstracted and represented criterial characteristics of the vertebrae structure of the spinal column by drawing on the material properties of the drinking straws as semiotic resources. She drew on the 3D properties of the straws, i.e. their hollow and lengthy form and their plastic material properties. On the one hand, its property of being upright, and on the other slightly bent and sliced, still allowed it to remain as a whole unit, representing the vertebrae's flexibility in motion and at the same time its upright nature. The material properties also enabled a contrast between the two drinking straws. This is reflected in the way she handled each of the drinking straws and the question she posed: *which straw do*

you think is more like the spinal column? That is, the drinking straws served as a rhetorical means to elicit contrasting opinions in class, which invited her explanation. In the science classroom context the drinking straws temporarily gained new significance and meaning beyond their inherent material properties, thus they became semiotic objects.

The transparencies

Jordan produced two OTs which are presented in figure 21. She copied schematic diagrams of bones from a textbook. One transparency shows two diagrams, one representing a cross-section of the knee joint and the second representing a front view of the structure of the knee joint. The diagrams were accompanied by written labels and commentaries which Jordan added, e.g. *the hipbone, the kneecap, the fibula, the structure of the knee joint: ligaments link the joint but allow free motion.* The second transparency shows a sector of the hipbone, through which she represented elements that comprise the structure of the bone accompanied by her written labels and commentaries: *hard solid bone, spongy light bone, the bone is a living tissue, rich with blood vessels.*

The use of the schematic diagrams towards the end of her presentation was an appropriate rhetoric decision although she was not fully successful in mediating the diagrams. For the class as an audience to receive the abstract meanings and intensity of information represented in the diagrams required a knowledge basis, which Jordan attempted to establish from the start of her presentation. But as she focused on structural features of the knee joint and the bone loaded with specialized terms it raised unrest in class. Jordan responded to the audience's unrest and concluded the performance as follows: *In brief, the bone is comprised of living tissue rich with blood vessels. That's it, I am done.*

The type of objects and the specific order in which Jordan used them as a rhetorical means is significant. It reveals a number of rhetorical choices Jordan made, consciously or unconsciously, both in the process of design and in the presentation, to position the audience in relation to scientific knowledge and to construct a coherent account of her topic even though she did not fully realize her rhetorical intentions. She rhetorically framed the event: by moving from the skeleton structure as a whole (mediated by the map and the written text) to sub-systems and parts in the human body (mediated by the simple model and the overheads); by moving from the outward structure to the inward and analytic view of the structure of bones; and by increasing the intensity of information by naming constituents of the entities such as "the skeleton structure" "the structure of the knee joint" and "the bone structure". That is, neither the skeleton map nor

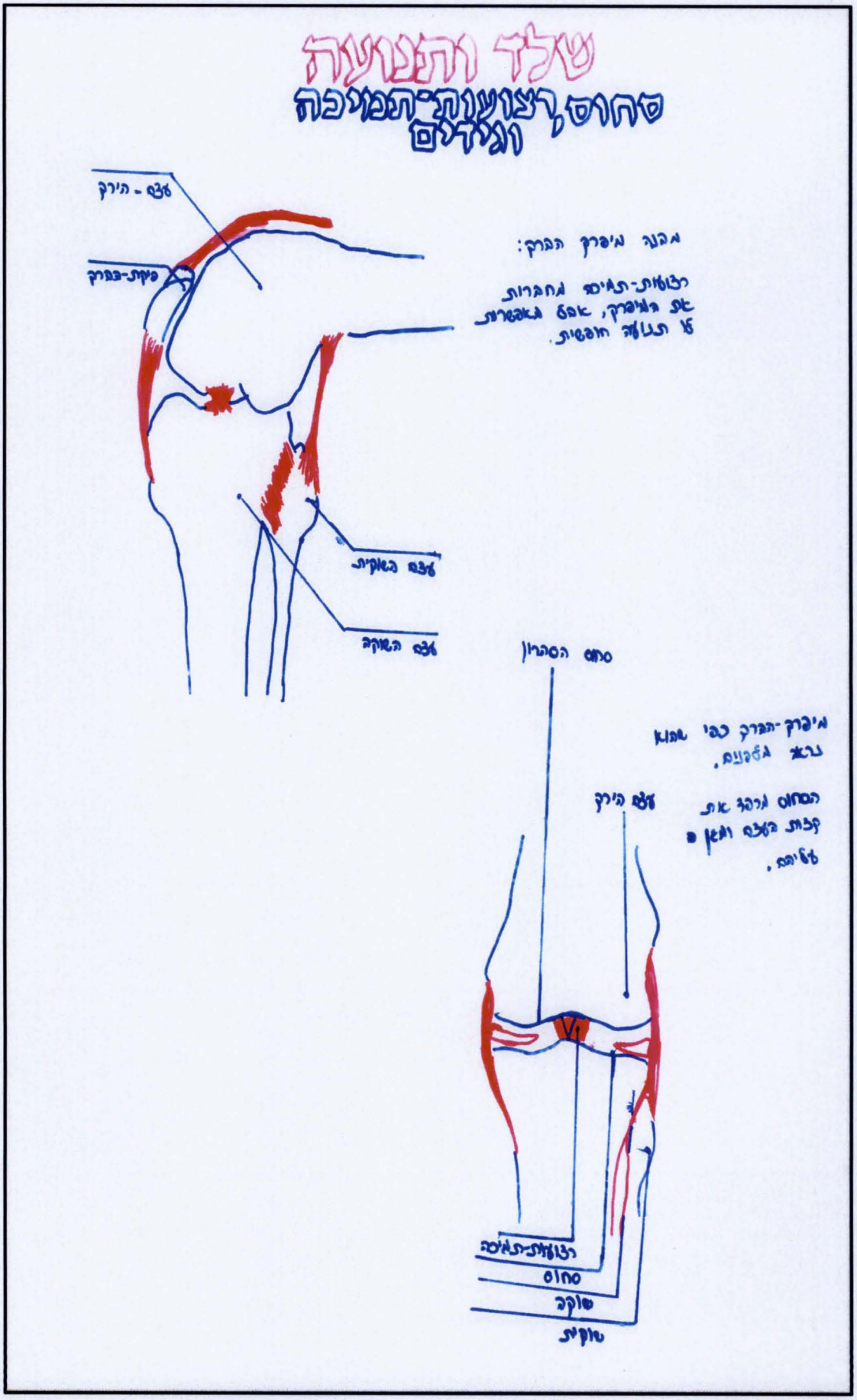
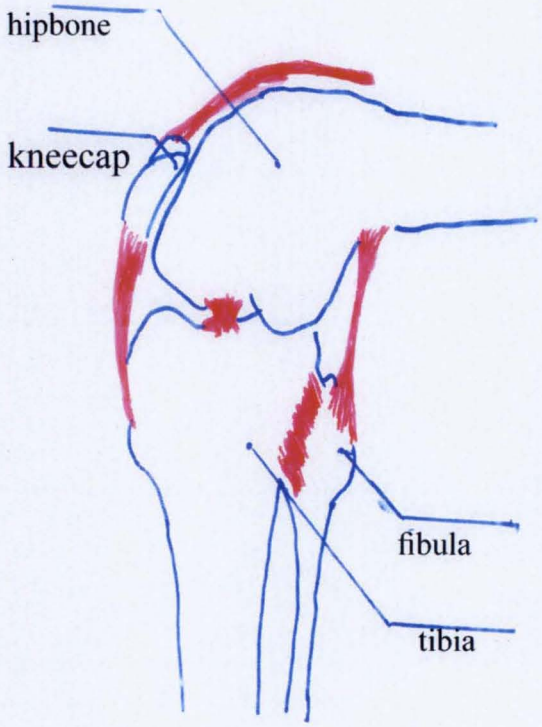


Figure 21. OT diagrams of bones (a) Knee joint; (b) Translation of knee joint; (c) Hip bone; (d) Translation of hip bone

Skeleton and motion
Cartilage, ligaments and tendons

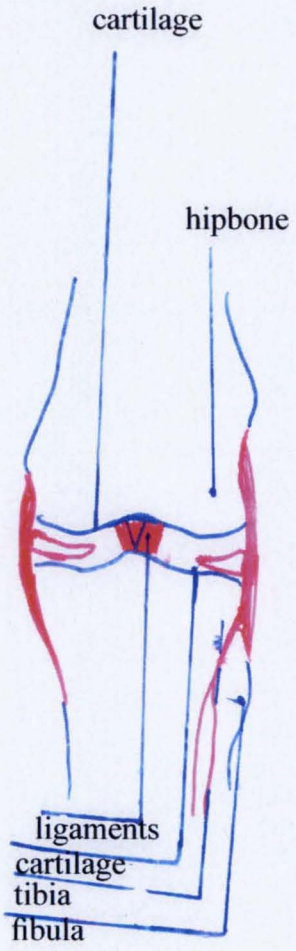


The structure of the knee joint:

Ligaments link the joint, but allow free motion.

The knee joint from a front view.

The cartilage pads the edges of the bone and protects it.

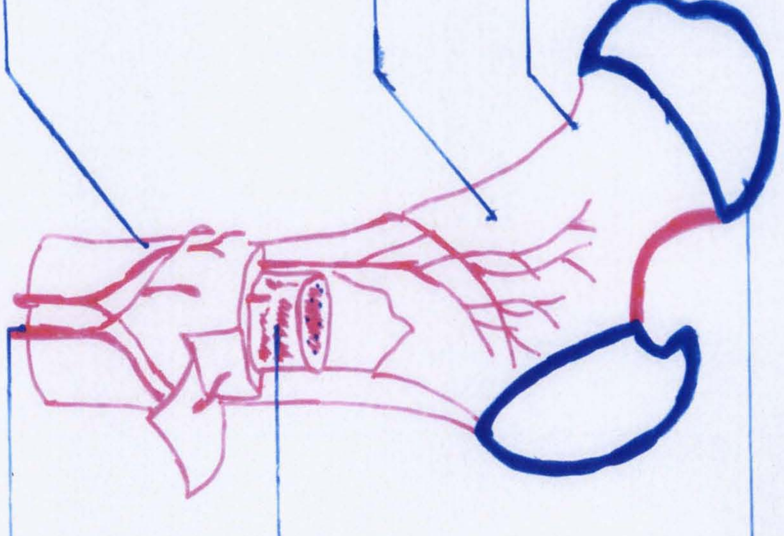


(b)

שלד ותנועה

מבנה העצם

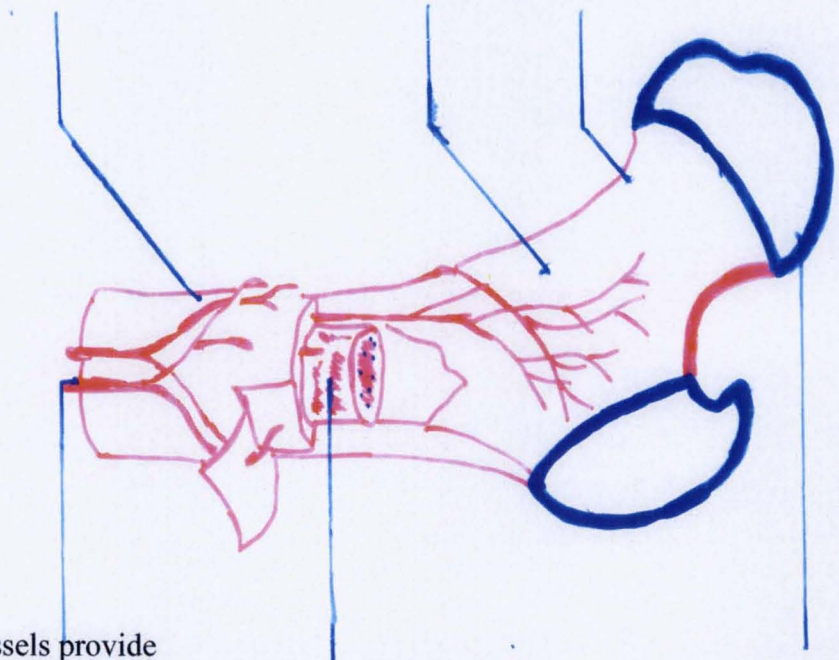
חתך בעצם הירך, המראה את המבנה הפנימי שלה.
העצם היא רקמה חיה, עשירה בכלי-הדם.



(c)

Skeleton and motion
The structure of the bone

A sector of the hipbone, it shows the inner structure. The bone is comprised of living tissue, rich with blood vessels.



(d)

the written text or the simple model and the schematic diagrams of bones could work independently as they did in combination and in the specific sequence she presented them in the rhetorical process of the presentation event.

Rhetorical strategies

Jordan used a number of rhetorical strategies to introduce her topic and to generate the class' involvement including: naming constituents, constructing entities, exhibiting, providing transition statements, demonstrating, creating difference, explaining and providing a closure statement. To illustrate the function of rhetorical strategies and the reasoning behind her choices I focus on two related strategies, naming elements and constructing entities. Jordan used these strategies in three units of the event; consider frames 1, 2, and 5 in table 8 under the category "rhetorical strategies".

Communicating and explaining phenomena concerning a system in the human body in a concentrated form of presentation are a complex task. On the one hand pupils have experience and everyday knowledge of the human body. On the other hand it is a system which had not yet been studied at that time in class, and it ought to be viewed and explained in a new and uncommon scientific view. Constructing an explanation of ideas of a topic, which was not yet studied at that time in class, requires the creation of an explanatory context. A part of an explanatory context involves the creation of resources, which include new terms and entities required for the construction of the explanation i.e. a new body of knowledge. For that purpose Jordan used the strategy of naming structural constituents, using specialized scientific terms of three entities: "the skeleton structure", "the structure of the knee joint" and "the bone structure".

My suggestion is that she focused on structural features rather than on relations between constituents within the system or between systems in the human body, because of the absence of a prior basis of knowledge on the topic in class and perhaps due to the short time frame of a presentation and the unrest in class, which arose in response to the high degree of technical terms she used.

Modes

Jordan's presentation is a multimodal event in which modes worked together in different ways to communicate scientific knowledge. In meta-functional terms she used the modes to realise ideational, interpersonal and textual meanings simultaneously. In three of the rhetorical frames, frames 1-2 and 5, the visual mode (the poster-map and overheads) worked in integration with speech and action to realize ideational meanings. In one unit, frame 4, action and speech worked in integration (the simple model) to

realize ideational meanings. In one of the units (frame 3), speech-spoken text was in the foreground to realise ideational meanings. The relative emphasis in the event is on ideational meanings. Similar to the case studies discussed thus far in the first part of this chapter, Jordan focused her rhetorical effort on communicating scientific knowledge. The relative emphasis on textual meanings and on interpersonal meanings occurs at the boundaries of the event and in shift units between rhetorical frames, realized by integration of modes or foreground modes. For example, action is the foreground mode to mark the intentions to start the event by the display of objects (frame 0) or to mark the shift in the rhetorical framing (shift between frame 2 and frame 3) by movement in space, posture and handling the written text as an object. Speech is the foreground mode to explicitly express the end of the event (frame 6). Speech and action work in integration to realise textual meanings. For example, in the shift unit between frame 4 and frame 5 Jordan provides a transition statement *I have something more,* which gains its coherence by her handling the transparencies.

Jordan's orientation to establish close interpersonal relationships is realised by action resources, gaze and meanings carried out by the spatial codes. On the one hand, taking the teacher's position at the front of the class, granted Jordan the power to temporarily take over the teacher's role. On the other hand, her move from the teacher's usual position closer to the class, "invading" their space (shift unit to frame 1) expressed her orientation to close interpersonal relationships with the class as an audience. This is consistent with her dialogic style of interaction reflected in the following excerpt.

Jordan: (reads) *an adult human being has 206 bones in his body when a baby is born he has 300 bones in his body...*

Pupils: *It is illogical!*

Jordan: *I also found it as amazing, but it is true! The baby's body entails much cartilage, and in the process of growth there is a process of ossification in which some bones become linked.*

The Rhetorical Orchestration of the Modal Ensemble

To illustrate Jordan's rhetorical orchestration of the modal ensemble I take a view along the horizontal axis of one unit in the rhetorical process of the event including the shift unit and frame 4 (consider table 8). In this unit the shift in the rhetorical framing of the event is realised by the integrated work of the simple model as a rhetorical means and two rhetorical strategies including the exhibition of the model and a transitional statement. The textual meanings can be inferred from Jordan's manifest communicative actions. Examples of these actions include Jordan's movement in space at the front of the

class; her shift to another semiotic object, the simple model; shifts in her position in relation to the teacher and in relation to the class as an audience; exhibition of the model and the statement she made, which generated the teacher's response:

Jordan: *I have a model*

Teacher: *Whatever you want to show, show it to the class, they are your audience.*

The meaning of some of Jordan's communicative actions in that unit throws light on the complicatedness of performing a presentation in the science classroom. Jordan specifically turns to the teacher at this point most obviously because of her unsuccessful experience with the small sized poster-map resulting in the teacher's attempt to provide her with assistance in the previous episode in the event. It seems that it raised some doubts as to the rhetorical appropriateness of her model of drinking straws, which is also small in size. The teacher's assistance also confused her conception of the role boundaries of who in fact is controlling the event, and of whom to address as her audience. At this point Jordan moved between the teacher and the class as two different audiences.

This episode exemplifies the complexity of performing before the class as an audience though bound to a task accomplished indeed for the teacher. In rhetorical frame 4 Jordan used the simple model as a rhetorical means and five rhetorical strategies to explain the relation between structure and function in the spinal column. The semiotic modes and the rhetorical strategies deployed are interrelated and based on the manipulation of the simple model including: exhibition, demonstration, initiation of a question, elicitation of contrasting opinions and explanation. Neither the manipulation of the simple model nor the different strategies alone, and speech or action alone could work in this case independently convincingly.

Jordan's very announcement: *I have a riddle type question,* not just a question, in integration with exhibiting the simple model are rhetoric strategies she used at the start of that unit to raise the audience's attention and involvement. Seemingly, children love riddles. Then she generated responses in class by means of demonstration of the properties of the two contrasting drinking straws in integration with the question she posed: *which straw do you think is more like the spinal column?* This elicited contrasting opinions in the class about which straw represents the structure and function of the spinal column. By means of these integrated rhetorical strategies she created a difference, which invited her explanation: *This is like the spinal column, the spinal column is comprised of vertebrae and therefore it enables motion. It is flexible like this* (demonstrating with the sliced straw). *If it were one piece like this* (lifting the whole straw) *it could break when we*

make movements. It seems that in this unit she bridged the difference between what they knew and where she wished to take them.

PRESENTATION FIVE – "THE BLOOD SYSTEM"

Leah was the first presenting pupil in a session that included five different presentations (the blood system, the digestive system, the senses system, stages in the development of an embryo, and the heart system). From a pedagogical point of view Leah's case interested me because she was one of the articulate pupils in the class. From the aspect of participation in communication in science class her place would be on the opposite side of the continuum in comparison to Jordan who was particularly quiet in class.

A Descriptive Summary of Presentation Five Rhetorically Framed

Frame 0 – preliminary actions

Leah displays her folder with the exploration report on the desk at the front of the class. She holds an OT.

Shift – She takes a position close to the board, not the teacher's usual position.

Frame 1 – introduction, the blood system is linked to the heart system

She directs her gaze at the OT in her hands at times to a distant point: *I have done work on the blood system. I have seen that the blood system is very much linked to the heart system. They exist together. The blood system functions together with the heart system.*

Shift - *So I want to show a transparency.* She displays the OT; the overhead projector does not work. There is unrest in class. The teacher silences the class.

Frame 2 – technical delay

The teacher and a pupil provide assistance, fixing the overhead. It caused a technical delay of about a minute. Meanwhile Leah took a position at the right of the board, leaning on the wall, waiting. Now the overhead projector works many in class call: *we cannot see, it is upside down, now it is not in focus.* The teacher assists.

Frame 3 – from simple to complex heart structure and blood system of living organisms

Positioned at the right of the board, she directs her gaze to the projected transparency: *I have done work on animals, in fact on the heart structure and blood*

system of animals. Pointing and tracing the image at the right side she speaks in a slow pace stressing certain words (underlined): *Here it is on fish. As you can see here, fish have just one pump, one atrium and one chamber, from here the blood moves to the arteries to all the organs of the body.* She quickly takes a position at the left side of the board pointing and tracing the image: *here it is on frogs, here you can see that a frog's heart has two atriums, here is the left atrium, here is the right atrium and there is only one chamber.* A pupil assists by changing the position of the transparency for better view. Leah proceeds: *Here is the entry of blood from the lungs rich with oxygen. Here is the exit of blood from the chamber to the main artery. This is the main artery. It leads blood to the body. Here is the entry of blood from the veins.* She kneels down beneath the projected text some pupils change their position to get a better view of Leah. Kneeled down, she moves from the left side of the board to the right side according to the three images. Directing her gaze at the board, pointing and tracing the images from the left to the right: *here it is on mammals. There are three stages. It is quite complicated.* The teacher comments quietly: *say it in words that you understand.* Leah proceeds: *Okay I will not show everything...here the atrium contracts, blood moves into the chamber. Here the chamber contracts blood is pushed with pressure into the main artery. This is the third stage.*

Pupil: *what is the main artery?*

Leah still kneeling and her body and gaze directed to the board answers: *It is like the biggest and the main pipe, which leads blood with oxygen all over the body. The third stage is the resting stage blood moves from the vein to the atrium here one feels the beats.* She demonstrates the heart beats by repeated gestures of an up and down movement on her left chest. *Arteries are like pipes leading blood with oxygen to the body, which comes back through the veins and so it repeats itself.* She gestures with her finger cyclic motions. She stands up, positioned at the board not making direct eye contact with the class: *I think that you do not understand it so well.*

Shift – There is unrest in class, the teacher silences the class. Leah: *just a moment, I have something more.* She picks up her folder from the desk, leans on the wall near the board, in a distant position from the audience.

Frame 4 – function and structure of the blood system

Browsing over her text, she comments and overviews the headings and certain sections:

> *My work is quite detailed but I will not tell everything. I have written on the structure of the blood system, on the functions of the system, on the*

*immune system, and on the blood system of other living creatures. The blood system is comprised of three constituents: one, the blood tissue, two, the blood vessels and three the heart structure, which I showed you on the transparency. The function of the heart is comprised of three stages as I showed you a. the contraction of the atriums ... The function of the blood is... In fact the blood system is comprised of three components including the blood tissue, the blood vessels and the heart system. About the heart and blood vessels I explained earlier. The blood tissue is comprised of red cells and white cells. The red blood cells are much more than the white cells and they lead the oxygen to the body by means of the haemoglobin...*many in class whisper: *we don't understand.*

Frame 5 - End

Browsing her text she states: *that's it, that's it.*

Table 9. Analysis of the rhetorical process of presentation five – "the blood system"

Rhetorical Frame		**Rhetorical means**	**Rhetorical strategies**	**Modes**
Min.	**Heading & No.**			
	0 Preliminary actions	Written report, OT		Action: movement, handling objects
	Shift			Action: movement, shift in position
0.30	**1** The blood system is linked to the heart system		- Naming the topic, - Connecting new to prior knowledge	Gaze + speech
0.40	Shift	OT- schematic diagrams	Transition statement	Speech + action: position and posture
1.40	**2** Technical delay	Fixing the overhead		Action- shift in position
4.40	**3** From simple to complex organisms	OT- schematic diagrams	- Naming the topic, - Mediating diagrams - Naming constituents - Constructing entities	Visual + speech + gesture + gaze
4.50	Shift	Folder with text	Transition statement	Speech + gaze + action
6.50	**4** Function and structure of the blood system	Text	- Review of headings, - Naming constituents - Constructing entities	Gaze + speech
7.00	**5** End		Browsing text, Closure statement	Speech + action

An Overview of the Categories of Analysis (consider Table 9)

Rhetorical means

Leah staged her presentation event around two semiotic objects she produced: the overhead transparency and her written exploration report.

The overhead transparency

The projected overhead transparency, presented in figure 22, under the heading *the blood system of animals* includes three separate sections, framed by separating lines. It shows five schematic diagrams and corresponding headings and written commentaries. On the top right side is a framed diagram of the heart structure and blood vessels of a fish. On the top left side there is a framed diagram of a frog's heart structure including the main blood vessels. On the bottom from the left to the right there are three separate framed and numbered images representing three stages in the structure of mammals' heart. This in fact is only the left side of the heart. Leah copied the images from the last section in the chapter she drew on from the textbook. She organised them spatially in a different manner than in the source text, which integrates the images in the written text.

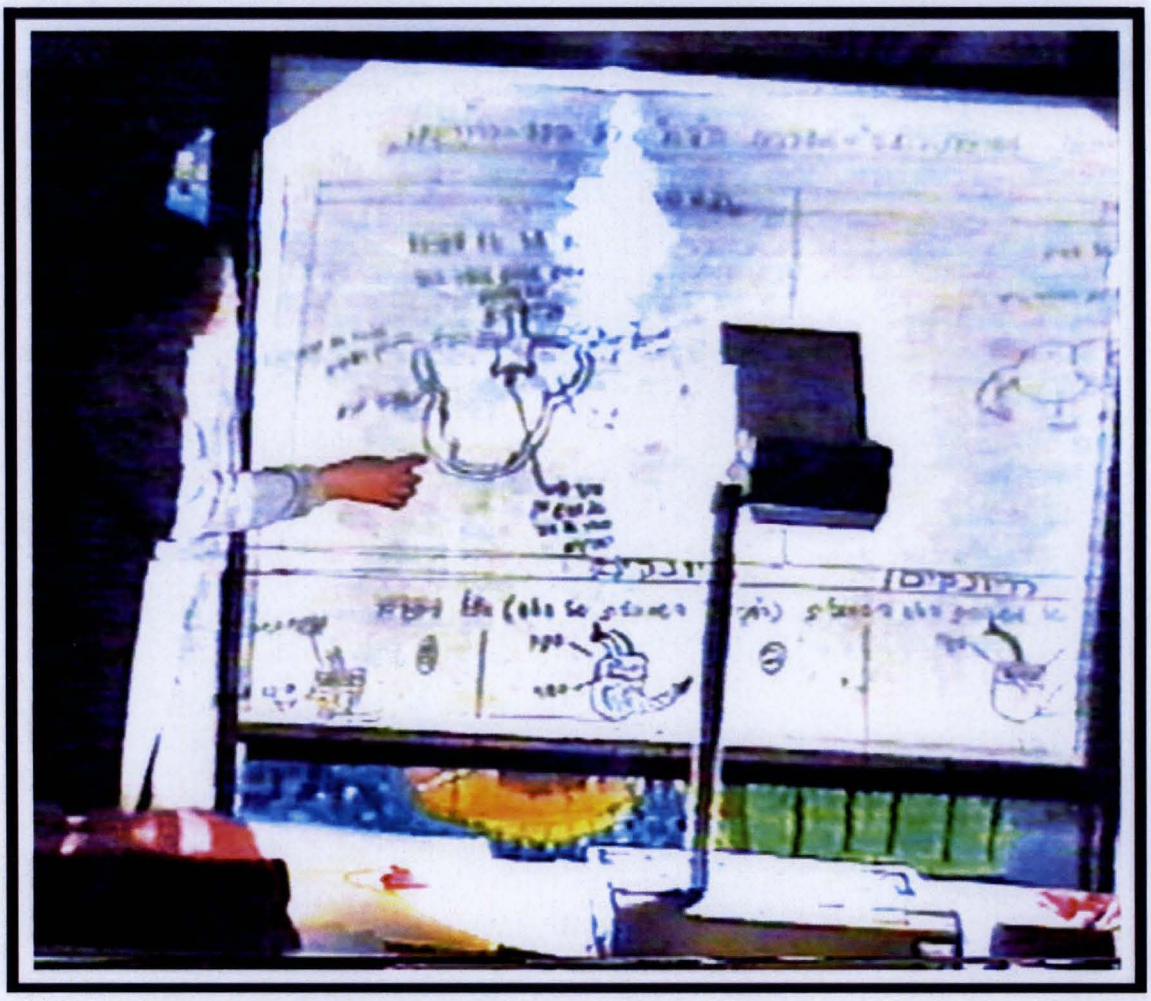


Figure 22. Projected OT – "The blood system of animals"

The written report

Leah produced a lengthy written report on her topic. She organised the content in accordance with two headings set by the teacher (i.e. the structure of the system and the function of the system) in combination with two headings from the source text (i.e. the immune system and the blood system of living creatures). In fact, she included a section at the end of her report, as it appears in the source text, on the blood system of living creatures, which was outside the task framework and the topic in class. In the presentation she introduced the headings of her report and short selected sections, which focused on the structure and functions of the blood system.

The choice, production and use of the semiotic objects as a rhetorical means and in that specific order in the presentation event are rhetorical decisions. Representation of an analytic view of organs through schematic images (i.e. the OT) is a common rhetorical means used by the teacher and pupils in the science classroom. The use of schematic images at the initial stage of presentation events was also used as a rhetorical means by other pupils performing (i.e. the skeleton map in Jordan's case). What puzzled me in this case is Leah's decision to place the blood system of living organisms at the beginning stage of her presentation. As noted, this topic is a minor section at the end of the source text and it was outside the task framework and topic in class. The question arose of what may have been the reasoning behind her rhetorical decision, whilst in her written report she placed this minor section, like in the source text, at the end.

My suggestion is that Leah took into consideration, consciously or unconsciously, the difficulty of both communicating and receiving the complex topic of the blood system. Given the constraints of the concentrated form and the short time frame of a presentation event; and that it is a topic, which at that time had not yet been studied in class, Leah's decision stemmed perhaps from the attempt to make a complex topic more accessible to the class. This she did by means of the transition from a relatively simple heart structure and blood system to the more complex one (fish-frogs-mammals). Thus the introduction of her written report on the blood system in the human body came afterwards.

Rhetorical strategies

Leah deployed a number of rhetorical strategies to communicate her topic and to ensure she had correctly done the presentation task, including: naming her topic; connecting prior knowledge to new knowledge; providing transitional statements (e.g. *I want to show a transparency)*, and attitudinal statements (e.g. *I think that you do not*

understand it so well); mediating diagrams, naming constituents and constructing entities; moving from simple to complex structures; introducing, reviewing and reading aloud elements from her written report. The function of rhetorical strategies will be exemplified in an integrated manner in the section "the rhetorical orchestration of the modal ensemble".

Modes

Leah communicated scientific knowledge through speech, visual and action resources. In certain units speech or spoken text was in the foreground (frames 1, 4 and 5). In other units the visual and the action mode worked in integration with speech (frame 3). Textual meanings were realised through speech by different statements in integration with the action mode. For example: *So I want to show a transparency* (shift to frame 2) or *just a moment, I have something more* (shift to frame 4) are statements which gained coherence by handling the objects of action and marked the shift in the rhetorical framing of the event. However the relative emphasis throughout the event was on ideational meanings as in the case studies discussed in this chapter.

Although Leah focused her semiotic and rhetorical actions on communicating scientific knowledge her case illustrates the significance of the dimension of interpersonal relations in communication and the uptake of scientific meanings by the class as an audience. In contrast to Jordan, who used gaze and close physical positioning as a means to establish close relationships with the class, Leah used the same communicative modes and spatial codes in the opposite orientation. My suggestion is that this influenced the kind of interaction and, to a certain extent, the pupils' difficulty to uptake her topic reflected in their being restless and comments such as *we don't understand.* Leah concentrated on the objects of action. She directed her gaze either to the close semiotic objects (projected diagrams on the board, her own text) or to a non-focused distant point as if addressing a distant presumed audience rather than the class in front of her.

The use Leah made of spatial and bodily resources, realising the interpersonal dimension of meanings, in a sense mismatched the situation of the presentation, which invites face-to-face interaction and direct eye contact with the class as an audience. However, this does not suggest that Leah did not understand the rhetorical situation of a presentation or that she was unaware of the audience's reactions. Her understanding of the situation is evident both in the pre-designed semiotic objects and in the range of resources she orchestrated in different modes during the presentation. This is evident for example in rhetorical frame 3 in the slow pace she mediated the schematic images, the stress she put

on certain words, the way she pointed at and traced each element on the schematic images in accordance with her speech, her movements in accordance to the position of the projected images and the gestures she used to represent ideational meanings i.e. the cyclic motion to represent the blood cycle and up and down movements of her hand above the chest to represent the heart beats. Although she did not make eye contact with the audience she realized their unrest and difficulty to construe the meanings she mediated by means of the OT, which she also expressed: *I think that you do not understand it so well.*

The Rhetorical Orchestration of the Modal Ensemble

Leah opened the presentation as follows: *I have done work on the blood system.* She did not just introduce her topic, for example as Jordan did (i.e. *my topic is skeleton and motion*) but also noted she has done "work" on the blood system. The expression "doing work" commonly refers in Israeli school culture to a written assignment. This is a similar strategy Hila and peers (case study two) used at the opening of their presentation. That is, informing the audience from the start that the accomplishment of the written assignment was significant to them.

In the introduction Leah stressed the link between the blood system and the heart system: *I have seen that the blood system is very much linked to the heart system. They exist together. The blood system functions together with the heart system.* In doing so Leah connected what she assumed as new knowledge for the class (pupils were less familiar with the blood system) with prior knowledge (the heart system was more familiar mainly through previous presentations). Further Leah's rhetorical effort to make the blood system accessible to the class is evident in the move she made from simple to more complex organisms by means of schematic diagrams (frame 2). She stressed that

> *Fish have <u>just</u> one pump, one circuit and a chamber...* Then she introduced: *...a frog's heart has two atriums, here is the left atrium, here is the right atrium and there is <u>only</u> one chamber. Here is the entry of blood from the lungs rich with oxygen. Here the entry of blood is from the body into the same single chamber. Here is the main artery. It leads blood to the body... Here it is on mammals...*

Although she stressed that fish have only one pump in their heart, and frogs have two atria but only one chamber she did not clarify what this actually means and how it affects the blood cycle. She did not clarify the notion that there is no good separation between blood leading oxygen and blood poor oxygen. However starting with simple structures by means of the diagrams shows her effort to make the topic accessible to the

class. She introduced specialized terms and some notions (i.e. *chamber, atrium, circuit, arteries, veins, arteries are like pipes leading blood with oxygen to the body, which comes back through the veins and so it repeats*), which she used as resources for further communication of knowledge concerning the blood system in the human body. Yet she did not use these as resources to clarify the idea of relations within the system and between systems. She focused on the construction of entities for example "the blood tissue":

> *The blood tissue is comprised of red cells and white cells. The red blood cells are much more than the white cells and they lead the oxygen to the body by means of the haemoglobin.*

Introducing elements from the written report to the audience (frame 4) was a strategy also used by other pupils (i.e. case study two and four) to reframe the topic in the wider context of learning and to ensure that the presentation task was done right. Reading aloud sections from the written report in a sense expressed what being scientific means to Leah, since she drew on a high level textbook at hand in the science classroom.

In summary, with respect to the second research question the analysis shows that both Jordan and Leah understood how to rhetorically orchestrate resources from different modes to communicate scientific knowledge on a topic explored presented to the class as the audience. The design and interweaving of the rhetorical means, rhetorical strategies and semiotic modes indicate their understanding of the rhetorical situation of presentation and their effort to get through to the audience and present a coherent account of the topic explored. Yet a number of factors caused the difficulty of the classmates to better construe the topic despite their efforts. These factors include: the absence of a basis of prior knowledge on the topics explored as the topics were not yet studied at that time in class, the breadth of the topics explored, and the complexity of the organ systems explored (i.e. the skeleton and motion system, the blood system). Consequently they "invested" rhetorical efforts in the constraining time frame of the presentation on structural features, naming constituents loaded with specialised terms, and constructing key entities of their topic. That is, they focused on the construction of resources that could have been the context of explanation rather than on explicating the idea of interrelations between structure and function, inter-relations within the organ system explored or between systems as required by the task framework.

By contrast the pupils presenting, discussed in the first part of the chapter, did not construct key entities and notions of the shared topic in class (i.e. sound); they presumed them as given knowledge established by the teacher on the topic in class. Thus, they could draw semiotic material from the teacher's lessons and use these terms and entities as resources for explanation of the specific phenomena explored through experimentation. In addition, in Leah's case there were a number of additional factors which caused the difficulty of the class to take up her topic including the influence of the high level source text she drew on; her focused attention on the objects of action; not making eye contact with the class and her choice to enact distant interpersonal relationships.

CONCLUSIONS

This chapter exemplifies how the framework proposed in this thesis can be used to address the rhetorical aspect in the science classroom from the pupil's perspective. In particular, this includes the ways in which fifth grade pupils deploy resources to communicate scientific knowledge on a chosen experiment or topic presented to the class as the audience.

The analysis shows that fifth grade pupils have an understanding of the rhetorical situation of presentation to the class as an audience, which sets different epistemological and rhetorical demands than the written assignment to be read by the teacher. Pupils' awareness of the audience and their understanding of the rhetorical situation are projected in the rhetorical process of the presentation, which points backwards to their planned design. Kress & van Leeuwen (2001) refer to the notion "design" (p. 31) as communicational practices involving the choice of material forms of realization of meanings and semiotic modes from an existing repertoire in a social cultural context, which the producer of the event considers as most apt and effective for specific purposes, audiences and occasions.

Although the pupils do not produce a script as an object in a material form, they engage in design processes involving planning, epistemological decisions and semiotic and rhetorical choices. They most certainly have a sort of a script in their mind, upon which the actual presentation is based. This is evident in the structured rhetorical framing of the presentations evoking a clear sense of beginning, middle and end of the events. The deliberate design is also evident in the choice, design and constitution of the rhetorical means, namely the material semiotic objects pupils produce in advance and use in the

presentation. The resources that constitute the material semiotic objects used provide different semiotic potentials and limitations, which the pupils know how to deploy for rhetorical purposes (i.e. models, posters, maps, schematic diagrams, overhead-transparencies, objects of experimentation, written reports).

Design motivations and the epistemological work done by pupils are also evident in the sequence in which the rhetorical means were presented in the process of presentation (i.e. model/image, poster flowchart, experimental report). The order in which the rhetorical means were used also points backwards to the process of transformation from medium to medium and the cognitive "transduction between modes" (Kress, 2001, p. 407).

Asserting that the rhetorical process of presentation events points backwards to design processes does not suggest that pupils "plainly" realize their deliberate design in the actual presentation. In presentation events at the front of the audience pupils are actively engaged in production processes involving semiotic choices and rhetorical decisions at the moment. In addition, the very process of articulation and the social, physical and material interactions in the presentation event bring life to their planned "script" and thus add further significant meanings (i.e. cyclic gestures representing the cyclic motion of the blood system).

The analysis shows that in the process of presentation pupils mediate visual representations and articulate significant meanings by bodily, spatial and action resources including gestures, body position, movement in space, body posture, gaze, orientation with the audience and objects of action, and manipulation and interaction with objects of action. Speech, as one among the other resources to articulate meanings, is deployed in the process of production in the unfolding event. Each of these communicative actions and their combinations are choices, which contribute to the rhetorical orchestration of the modal ensemble carried out to communicate scientific knowledge.

Pupils presenting make epistemological decisions and semiotic rhetorical efforts to explain the phenomena explored in scientific terms (case studies one – three) or to construct new entities and terms to establish a base of knowledge on topics not yet studied at that time in class (case studies four – five).

The epistemological work done by pupils is evident in the different ways they position the audience in relation to scientific knowledge, transform everyday objects into semiotic objects, create and interact with material rhetorical means, transform meanings from one mode to a different mode, integrate rhetorical strategies, develop a topic, shift between communicative modes and deploy resources to resolve problems. Take for example the epistemological work projected in the different ways pupils use semiotic resources to work out solutions of problems of representation and communication of scientific meanings. For instance, they resolved the problem of how to bring the entity of "vibration" into existence even though it is unobservable and dynamic by nature. This was accomplished (case study one) by the translation of meanings from medium to medium. First the experiment was demonstrated, i.e. notes were produced on bottles filled with water. Then vibrations were depicted by means of an image (i.e. a red broken line) and by speech and gesture (rapidly opening and closing the fingers). Another problem was solved, i.e. how to turn an everyday obvious phenomenon into a scientific case that needs an explanation. This was achieved by initially distancing the production of the pitch level of notes from the empirical experimentation on an actual xylophone (case study two) by using a model/image xylophone. Then a shift was made to a poster/flowchart and finally to the written report. A third case involved the problem of how to make scientific function principles of a suggested "technological" development accessible by demonstrating the operation of an innovative model/invention. The fourth problem dealt with how to introduce the human body in scientific terms to a class with everyday knowledge about the subject. This was achieved by moving from the skeleton system as a whole to sub-systems in the human body and from the outward to the inward structure of bones. Finally, the fifth problem was how to make a complex topic, such as the blood system, accessible to the class. The solution in this case was to move from simple to more complex blood systems of living organisms, (i.e. fish-frogs-mammals), mediated by schematic diagrams on overhead transparencies.

The analysis shows that each of the epistemological decisions involved transformation of meanings from medium to medium and implied the use of multiple semiotic resources transformed by the performers' interests, for rhetoric purposes. The processes described not only realized expressions of scientific knowledge they also conveyed pupils' epistemological positioning and what it meant to them to be scientific in the science classroom. The processes included diverse relations, affective and cognitive work of the producer/performer and reactions of pupils in the audience as interpreters.

In the analysis I have shown the different ways pupils deploy functional specialisation, possibilities and limitations of action, speech and visual resources (i.e. gesturally enacting the dynamic property of vibrations, which the image is limited in representing and speech would be inefficient in mediating), to communicate scientific knowledge. At times one of the modes is in the foreground in the combination of modes deployed and at times the rhetorical power lies in the integration of communicative modes. The analysis shows that in presentation events, visual, bodily and action resources are not just illustrations of speech. They are mediums of thought, realize ideational, interpersonal and textual meanings, create involvement and interaction, connect between everyday knowledge and scientific knowledge, bring entities into existence, and are resources for the construction of entities and scientific explanations.

The analysis shows that communicating scientific knowledge in presentation events is a complex rhetorical task. The rhetorical task is even more complex in view of the fact that even though pupils perform for the class, they are bound to a task accomplished indeed for the teacher. This, at least partially, explains the move some of the pupils make between the class and the teacher as two different audiences (i.e. case study two, the move from a monological and canonical written style of interaction to a dialogical and oral style of interaction). The analysis shows that in presentation events pupils not only communicate scientific knowledge and present themselves as science learners they actively participate in the process of constant transformative action of making and remaking the resources of representation and communication both on an individual level and on the public level in science class as a community.

In summary the analysis shows that the use pupils make of resources, interweaving rhetorical means, rhetorical strategies and communicative modes surrounding a chosen experiment or topic result in distinctive characteristics making the rhetorical process of each presentation both similar to and different from others. On the one hand the set of characteristics outlined below, are broad enough to cover the various ways in which pupils rhetorically orchestrate modal ensembles to communicate an experiment or a topic explored presented to the class. On the other hand they are not so broad as to obscure the significant differences expressing individual interests, subjectivities and epistemological positioning.

Characteristics of the rhetorical process of presentation events

The analyses revealed the following characteristics of the rhetorical process of presentation events in the science classroom:

- The presentation is patterned and structured evoking a clear sense of beginning, middle and end of the event, taking place in a defined setting of space and time boundaries. (The average duration of presentation events is 3–6 minutes, comprising 6–7 units of rhetorical framings, unequal in size in terms of intensity of information and time frame).
- The rhetorical process of presentation events points backwards to design processes and provides insights about pupils' reasoning, semiotic choices, epistemological and rhetorical decisions and their understanding of the rhetorical situation of presentation.
- Semiotic resources are used to contemplate solutions for problems of representation and communication of scientific knowledge; to construct entities and explanatory contexts and to establish a basis of knowledge; to produce scientific explanations of phenomena both in the process of design and in the actual presentation.
- Pupils deploy functional specialisation, semiotic possibilities and limitations of each of the modes, action, speech and the visual mode. Each presentation deploys different combinatorial possibilities of functional specialisation of modes and rhetorical devices projecting different interests, subjectivities and epistemological positioning.
- Pupils presenting combine and integrate modes to realize ideational, interpersonal and textual meanings. The relative emphasis on one of the three kinds of meanings depends on the place of a unit in the rhetorical process of the event.
- Each presentation event contributes to the process of making and remaking the resources of representation and communication both on an individual and a public level in science class.
- The teacher's pedagogical framing or loose framing influences the choice of aspects of content, the use of resources and rhetorical strategies and impacts communication and construal of scientific knowledge in presentation events.
- The rhetorical process of presentation reflects how pupils present themselves as learners and what it means to them to be scientific in the science classroom.

The practice of presentation from a pedagogical point of view

Seen from the pupil's perspective the practice of presentation remained open to pupils' interpretation, design and production, since the task of presentation was not actually framed in both science classes observed. Nonetheless, the distinctive pedagogical

framing of the topics and pupils' enquiry work in which the presentation events were embedded in class 1 (i.e. discussed in part II) in contrast to class 2 (discussed in part I of this chapter) influenced the use of rhetorical resources, communication and construal of scientific knowledge. When the teacher established a basis of knowledge on a shared topic in class (i.e. sound) and clearly framed pupils' independent experimentation, the pupils drew on the teacher's framing as semiotic material which they used as resources for explanation of the specific phenomena explored (case study examples one – three). When the teacher loosely framed pupils' enquiry work, theoretical in nature, and did not establish a basis of knowledge on topics explored that were not yet studied at that time in class, pupils presenting focused their rhetorical efforts on the construction of resources for explanation (i.e. the construction of entities and specialised terms) rather than on explanations of complex ideas (i.e. interrelation in organs systems) of their topic. The analysis shows that in the later cases the class as an audience had difficulties in construal and uptake of communicated meanings.

It seems that a number of underlying conceptions, or rather misconceptions from a multimodal and social semiotic view, may have guided the teacher, in a conscious or unconscious fashion, regarding the framing or rather loosely framing of the presentation task. One misconception is that the content and information that texts or events entail is the most significant element in science learning and content is separable from the form and frame within which it is packaged. Focusing on content, not marking the frame and not acknowledging the rhetorical aspect in classroom practices according to Feldman & Kalmar (1996) is a widely shared educational conception. The second misconception is that communicating knowledge to others is unproblematic once you have dealt with the content and constructed knowledge for yourself. This according to de Beaugrande (1997) is a widely shared educational conception. The third misconception, which may have guided the teacher, is that the written text is the real significant means for the expression of scientific knowledge. This may perhaps explain the different ways (i.e. just displaying it, just holding it, introducing sections from the text, reading the whole text aloud) in which the pupils presenting used the written report to ensure they had performed the presentation task correctly.

Despite the misconceptions mentioned and pupils' presenting within a frameless frame, from a pedagogical point of view I consider the practice of presentation very important since it embodies characteristic features of the habitus of school science. It

embodies processes concerned with exploring, experimenting, focusing on an issue or topic, designing, producing a range of artefacts, presenting, engaging in a range of material resources and semiotic modes, demonstrating, developing a topic, engaging in face to face interaction, negotiating meanings, explaining to others. Furthermore presentation is a versatile means of communicating scientific knowledge and it contributes resources pupils can draw upon in writing science. The relation between writing in the science classroom and operating communicative modes in presentation events and related communicative events is the focus of the following chapter.

CHAPTER 6

THE RELATION BETWEEN WRITING AND COMMUNICATIVE EVENTS

> Writing is never merely reproductive; it is always more than expressive; it is an act of transformation, in which the writer transforms the expressive/transformational means; transforms her or his own subjectivity; and therefore transforms the world in which the newly made sign appears.
>
> (Kress, 1995, p. 72)

INTRODUCTION

The purpose of this chapter is to exemplify how the framework proposed in this thesis can be used to address the aspect of writing in the multimodal environment of the science classroom from the pupil's perspective. In particular, this includes the ways in which fifth grade pupils transform resources they draw from communicative events and integrate into their revised exploration reports. In other words this chapter takes up the third research question of this thesis illustrated by two case study examples (i.e. how do pupils integrate resources they draw from presentation events in the production/revision of their exploration report?).

To trace the resources pupils drew from communicative events and integrated into their revised report I will compare the two versions of report, the first version produced prior to the presentation and the second produced following the overall presentation. The analysis is according to the following dimensions: genre, mode and organisation of content with respect to conformity to the task framework. Further I will link the analysis of the written reports to the analysis of sample episodes from the overall presentation that unfolded between the two versions of text. I call related communicative events "the overall presentation", which includes a performer's presentation and a communicative event or a number of events that emerged in response to the presentation. The analysis of sample episodes from the overall presentation is from the aspect of mode considered also in metafunctional terms. The framework for analysis of data in this chapter has been discussed in detail in the methodology chapter.

The pupils were to select and independently explore a system in the human body which was not yet studied at that time in class. The teacher set headings for the written exploration report to be handed in for her review prior to the presentation to the class as follows: (a) The structure of the explored system; (b) The function of the system; (c) The relation between structure and function; (d) The relations among elements within the

system; (e) The reciprocal relations between the system and other systems in the human body.

Following the presentation pupils were encouraged by the teacher to revise their written report if she deemed necessary.

CASE STUDY EXAMPLES

CASE STUDY EXAMPLE ONE

Jordan's overall presentation consisted of three related communicative events. The first event was Jordan's presentation discussed in detail in the previous chapter. The second was an unplanned reflective event initiated and led by the teacher in response to Jordan's presentation. The last event was an additional unplanned performance of Jordan, encouraged by the teacher and recommended by the class.

As expected, Jordan produced a written text prior to her presentation on the system she explored, "skeleton and motion". The text, translated from Hebrew to English, text no. one, is presented in figure 23. She also produced a second version of the text under the same heading, which she revised following the overall presentation as suggested by the teacher. The translated text, text no. two, is presented in figure 24.

Analysis of the Texts Produced Prior and Following the Presentation

A quick comparative overview of Jordan's two written texts, presented in figure 23 and 24 reveal that the texts differ remarkably. (Jordan marked the elements integrated from her first written text, figure 23, in the revised text with two asterisks as depicted in figure 24.) This is immediately apparent both because of the length and the spatial organization of the texts. A deeper review reveals that in the revised text Jordan deployed a wider range of resources to express scientific knowledge. This resulted in an organized text, which elaborates on the topic in more explicit scientific terms and considers complex relations in the organ system explored which were absent in text one. To trace the difference of the resources Jordan drew upon and transformed into the revised text in comparison to the first version of the text I will first analyze each of the texts she produced.

Skeleton and motion

1. An adult human being has 206 bones in his body. When a baby is born he has 300 bones in his body. There are 656 muscles in our body, which is more than the number of bones.
2. There are organs, which need more protection than other organs: the brain, for example, is protected in the skull and the spinal chord is protected in the spinal column. The heart, the lungs, the liver and the intestine are all sensitive organs and therefore they are protected by the ribs, the pelvis and the spinal column.
3. The reciprocal-relation between the system of skeleton and motion and other systems are: the organs which are protected by the skeleton the brain and more...
   (They are listed above)

Figure 23. Text one "Skeleton and motion" (translation of original text)

ANALYSIS OF TEXT ONE "SKELETON AND MOTION"

This is a short written text organised in one unit (i.e. the original text in Hebrew) under the heading *Skeleton and motion.* The generic structure of text one comprises three parts and unfolds as presented in table 10 (for the convenience of analysis I reorganised and marked the translated text in three sections as presented in figure 23, according to my interpretation of the generic structure and Jordan's attempt to adhere to the headings set by the teacher).

Table 10. The generic structure of text one presented in Figure 23.

Part one	Part two	Part three
Contrast	> General statement + explanation	> General statement/conclusion

The first part of the text is structured as a contrast. It contrasts the number of bones in a grown up human body (206) versus the number of bones in a newborn's body (300). It proceeds with another contrast between the number of muscles and bones in the human body: *There are 656 muscles in our body, which is more than the number of bones.*

The second part provides a general statement on a function of the skeleton followed by exemplifications and an explanation:

> *There are organs which need more protection than other organs the brain for example is protected in the skull...*

The last part provides a general statement on reciprocal relations. This part can be seen as the conclusion of the piece as it is explicitly linked to the content of the second part:

The reciprocal-relations between the system of skeleton and motion and other systems are: the organs which are protected by the skeleton the brain and more... (They are listed above).

In the production of this text Jordan has taken up some conventions of the genre, which collectively are called a "report" (Halliday & Martin, 1993, p. 187). Reports are about what things in the experiential world are like. The function of the report genre is to describe things in general terms rather than to explain why things are as they are, though explanations can form a part of the meaning of the overall text (Martin, 1989). According to Halliday & Martin reports are a common genre in school science textbooks. Reports share a number of distinctive linguistic features: generic participants, timeless verbs in the present tense and a large percentage of being and having clauses. These features are evident in text one in the use Jordan made of language resources to express scientific knowledge as general and objective facts. This is achieved by the use of the present tense across the text i.e. *when a baby is born he has*; by the use of having and being clauses i.e. *There are organs which need more protection*; and by generic participants i.e. *An adult human being, a baby, organs, our body.*

As for conformity to the headings demanded by the teacher, the organisation of content in this text can be seen as comprising three parts, summarized in table 11. Part one deals with structural features, (i.e. the number of bones and muscles), which conforms to heading A though it covers the heading partially. Part two deals with a function of the skeleton (i.e. protection of sensitive organs) this conforms to heading B, which is also covered partially. Part three conforms to heading E (i.e. reciprocal relationships between the system of skeleton and other systems), although the idea of reciprocal relations is not elaborated. Instead the idea is exemplified by the function of the skeleton already introduced in the previous part, namely the protection of sensitive organs. In this text Jordan did not deal with the interrelations and interconnectedness between structure and function (heading C) and among elements within the system (heading D) as demanded by the task framework.

Although short and incomplete the organization of content in text one indicates Jordan's attempt to adhere to the headings demanded by the task framework. However, as Jordan provided information sparsely and did not cover the set of headings demanded, the teacher suggested Jordan revise her text in accordance with the headings.

Table 11. Organisation of content in text one – "Skeleton and Motion"

Text structure	Content	Conformity to headings
Part one	The number of bones and muscles in the human body	A- The structure of the system
Part two	The skeleton protects sensitive organs	B- The function of the system
Part three	Reciprocal relations between the system and other systems by the protection of organs	E- Reciprocal relations between the system and other systems in the human body

ANALYSIS OF TEXT TWO "SKELETON AND MOTION"

In comparison to text one this is a lengthy text (consider figure 24) under the same title *Skeleton and motion* organised into six parts under sub-headings. There are five parts under the following subheadings: *Form and function, the skull, description of the skeleton, the number of bones and muscles in our body, reciprocal relations between systems*. The subheading of the last part combines writing and an image as follows: *a suggestion: it is worthwhile to build a model and its shape...* The completion of the heading is represented visually, by a schematic drawing of the suggested model. The image represents a kind of interactive model exemplifying the function of the muscles in the act of breathing.

The generic structure of text two unfolds as presented in table 12. The text begins with a general statement, which classifies the skeleton system as a whole: *The skeleton is a system of bones*; it further classifies the skeleton under three categories: *The human body is constructed from the skull to the tiptoes from the following types of bones: Flat bones, long bones, short bones;* then it specifies the functions of the skeleton: *It holds the body and gives it posture and protects it.*

Table 12. The generic structure of text two presented in figure 24

Part one	Part two	Part three	Part four	Part five	Part six
Classification	> Description + explanation	> General statements + description	> Specification + explanation	> General statement + explanation	> Instructions

Part two provides a description of the skull's structure and an explanation of the relations between its structure and function:

> *The skull is constructed of joints...The skull bones are flat and round like and therefore the skull has support (by an arch). If the skull was a flat surface it would have been very easy to break it, and then the brain would be hurt... And so you can see the connection between the skull's structure and function.*

Skeleton and motion

Form and function

The skeleton is a system of bones, which functions like any other system in our body, at day and at night – when we sleep. It holds the body and gives it posture and protects it. For example: I sleep on my stomach and in the morning I wake up on my back.

The human body is constructed from the skull to the tiptoes from the following types of bones: Flat bones, long bones, short bones.

The skull

The skull is constructed of joints, between which there are thin threads called stitches. The joints have an important function in our body which is to support the skull and to protect the brain from any injury. The skull bones are flat and round-like and therefore the skull has support (by an arch). If the skull was a flat surface it would have been very easy to break it, and then the brain would be hurt. But because it is arch shaped it is hard to press against it. And so you see the connection between the skull's structure and function.

Description of the skeleton

The skeleton has an important function which gives support to the body. Its second function is the protection of organs. *There are organs which need more protection than others. The brain for example is protected in the skull, and the spinal chord is protected in the spinal column. The heart, the lungs, the liver and the intestine are all sensitive organs, and therefore they are protected by the ribs, the pelvis and the spinal column. The spinal column that connects the skull to the pelvis is like a bridge that connects places. It connects the parts of the body. Its bones are not flat, they are called vertebrae. The spinal column is strong and so it can hold us and support our body. If we would not have cooperation between the body systems (the bones system) the spinal column could not support our body.

Between the vertebrae of the spinal column there is cartilage, muscle and tendons, which enable us to move from one place to another, or enable us to bend and stretch. The spinal column protects the spinal chord.

The sternum, the ribs and the pelvis protect the sensitive organs. The ribs are made of strips connected by cartilage, which allow the ribs motion ability and flexibility.

The upper limbs, the hands, and the lower limbs, the legs, are connected to our body with curved joints, which allow the limbs to rotate and move.

The number of bones and muscles in our body

**An adult human being has 206 bones in his body. When a baby is born he has 300 bones in his body. The number of muscles in our body is 656, which are more than the number of bones.

A baby has more bones than an adult because the bones connect. In the palm and feet there are many bones but the bones are small, which enable more motion than bigger bones (see skeleton map). And so you can see the relation between the form and function.

Reciprocal relations between systems

Between the skeleton and motion system there are reciprocal relations. For example, the muscle system – as the body cannot move by itself without the muscles.

The system of muscles and the bones are connected to the nerves and the nerves connect them to the brain. The skeleton and motion system connects between systems by protecting sensitive organs such as the heart, the lungs, the intestine, the stomach, and the liver...

The ribs and the muscles have a function in the breathing system, which is to move the ribs by their expansion and contraction when we breathe.

A suggestion: it is worthwhile to build a model and its shape: (diagram of a model)

Its components: two – three straws, two balloons and a sheet of paper.

How does it work?

When you blow into the main straw (the one marked in red) the balloons are blown and the paper is stretched, when they are emptied, the paper shrinks back.

Figure 24. Text two "Skeleton and motion" (translation of original text)

Part three begins with a general statement on the functions of the skeleton: *The skeleton has an important function which gives support to the body its second function is the protection of organs.* Then the relation between structure and function is exemplified i.e., *the ribs are made of strips connected by cartilage, which allow the ribs motion ability and flexibility.*

Part four specifies the number of bones and muscles in the human body and exemplifies the relation between structure and function. It also provides an explanation regarding the differing number of bones in a baby's body versus an adult i.e. *a baby has more bones than an adult because the bones connect.*

Part five begins with a general statement followed by an explanation on the idea of reciprocal relations: *Between the skeleton and motion system there are reciprocal relations for example, the muscle system- as the body cannot move by itself without the muscles.* Then other general statements discuss reciprocal relations i.e., *the system of muscles and the bones are connected to the nerves and the nerves connect them to the brain.*

The last part provides instructions on how to construct and manipulate a suggested interactive model i.e., *it is worthwhile to build a model...when you blow into the main straw.* This form of text often appears in school science textbooks before or following different types of text to motivate pupils' activity. Here the reader/pupil is directly addressed although the teacher was the ultimate reader of the text.

With respect to conformity with the task framework, text two covers the set of headings demanded from A – E, summarised in table 13, though not organised in the same sequence as proposed by the teacher. In addition the sub-headings are not all formulated as the headings suggested by the teacher. Although the content of the last part of text two is outside the task framework (i.e. instructions for the interactive model) it relates to heading E as it provides a concrete exemplification of the interrelations between the muscles and ribs in the act of breathing.

In summary, in the production of text two, like in text one, Jordan has taken up some generic conventions of the report genre and yet the two texts differ remarkably as summarised in the following six points. These indicate of the wider range of resources Jordan deployed in the production of text two in comparison to text one.

1. The starting point – text one starts with details of structural features of the skeleton and the muscles whereas text two starts with general statements that classify and

specify the skeleton system. This better orients the reader in relation to the topic than text one.

2. Organization – The structure of text two that breaks down into parts under sub-headings highlights the internal organization of the text. In addition, the general statements at the opening of each part of text two orient the reader in relation to the development of the topic. In comparison, the shift to new ideas in text one is not explicitly marked.

Table 13. Organisation of content in text two – "skeleton and motion"

Text structure	Sub-heading	Content	Conformity to headings
Part one	Form and Function	The skeleton comprises different types of bones	A – The structure of the system
Part two	The skull	The skull's structure & function	C- Relation between structure and function
Part three	Description of the skeleton	The functions of the skeleton Relations between elements	B – Function of the system D – Relations between elements in the system
Part four	The number of bones and muscles in our body	Structural features Relation between structure and function (i.e. in the palm and feet)	A – the structure of the system C- relations between structure and function
Part five	Reciprocal relations between systems	Connection of skeleton and muscles to nerves and brain	E – Relations between the system and other systems
Part six	A suggestion: it is worthwhile to build a model and its shape…	Instructions for the model	Outside the task framework but related to heading E

3. Expansion of knowledge in explicit scientific terms – in comparison to text one Jordan expands on the topic in text two in explicit scientific terms by introduction of new information, entities, terms of description and explicating complex ideas, which indicate of a deeper understanding of the topic. Text two not only adds new entities (i.e. system, motion system) and informative details on structural and functional features of the skeleton and the muscles it also deals with interrelations and interconnectedness between organs within the system and between systems. The interrelations the text deals with include: between structure and function of specific organs, for example, *the ribs are made of strips connected by cartilage, which allow the ribs motion ability and flexibility*; between the skeleton system and the muscles system, *between the skeleton and motion system there are reciprocal relations. For*

example, the muscle system – as the body cannot move by itself without the muscles; and between the skeleton and muscle system and other systems, *the system of muscles and the bones are connected to the nerves and the nerves connect them to the brain.*

4. Generalisations – In text two she uses generalisations which better position the reader in relation to scientific knowledge on the topic. For instance in text two she generalises about the function of the skeleton: *The skeleton has an important function which gives support to the body. Its second function is...* By contrast, in text one she detailed a number of protected organs without generalising about the skeleton's function: *The heart the lungs the liver and the intestine are all sensitive organs and therefore they are protected by...*
5. Mode – In the last part of text two Jordan combined written and visual elements to realize meanings, whereas text one is entirely in the written mode.
6. Conformity to headings – Text two better covers the set of headings demanded (A-E). Text one covers the headings sparsely and partially (A, B and E).

One of the ways to understand the differences pointed out is to trace the resources Jordan could potentially draw from the communicative events that unfolded between the productions of the two versions of text. Therefore I will analyse selected episodes from the communicative events following Jordan's presentation with reference to the analysis of her presentation in the previous chapter and both her texts. Before embarking on the analysis below I would like to note that on the basis of my observations it seemed to me that the great difference in the use of writing as a modal resource in the two versions of text can be explained at least partially, due to Jordan's major concern with presenting a good presentation to the class. Therefore she may have put great effort and spent long periods of time in the production of the different artefacts and the overall design of her presentation. Although this might provide a part of the explanation, from a semiotic point of view and from a pedagogical point of view, it is significant to trace the resources she drew upon and integrated in text two in comparison to text one.

MULTIMODAL ANALYSIS OF EPISODES IN THE OVERALL PRESENTATION

TALKING SCIENCE

Following Jordan's presentation, discussed in the previous chapter, the teacher led Jordan and the class to "talk science" (Lemke, 1990; Mortimer & Scott, 2000, 2003) by reflecting on her presentation event. Learning to reflect, according to Short and Burke

(1991) is learning to "stand both inside and outside of an event at the same time" (p. 21). It is realizing that one can look at an event from one's own perspective and from that of someone else's, which increases one's awareness of learning. Returning to Jordan's case, to illustrate the role of talking science in the extension of semiotic matter, which Jordan could potentially draw upon and transform into her revised text, I will consider five excerpts from the event of reflection led by the teacher.

Excerpt one – reframing Jordan's topic

Teacher: *Our topic is systems in the human body. First, what is the system she dealt with?*

Pupil: *the skeleton system.*

Teacher: *the skeleton and motion system.*

Excerpt two – re-examining semiotic objects in terms of a system

Teacher: *Jordan used three different means, the map, the model of drinking straws and the transparencies... Has reference been made to system characteristics by the three means presented by Jordan? Okay, let's think together. What is represented here?* (Lifting the poster and pointing to the skeleton map)

Pupil 2: *the skeleton.*

Teacher: *is there reference to a system?*

Pupil 3: *yes.*

Teacher: *prove that it is a system.*

Pupil 5: *It is a system because it is comprised of parts, which are linked to each other.*

The excerpts above illustrate how through speech the teacher reshaped Jordan's multimodal presentation. By talking science the teacher reframed Jordan's topic in the wider framing in science class; she specified her topic in terms of a system; and made the notion "system" explicit, which was implicit in Jordan's presentation and not expressed in text one. This generated semiotic matter Jordan could draw upon and reshape into writing as evident in the way she classified and specified the skeleton in terms of a system in text two i.e. *the skeleton is a system of bones, which functions like any other system in our body...*

The teacher also challenged the class to re-examine the meanings carried by the semiotic objects Jordan used as rhetorical means. She challenged them to reconsider also the objects that represent only elements in the human body, in terms of interrelations of a

system (i.e., the simple model of drinking straws and the diagrams of bones), as exemplified in excerpt three.

Excerpt three – re-examining sub-systems according to criteria of a system

Teacher: *...The transparencies presented diagrams of bones* (for a moment she displays a transparency on the overhead projector). *There was reference here to the structure of the bone, the function, the growth of the bone etc., was there reference to a system?*

Pupil 6: *yes, there was reference to the system of bones because she said; she explained what constitutes the system of bones and how it functions.*

Teacher: *but on the transparencies she referred to a single bone.*

Pupil 6: *yes, but she referred to one bone and how it helps the other bones in the system.*

Teacher: *can a bone also be considered in terms of a system? This is in fact my question. Please.*

Pupil 3: *a bone is also a system, it contains muscles and blood vessels and tendons and bones are also linked to each other.*

At a certain point, the teacher talked directly to Jordan declaring explicitly that the general notion under discussion, the system and an organizing principle, i.e. the move from the system as a whole to sub-systems, are in fact embedded within her presentation, even if not clearly manifested, as illustrated in excerpt four.

Excerpt four – revealing an organising principle

Teacher: *Even if on the surface it seems as if there was no explicit reference to system characteristics* (Looking at Jordan) *you did work on system traits. You started with the system as a whole...* (The teacher lifts the poster-map) *then you shifted to a sub-system* (she lifts the simple model) *and then you shifted to another sub-system...* (She lifts the transparencies with schematic diagrams of bones).

Revealing an organizing principle and reconstruction of Jordan's presentation event may have contributed to the resources she deployed to better organize her revised text. Furthermore the teacher challenged Jordan to reconsider the semiotic objects she used from the aspect of interrelations between systems in the human body exemplified in excerpt five.

Excerpt five – revealing reciprocal relationships

Teacher: *This question is directed to you Jordan. Did you refer in your presentation to reciprocal relations between systems?*

Jordan: *yes, I did refer to it.*

Teacher: *where?*

Jordan: *in the system as a whole, I referred to the skeleton and motion system. I talked about the bones and the muscles.*

Returning to Jordan's reports, text one provides a general statement on reciprocal relations but the idea is not explicated and elaborated. In contrast, text two explicitly deals with the phenomenon of reciprocal relations. She even allocated a section in the text (part 5) for that idea:

> *Reciprocal relations between systems*
>
> *Between the skeleton and motion system there are reciprocal relations. For example, the muscle system – as the body cannot move by itself without the muscles. The system of muscles and the bones are connected to the nerves and the nerves connect them to the brain...*

It is noteworthy that the teacher reconsidered only three of the four semiotic objects Jordan used as rhetorical means in her presentation. It seems that the teacher considered the semiotic objects as didactic means, and she did not include the written report Jordan introduced in her presentation under this category.

In summary, the discussion and the integrated excerpts illustrate how through talking science the teacher and the class transformed and reshaped Jordan's multimodal presentation event into spoken ideas, using explicit scientific terms to reconstruct scientific knowledge and clarify central notions of her topic. With respect to the research question this chapter attempts to answer, in a sense the process of reshaping Jordan's multimodal performance into spoken ideas provided a kind of spoken "draft" Jordan could draw from in reshaping the ideas into the written mode in her revised text. It is noteworthy that the teacher did not add new information on Jordan's topic. She rather guided Jordan and the class to make connections between known facts and to explicate interrelations in explicit scientific terms (i.e. system, sub-system, function, structure, reciprocal relations). This most obviously contributed to the resources Jordan could draw upon and transform into her revised text in the written mode.

However, it was not the teacher alone who contributed to the extension of semiotic matter Jordan could transform from talking science into writing science. It is also the interactive construction of scientific knowledge in class led by Jordan, with the teacher's support, through action and talk surrounding the skeleton model.

ACTION AND TALK SUROUNDING THE SKELETON MODEL

Following a short recess Jordan was offered a second opportunity to introduce the skeleton by means of the skeleton model. It was encouraged by the teacher and recommended by the class as an alternative to the small sized poster-map she had used in her presentation. Although unplanned, a lengthy (about ten minutes) interactive event emerged in response to the pupils' recommendation.

Mediating meanings by action and speech

Using speech, pointing and tracing gestures Jordan mediated the skeleton structure and function beginning at the top, from the crown of the head to the toes:

> *I will explain about the skeleton and motion and I will explain where everything is. Here is the skull, which protects the brain... These are the spherical joints they are called this because they are curved joints...*

At a certain point one of the pupils interrupted Jordan's monologue with a question, to which she responded promptly:

Pupil 1: *What is the function of the spinal column? How is it related to the other parts?*

Jordan: *The spinal column supports the body, it supports the skull, which protects the brain, it supports the chest, which protects the lungs, it connects the skull to the pelvis, and it holds and supports the body...*

For illustration purposes I consider the above-cited moves with reference to Jordan's texts. In text one Jordan referred briefly to the spinal column as follows: *the spinal chord is protected in the spinal column,* whereas in text two she extended the information and elaborated on the relations between structure and function of the spinal column and the interconnectedness between the skeleton and the body as a whole:

> *The spinal column that connects the skull to the pelvis is like a bridge that connects places. It connects the parts of the body... The spinal column is strong and so it can hold us and support the body. Between the vertebrae of the spinal column there is cartilage, muscle and tendons, which enable us to move from one place to another...*

I am not suggesting that dealing with interrelations in the human body in her revised text was a straightforward process following the interaction in class. Nonetheless, with respect to the research question taken up in this chapter, it is significant to consider what might have potentially contributed to Jordan's use of a wider range of resources to realise scientific knowledge in writing.

It seems that Jordan's willingness to promptly answer the first pupil's question was perceived by other pupils as an invitation to ask her questions as well. She could have responded differently, such as overlooking or rejecting the question or delaying the answer. However the two moves, cited above, marked a shift in the style of interaction. There was a shift from a monologic style of interaction to a dialogic style. It marked the start of an interaction, which emerged in the form of pupils' questions and Jordan's responses. Twelve different pupils took an active part in the interaction, by initiating nineteen different questions. This type of participation structure was quite unusual in the teacher's lessons. It should be noted that eighteen questions were derived from or related to the headings set by the teacher. Some of the questions were purely factual and simply answered by Jordan while some other questions were general or an invited explanation of interrelations in the human body.

For illustration purposes I will consider two sample questions, which invited scientific explanations, demonstrating the function of the body, action and speech as resources Jordan could draw upon and transform into the revised text.

Example one:

Pupil 3: *What is the difference between the joints of the legs and the joints of the upper limbs, the arms?*

Consider Jordan's response to the question in figure 25. To answer the question Jordan used bodily resources, the model, action on and with the model and speech, at times in integration and at other times consecutively. By swinging her right arm again and again she demonstrated a full circular motion, which was enabled due to the spherical structure of the joints. In contrast, she demonstrated how the structure of the joint in the elbow (in Hebrew, the term is axis joint) enables only bending and straightening movements, which she also demonstrated on the model's arm. This she could represent by means of the model only in a limited way, i.e. the distinctive function of two different kinds of joints, she demonstrated by dynamic motion through action with her body.

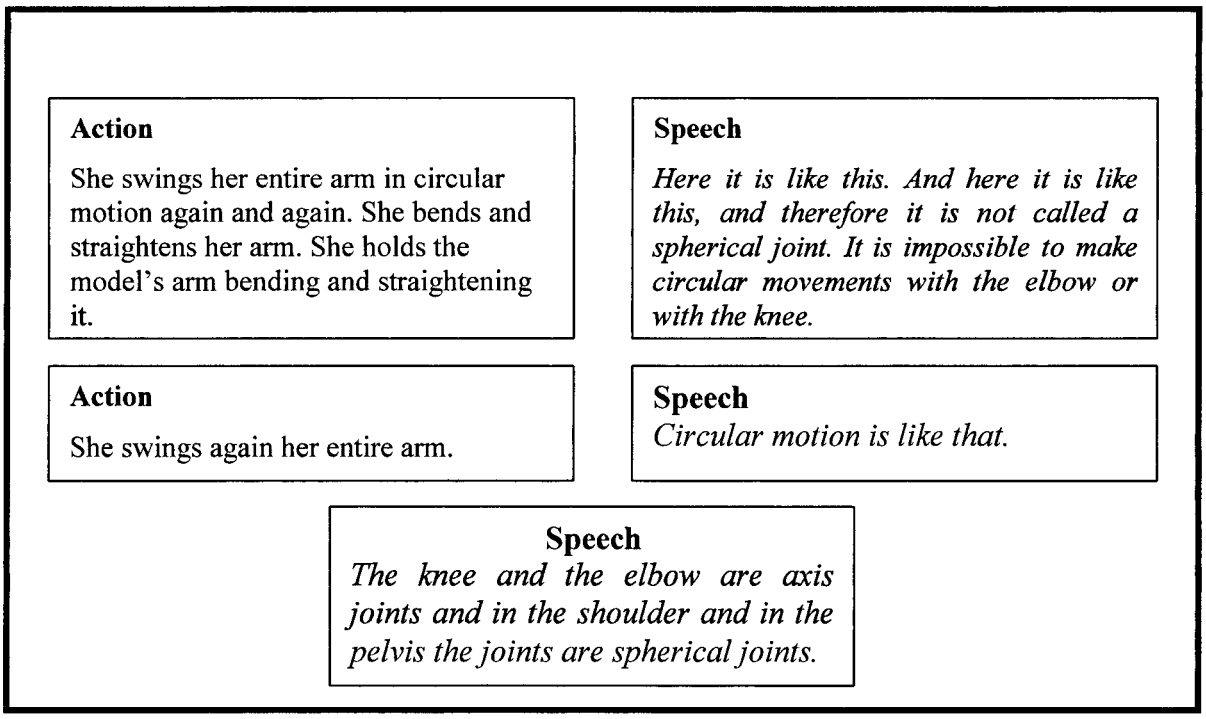


Figure 25. The differing role of action and speech in explaining the distinctive structure and function of joints

The resources, which constitute the model skeleton, provide different semiotic potential, possibilities and constraints, than the two-dimensional poster-map Jordan used in her first performance. On the one hand, the 3D model enabled pupils to view the kinds and the proportions of bones in the human body, i.e. which is invisible in the living body or not possible to sense on the map. On the other hand, Jordan acted with her own body to represent dynamic motion and functions, which both the solid and static model and the schematic map are limited in representing. Through action with her body and the model she demonstrated the distinction between the functions of the two kinds of joints. Finally she used speech to name the different joints, using the specialized terms, namely spherical and axis joints. That is, she used the different functional specialisation of action and speech, to represent and communicate different aspects of phenomena in the human body.

For illustration purposes I will again consider Jordan's texts. In her first text the idea of motion in the human body and how organs are interconnected is not expressed, whereas at different points in her revised text, she explicitly deals with interconnections and motion in the human body, which is central in the system she explored. For example, she explicitly considers the function of the spherical joints, which she also demonstrated by action with her body in response to the question cited above, as follows: *The upper limbs, the hands, and the lower limbs, the legs, are connected to our body with spherical joints, which allow the limbs to rotate and move.*

Example two:

Further in the discussion one of the pupils left her seat and approached the model. While pointing and holding the model's arm and palm she raised a question, which also invited an explanation:

Pupil 7: *Here is a big bone and here are many small ones, why?*

Consider Jordan's response to the question in figure 26.

Action	**Speech**
She holds the palm of the model in her hands; she moves her fingers in her own palm, small and gentle movements.	*Let's say, if it were one bone only, if it were not divided into small bones, you could not move your hand. It is like a soccer team. If one player is missing, for instance the goalkeeper, is it possible to play? It is not possible, you need him.*
Action	**Speech**
She moves her whole body. She bends down. She makes a stiff and upright position of the body.	*It is like in the spinal column, like the model of the drinking straws I showed you. If there were no vertebrae and only one upright bone you could not move.*

Figure 26. The role of action and speech in explaining the distinctive structure and function of different types of bones

Jordan explained the distinction of the structure and function of bones through action with her body in integration with the model and speech. She shifted from the model to her own body back and forth, as complementary actions. She demonstrated the function of small bones by moving the model's palm fingers and her or own fingers (consider figure 27) in combination with speech, not articulating every demonstrated movement. Here again, she exploited the functional specialisation, the meaning potential of each of the semiotic resources, which she used in combination, as complementary.

For illustration purposes consider the following excerpt from text two, which carries traces of the interaction in class: *In the palm and feet there are many bones but the bones are small, which enable more motion than bigger bones. And so you can see the relation between form and function.*

Figure 27. Demonstration of the distinctive structure and function of different types of bones

In text one Jordan provided informative details on the number of bones in the human body but in text two she both extended the information and explicitly dealt with the idea of interrelations as exemplified above, between the structure and function of different bones in the human body.

In summary, in light of the discussion around the examples from Jordan's overall presentation, in the present chapter and in the previous chapter, I suggest the following set of factors as potentially contributing semiotic matter Jordan could draw from and transform into the written mode in her revised text and thus provide a possible answer to the research question taken up in this chapter.

- The role of transformation of Jordan's multimodal presentation into spoken ideas led by the teacher in the reflective event; talking science; reorganizing and reconstructing scientific knowledge in explicit scientific terms.
- The role of action and bodily resources as a medium for thinking and construction of scientific knowledge i.e. in the construction of the explanation of the distinctive function of joints in the human body.
- The communicative power and semiotic potential of bodily and action resources as complementary with the resources that constitute semiotic objects such as those Jordan used (model, map, diagrams, written text) with a strong coupling of materiality, and the conjunction of doing and meaning.
- The role of the interactive construction of knowledge on the social plane in the form of questions and responses.
- The kind of questions the teacher directed to Jordan concerning complex key notions (i.e. system characteristics, reciprocal relations) and the kind of questions pupils posed deriving from or relating to the headings demanded in the task framework and generating scientific explanations.

CASE STUDY EXAMPLE TWO

Leah's overall presentation comprised two related communicative events. The first event was her presentation discussed in detail in chapter five. The second was an additional communicative event, which she initiated and performed a week following her presentation. As expected Leah produced a written text on the system she explored "the blood system" which she handed in for the teacher's review. This text, text no. one, is particularly lengthy therefore I present only a part of the text, translated from Hebrew, in figure 28. Following the overall presentation Leah produced a second version of her text,

text no. two, which combines written and visual elements and the written element, is remarkably reduced in comparison to text one. A part of the written element of text two, translated from Hebrew, is presented in figure 29 and samples of the visual elements are presented in figure 30.

From a pedagogical point of view this case interested me because it differs remarkably from Jordan's case. Unlike Jordan Leah initiated the additional communicative event following her presentation and she also initiated the production of the second version of her exploration report although the teacher did not propose it. To trace and understand the difference in the resources she deployed and transformed in the two versions of text I will first analyze each of the texts she produced. This is followed by analysis of operating modes in episodes from the communicative event she initiated with reference to her presentation event and the texts she produced.

The blood system
It is well known that the blood seems like a red colour solution and it tends to congeal when we get injured, but the blood is not as simple as it seems to be. The blood in our body entails a lot of tiny bodies, which are cells of different kinds, which can be seen only through the microscope.

1. The structure of the system
The blood system consists of three constituents
a. The blood tissue
b. The blood vessels
c. The heart.

A. The blood tissue
The blood is called tissue because it consists of groups of cells, which have a similar and a common function. There are different tissues in our body such as the muscle tissue or the bone tissue but the blood tissue is exceptional because its cells are not tight but scattered in a watery solution. The blood in our body consists of red blood cells, white blood cells and water. The blood cells can be seen only through the microscope. The red blood cells are thousand times more than the white blood cells and therefore the blood gets its red colour. The role of the red blood cells is to lead oxygen from the lungs all over the body. Each red blood cell has a special red matter called haemoglobin. The haemoglobin links the oxygen from the lungs and so it gets all over the body. A part of the CO2 emitted from the cells in the body is linked to the haemoglobin instead of the oxygen and so it goes back in the blood out of the lungs when we exhale. The blood also entails white blood cells. Their role is to fight germs and viruses, which attack our body and cause illness. The blood cells are very busy and are in motion all the time therefore their life is short and new cells are created all the time in our body. The blood also entails water, which is very important because the blood cells are scattered in the water and so they can move from place to place in our body. The different nutrition materials dissolve in the water and so they get all over the body through the blood.

Figure 28. A part of text no. one "The blood system" (translation of original text)

ANALYSIS OF TEXT ONE "THE BLOOD SYSTEM"

In the production of text one Leah drew upon a chapter in a high level textbook under the title "The blood system" (comprising 17 pages). From the aspect of genre Leah's text is structured as a large report broken down by headings and subheadings into parts. The text comprises a short introduction and four parts, two of the parts broken down into sections by sub-headings. Each part in the text starts with a general statement, such as a classification, a definition, specification, or a general statement on the structure or the function of the system or elements in the system followed by descriptions at times by exemplifications and explanations. This is unlike the source text, which comprises mixed generic structures including: instructions, segments of reports, historical recounts (i.e. about relevant inventors and inventions) and sections of journalistic writing (i.e. about health matters). Since Leah's text is particularly lengthy I will exemplify the analysis by referring to only part of her text as presented in figure 28. This can illustrate how she used generic conventions as a resource to repackage scientific content from the source text in the text she produced. The generic structure unfolds as presented in table 14.

Table 14. The generic structure of the text presented in figure 28.

Part one	Part two	Part three	Part four	Part five	Part six
Introduction>	Classification >	Definition>	Exemplification>	Classification>	Description+ explanation

The text begins with the following introduction:

> *It is well known that the blood seems like a red colour solution and it tends to congeal when we get injured, but the blood is not as simple as it seems to be. The blood in our body entails a lot of tiny bodies, which are cells of different kinds, which can be seen only through the microscope.*

Leah's introduction is a transformation in a reduced manner of a section in the introduction in the source text. It juxtaposes common everyday knowledge on the blood and scientific knowledge, where the text aims to take the reader.

This is followed by classification of the blood system into three constituents: *The blood system consists of three constituents: the blood tissue, the blood vessels, and the heart.* Then a definition follows: *the blood is called tissue because it entails groups of cells, which have a similar and a common function.* The term "tissue" is then exemplified and elaborated as follows: *There are different tissues in our body such as... but the blood tissue is exceptional because its cells are not tight but scattered in a watery solution.* This

is followed by classification of the blood constituents: *The blood in our body consists of red blood cells, white blood cells and water.* Then the function of the blood constituents is specified i.e. *the role of the red blood cells is to lead oxygen...* This is followed by description: *The blood cells are very busy and are in motion all the time.* Further the description is followed by an explanation i.e., *the blood also entails water, which is very important because the blood cells are scattered in the water and so they can move from place to place in our body.*

Leah did not import the generic structure from the source text that consists of mixed generic structures. She selected content elements from the source text, which she transformed and repackaged into a report. She expressed scientific knowledge as objective general facts by using the present tense i.e. *the arteries are the pipes that lead the blood from the heart*; generic participants and a high degree of specialized terms (i.e. *blood tissue, haemoglobin, hormones, muscle tissue, valves, chamber, atrium, vaccination, immune system, antibodies*). She integrated terms, which were marked orthographically by bold fonts in the source text. Marking terms orthographically, mainly those terms, which appeared the first time in the text signals that they are given a field-specific meaning. When terms are given specialized field-specific meanings they become specialized terms or what Halliday calls "technical terms" (1993, p. 144).

It seems that Leah, like Jordan, has taken up some conventions of the report genre expected implicitly by the teacher. This can be inferred from the range of handout material the teacher designed and provided to pupils, which included mainly texts in the form of reports rather than mixed generic structures.

With respect to conformity to the task framework, Leah transformed content elements she selected from the source text in an attempt to adhere to the headings demanded, as summarized in table 15. She dealt in great detail with the structure of the blood system (i.e. heading A) and the functions of the system leading materials and protecting the body from germs and diseases (i.e. heading B). She also explicitly used these headings as subheadings in her text. In an implicit manner she also dealt with the relations between structure and function of certain elements in the system (i.e. heading C) though she did not explicitly express the idea in terms of interrelations, for example:

> *There is a difference between the thick blood vessels...and narrow blood vessels. Thick blood vessels lead the blood in speed and narrow blood vessels delay the flow of blood...*

Guided by her interest and influenced by the source text she also included in her report the last section from the source text concerning the blood system of other living organisms, which was outside the task framework and topic in class.

Although Leah did not fully cover the set of headings demanded and she included a section, which is outside the task framework and topic in class, the teacher did not propose to revise her text. It seems that the teacher took into consideration the serious effort and work Leah invested in the production of a particular lengthy, elaborate and coherently organized written report. A type of written text expected inexplicitly by the teacher. Nevertheless, Leah initiated and produced a second version of her exploration report. Following the overall presentation she must have realized that her written report was incomplete.

Table 15. Organization of content in text one – "the blood system"

Text structure	**Text headings and subheadings**	**Content**	**Conformity to headings**
Introduction	The blood system	The blood is not simple as it seems	A (structure)
Part one, a.	The structure of the system. a. The blood tissue	Constituents of blood tissue, function and relations between structure and function	A (structure) + B (function) + C (relations between structure and function)
Part one, b.	b. The blood vessels	Structure and function of blood vessels (arteries, veins, capillaries) and relations between structure and function	A + B + C
Part one, c.	c. The heart	Structure, function and relations between structure and function	A + B + C
Part two	The function of the blood system	Leading (oxygen, nutrition, water disposal, heath, exchange of gases)	B
Part three	Vaccination and the general immune system of the body	The function of white blood cells	B
Part four	And what is happening with other living organisms?	Structure and function of the heart and blood system of living organisms	Outside the task framework

The blood system

1. Reciprocal relations!

A. Reciprocal relations between the constituents of the system
There are reciprocal relations between the constituents comprising the blood system. There are three constituents the heart, the blood vessels and the blood tissue.
The heart pumps and pushes the blood, the blood vessels help to transfer the blood and the blood tissue contains the essential materials (nutrition, oxygen, water, disposal, heat) lead through the blood vessels to each organ and place in the body.
"The heart" - This is the organ that works as "a blood pump". It is in fact a special muscle which works ceaseless like a pump all life long. It contracts and expands in a steady pace and so it pumps blood from the body and then it pushes the blood to the body in a closed cycle. The heart is also a system in itself, which is comprised of two parts separated by a muscle partition into "the left pump" and "the right pump". In the left side of the heart flows artery blood rich with oxygen and in the right side vein blood with CO_2.

B. Reciprocal relations between the system and other systems
There are reciprocal relations between the blood system and other systems in the body:
"The brain" – the brain and the blood system work in cooperation. The blood system functions by means of the brain because the brain commands all the systems and organs of our body. But the brain cannot function without blood, because the blood leads oxygen to the brain and it nourishes the brain.
"The respiratory system" – the respiratory system and the blood system work in cooperation. The red blood cells take the oxygen from the air, which our lungs take in and transfer through the net of arteries and capillaries all over the body. The blood flows back from the body through the veins and takes CO_2 emitted from the cells in our body back to the right atrium from there to the lungs where it is exhaled to the environment and exchanged by oxygen then the blood flows back to the left atrium and again to the body and so it repeats itself all the time. This is how the respiratory system and the blood system work in cooperation.

Figure 29. A part of text no. two "The blood system" (translation of original text)

ANALYSIS OF TEXT TWO "THE BLOOD SYSTEM"

As noted, text two combines written elements and visual elements. From the aspect of genre the written element in text two is also structured as a report and unfolds as presented in table 16. The introduction is a short paragraph providing general statements on the functions of the blood system. This paragraph is a reduced version of a section in Leah's first text.

Table 16. The generic structure of the written element in text two presented partially in figure 29

Part one	Part two	Part three
General statements	> general statement + definitions + description	> general statement + exemplifications + descriptions

The first part of the text under the heading *Reciprocal relations* breaks down into two sections: a. *Reciprocal relations among elements of the system:* b. *Reciprocal relations between the system and other systems.* The first section concerns reciprocal relations between the constituents of the blood system. It begins with a general statement followed by specific statements on the connection between the constituents: *There are reciprocal relations between the constituents comprising the blood system... The heart pumps and pushes the blood and the blood vessels help to transfer the blood... and the blood tissue contains the essential materials...* This is followed by definitions and more detailed descriptions of the blood system constituents for example: *"The heart" - This is the organ that works as "a blood pump"... The heart is also a system in itself, which constitutes two parts separated by a muscle partition into "the left pump" and "the right pump"...* In this section Leah did not add new information on the system constituents, which she provided in detail in text no. one. She rather made the connection between the three constituents of the blood system and explicitly expressed the idea of relationships among them, which was not expressed in her first text.

The second section presented partially in figure 29, concerns reciprocal relations between the blood system and other systems. It begins with a general statement: *There are reciprocal relations between the blood system and other systems in the body.* This is followed by a description of three specific examples of reciprocal relations between the blood system and other systems: the brain, the heart and the respiratory system. Following the written elements of the text, three successive pages also visually represent the idea of reciprocal relations between the blood system and other systems in the human body (i.e. the brain, the lungs, the heart) and one page visually represents the blood system of other living organisms. Leah visually represented certain organs in the human body by isolated circles with contour lines in blue colour. She also represented blood vessels by pipe like forms in red colour emerging from the circles/organs. The images are labelled and accompanied by written commentaries and definitions of specialized terms, consider the samples in figure 30.

With respect to conformity to the headings demanded, summarized in table 17, text two focuses on the headings she did not cover in text one. This includes the idea of reciprocal relations among constituents of the system (i.e. heading D) and reciprocal relations between the blood system and other systems (i.e. heading E), which is also represented visually in the text. It follows that from the aspect of the task framework text two can be seen as complementary to text one, though in the boundaries of the text she included brief paragraphs from her first version.

Table 17. Organization of content in text two – "the blood system"

Text structure	Headings and sub-headings	Content	Conformity to headings
Introduction	The functions of the system	The blood leads nutrition, oxygen, disposal etc.	B
Part one a.	Reciprocal relations among elements of the system	Reciprocal relations between the blood tissue, blood vessels and the heart	D
Part one b.	Reciprocal relations between the system and other systems	Relations between the blood system and the brain, the respiratory system, and the heart	E
Part two	And what about other living organisms?	The blood system of other living organisms	Outside the task framework

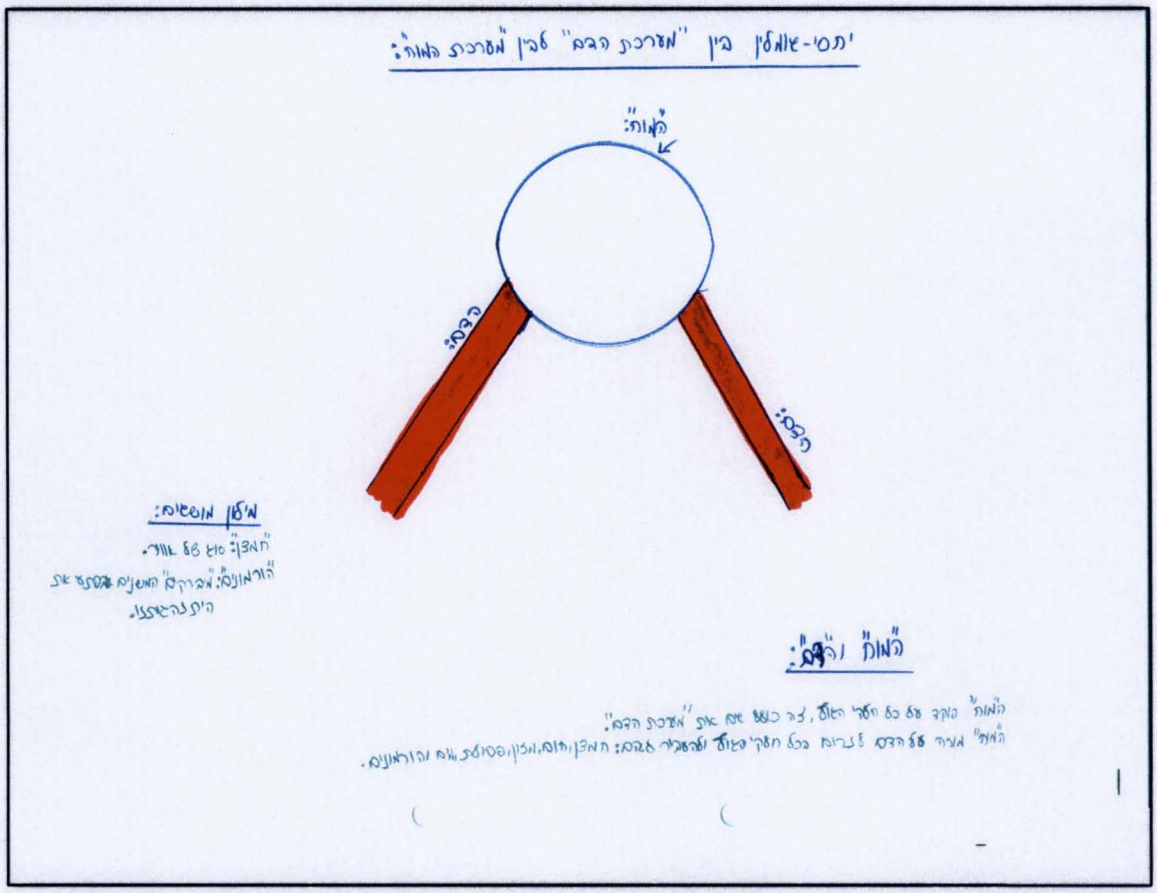
OPERATING MODES IN THE COMMUNICATIVE EVENT

ACTION AND SPEECH

Leah took the floor in a close position to the class as the audience. At times she made direct eye contact. She directly addressed the class:

> *It seems to me that you did not understand the transparency I have shown you and my work so well, so I want to explain some things to you. The main function of the blood is leading... The heart is most important because it pushes the blood to the body and pumps the blood from the body; it is a very unique pump...*

At a certain point one of the pupils interrupted her monologue by a question to which Leah responded. It seems that the closer relationships she established in this event (e.g. in contrast to her presentation event discussed in chapter 5) generated the emergence of a dialogic construction of scientific knowledge on the topic in class. She realized closer relationships through multiple resources, by her close position and orientation to the audience, by gaze, speech, and her willing to enter into interaction. Similar to Jordan's case pupils' questions and Leah's responses resulted in the construction of scientific ideas through multiple modes. This in turn generated resources Leah could draw upon and transform into writing in her revised text; consider the following two excerpts and discussion.



(a) Reciprocal relations between "the blood system" and the " brain system"

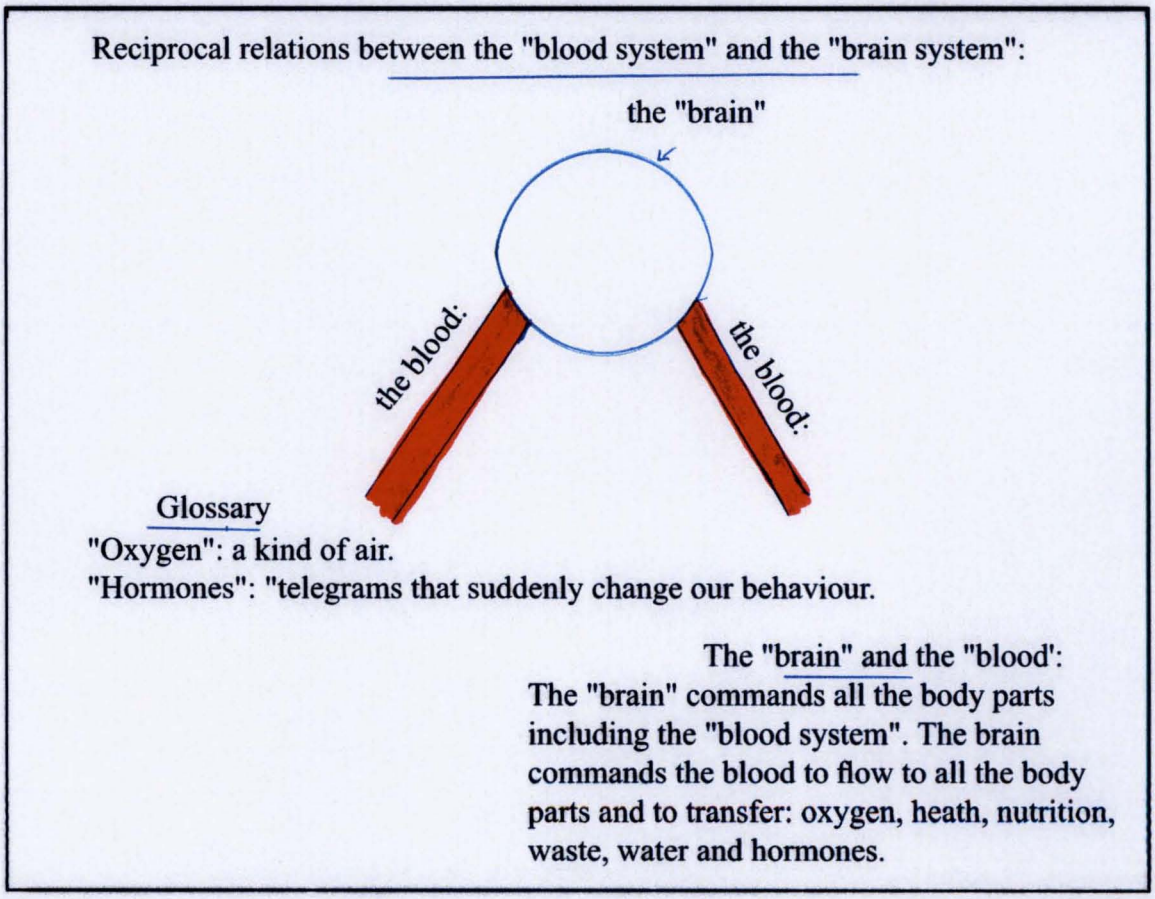
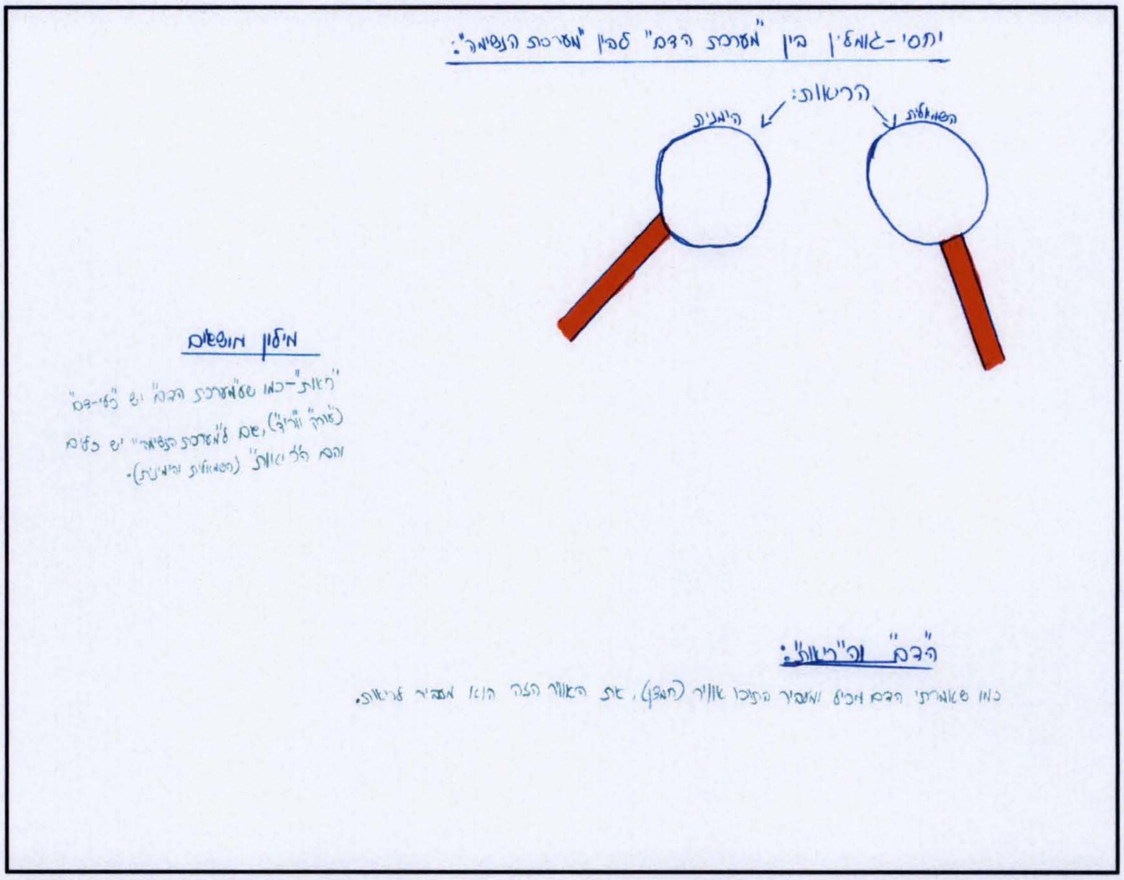
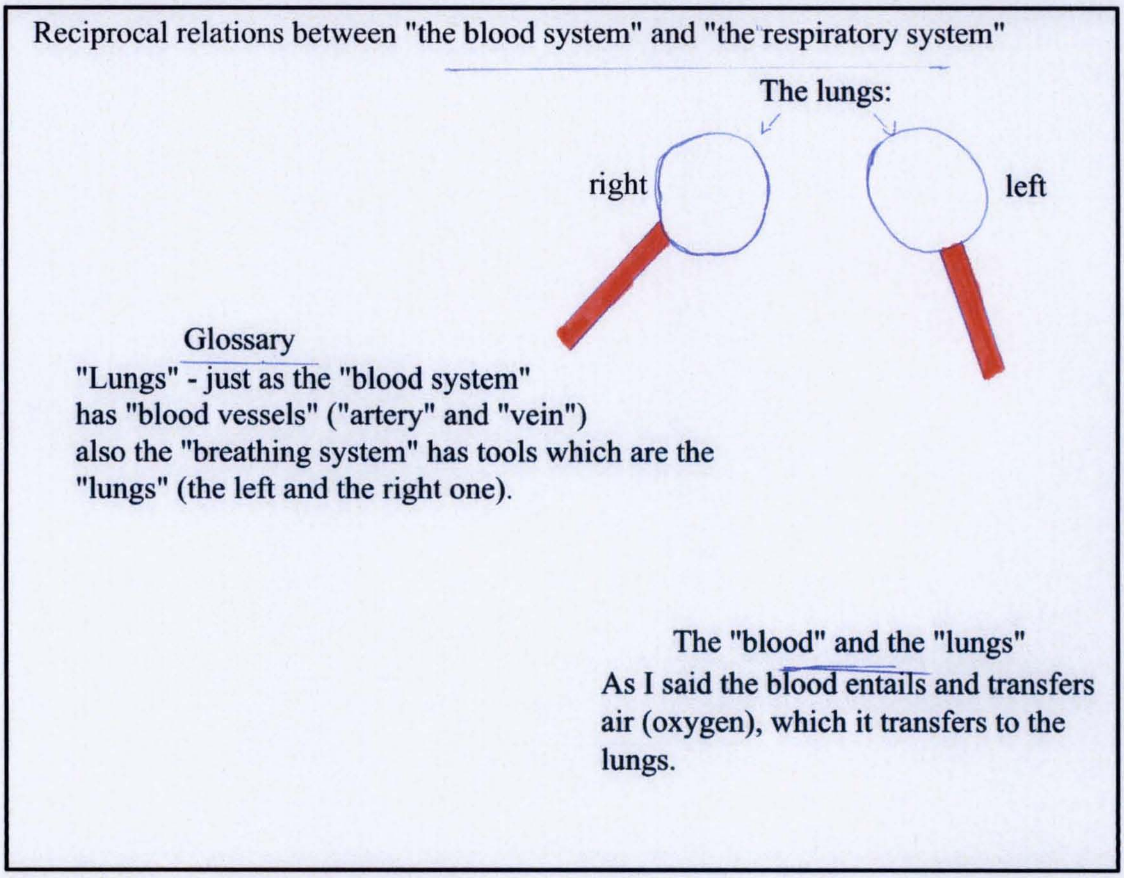


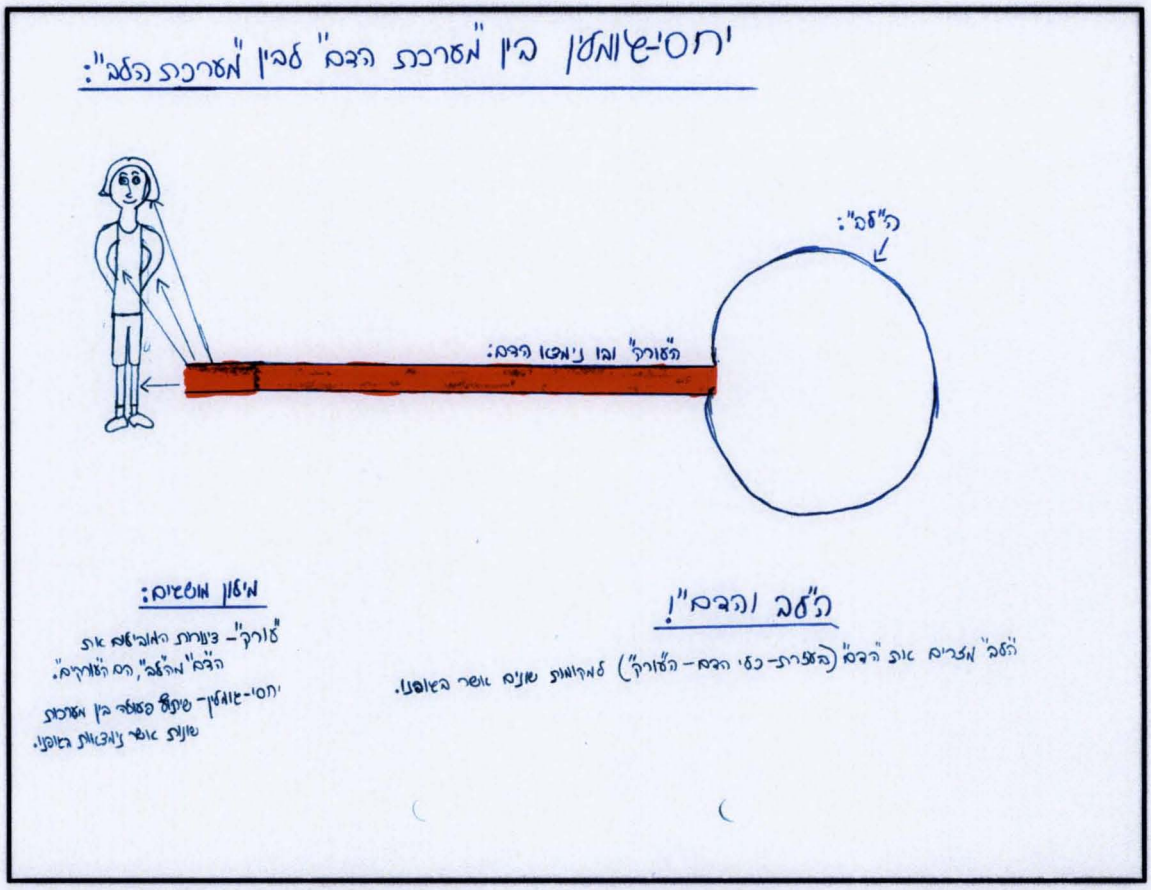
Figure 30. Samples of visual elements of text two (a – f);(b) translation of text in (a)



(c) Reciprocal relations between the blood system and the respiratory system



(d) Translation of the original text in (c)



(e) Reciprocal relations between the blood system and the heart system

(f) Translation of the original text in (e)

Excerpt one – talking science

Pupil 5: *How is the blood related to other systems in the body except the heart?*

Leah: *In fact the blood system is related to all the systems in our body, it leads oxygen and it is nourishing and protecting our body.*

Pupil 5: *For instance with which system is it linked?*

Leah: *For instance with the brain, the blood system leads oxygen and other materials to the brain; without oxygen without blood our brain cannot function and the body cannot function without the brain...*

Similar to the excerpt above text two explicitly deals with reciprocal relations between the blood system and the brain:

> *"The brain" – the brain and the blood system work in cooperation. The blood system functions by means of the brain because through the nerves the brain commands all the systems and organs of our body. But the brain cannot function without blood, because the blood leads oxygen and other materials to the brain...*

That is, Leah selected elements from the interaction in class, which concern conceptualization of the phenomenon of interrelations in the human body, which she left out in text one. She transformed elements from the interaction in class in the form of questions and answers, which she reshaped and repackaged into the generic structure of a report accompanied by visual representations.

VISUAL, ACTIONAL AND LINGUISTIC RESOURCES

Excerpt two – Explaining the idea of reciprocal relations by visual, actional and linguistic resources

Pupil 6: *I think the blood system is linked also to the lungs because the air goes into the lungs and from there to the blood.*

Pupil 7: *Leah, how does it happen?*

To answer the question Leah moved to the white board and drew an image accompanied by her comments and gestures. The image consisted of two identical isolated circles each representing one of the lungs, one isolated larger circle representing the heart and pipe like forms emerging from and connecting the circles/organs representing the blood vessels. While drawing on the board and then by pointing, tracing and gestures she mediated the meanings carried by the image:

Let's say this is the right lung and this is the left lung. Here the blood takes the oxygen from the air in the lungs to the heart, in fact to the left side of the heart, and it transfers it through the blood vessels all over the body. Then the blood flows all the way back from the body and brings CO_2 to the right side of the heart and from here it moves to the lungs and here it is exhaled and so it repeats all the time.

The teacher commented: *This is indeed an example of reciprocal relations between the blood system and the respiratory system.*

The excerpt exemplifies how Leah deployed visual resources to resolve the problem of how to explain an abstract relational process in the human body – the interrelations between the respiratory system and the blood system. She resolved the problem by visually depicting the participants involved in that process. Through the abstract image and the very act of drawing in integration with gestures and speech she attempted to clarify the idea of reciprocal relations between the participants (i.e. the lungs, the heart, the blood vessels, oxygen, CO_2) in the process. The images she drew in a spontaneous manner on the board and then in her second version of the report are not conventional drawings in science class.

It seems that she imported, in a conscious or unconscious fashion, a visual element from the textbook she drew upon, which she transformed into an innovative new sign. In the textbook the form of a circle appears throughout the book as a frame signifying the microscope lens. Within the circle/frame in the textbook there is usually a magnified element under focus (i.e. a red blood cell, white blood cell, blood platelets). Unlike the source text she used the form of the circle itself to represent organs in the human body (i.e., the left and the right lung, the brain, the heart) first on the board and then in her revised text. She combined the form of circles/organs with pipe like forms, which conventionally represent blood vessels in various diagrams available in the science classroom. The spontaneous act of drawing as a medium of thinking at the moment of performance was very rarely used by pupils but often used by the teacher in her lessons (consider case study example 3 in chapter 5 where the teacher clarified a point by drawing a schematic diagram on the board, i.e. the function principle of pupils' suggested model as a closed electric circuit). In Leah's case the teacher's conclusion of the episode explicitly formulated the idea in terms of the heading she demanded: *This is indeed an example of reciprocal relations between the blood system and the respiratory system.*

Returning to Leah's texts for illustration purposes, she used writing as a modal resource to transform elements from the multimodal event in the revised report. These included explicit expressions of interrelations between the blood system constituents and

between the blood system and other systems in the human body accompanied by visual representation, for example:

> *The respiratory system and the blood system work in cooperation. The red blood cells take the oxygen from the air... The blood flows back from the body through the veins and takes CO_2 emitted from the cells in our body back to the right atrium in the heart... from there it moves to the lungs where it is exhaled to the environment and exchanged by oxygen... This is how the respiratory system and the blood system work in cooperation.*

In summary, Leah's second version of the report can be seen as complementary to her first written report both from a semiotic aspect and the task framework. Similar to Jordan's case the multimodal experience of communication and the classmates' questions did not provide Leah new information on her topic. This rather provoked her thinking, to make connections between known facts and to clarify issues. With respect to the answer of the third research question taken up in this chapter, the important point to be made here is Leah's choice to visually realise meanings, which she could not realise purely linguistically. She used drawing as the medium of thinking in integration with speech through which she could clarify the complex idea of the interrelations in the human body, not only to others but also to herself. This may have contributed to the resources she transformed from spoken ideas into writing in the second version of her report. Although non-conventional, Leah's motivated signs/drawings provide evidence of her serious effort to deal with problems of representation and communication of complex scientific ideas at the initial stage of her disciplinary studies in the science classroom.

At this point it is worth noting that conceptualization of the phenomenon of interrelations in organ systems in the human body (i.e. between structure and function, between organs as interrelated structures in a system, between a system and other systems) was more or less problematic for all the pupils engaged in independent productions of exploration reports, theoretical in nature, in the science classes observed. This is projected in the various data I gathered of which the two case studies in this chapter are only instantiations.

CONCLUSIONS

This chapter exemplified how grade five pupils transform resources they draw from communicative events comprising the overall presentation into a revised report on a topic explored. It exemplified that practices of learning science, from the pupil's perspective are enacted in a wide range of modes. That is to say, language as speech or writing is

integrated as one among a multiplicity of modes used by pupils for representation and communication of scientific knowledge in the science classroom; a combination that some of the researchers (Lemke, 2000; Osborn, 2002) denote as multiple "scientific literacies".

In spite of the remarkable differences between the case study examples discussed, the analysis shows that in each case the revised text is an improved text with respect to aspects of scientific content, and/or a number of textual features (i.e. organization, headings and subheadings) and conformity to headings demanded by the teacher.

With respect to content the analysis shows that in text one the pupils focused on the structure and function of specific organs within the system explored or the system as a whole. Yet they left out the idea of interrelations between structure and function, within and between organ systems in the human body required by the task framework. This finding is in agreement with Reiss & Tunnicliffe's (2001) findings on the little appreciation students of different ages had on how organs exist as interrelated structures within organ systems in the human body. This was revealed in their research on the productions' of students of different ages when they were asked to draw what is inside them. Returning to my data, the analysis shows that in the revised text the pupils conceptualised the idea of interrelations in the human body which they left out in text one.

With respect to textual features, in case study example one the revised text was better organized, lengthy, better oriented the reader in relation to the topic, extended information, elaborated on the topic, provided explanations, considered the idea of interrelations and was more explicit than text one. In case study two, the written elements in the revised text were reduced in comparison to text one; it was produced as complementary to text one. In this case the focus was on the idea of interrelations both in the written and the visual elements of the text, which the pupil left out in text one.

With respect to conformity to the headings demanded, in case study example one text two better covered the set of headings demanded in comparison to text one. In case study example two, text two was produced as complementary to text one; it focused on the headings which were not dealt with in text one.

At this point I wish to emphasize that I do not take the view that the transformation of communicative resources into the revised reports was a straightforward process following the overall presentation. Yet even the slightest extension of writing resources and the improvement of writing from any aspect justifies exploring and tracing the resources pupils may have potentially drawn from in the process of making and

remaking the signs/reports. This is particularly significant in light of the difficulties children face in the process of writing science at school as documented in research literature (Martin, 1989; Sutton, 1992; Halliday & Martin, 1993; Hand, Lawrence & Yore, 1999; Peacock & Weedon, 2002). One of the problems children face in the situation of writing is the absence of an immediate audience, which has a range of consequences on the production of texts (Kress, 1982; Sutton, 1992). In contrast, the performance of presentations to the class as an immediate audience and the related communicative events are interactive situations. The very co-presence of the audience has an impact on communication, all the more so with an active responsive audience as in the science classes observed. The analysis highlights Vygotsky's (1978) notion that scientific ideas communicated on "the social or intermental plane" (Mortimer & Scott, 2000) enhance understandings of scientific ideas on the individual plane.

The analysis shows that in the communicative events that emerged in response to a pupil's designed presentation the interactive construction and reconstruction of scientific knowledge in class increased and transpired in the form of questions (i.e. posed by the teacher and/or by pupils) and the performer's responses. A question in the exchange of meanings is a demand (Halliday, 1994a). It places a constraint on the next move in the interaction (Fowler, 1996). The questions imposed on pupils presenting the task of reconsidering scientific information in explicit scientific terms; extending information, elaborating on the topic, clarifying issues, resolving problems of representation and communication and constructing scientific explanations. In response to challenging questions, particularly questions that invited explanations, performers clarified issues not only for the audience but also for themselves, since explaining to others may be "a prime support for understanding it better yourself" (de Beaugrande, 1997, p. 432). The construction of texts in the form of questions and responses typifies interactive situations, not written texts. The analysis shows that fifth grade pupils can differentiate, consciously or unconsciously, between the demanded strategies in the two differing situations.

The issue I wish to emphasize beyond the interactive construction of knowledge is the contribution of multiple operating modes in the overall presentation to the extension of semiotic material pupils could potentially draw upon, and transform into the revised report. The analysis shows that in response to specific challenging questions (i.e. concerning interrelations within and between organ systems in the human body) pupils presenting shaped their thoughts and constructed scientific explanations through multiple modes, and not as commonly conceived through purely linguistic resources. They

exploited the functional specialisation of the different modes, possibilities and constraints of bodily, actional and visual resources alongside speech. At times talking science was in the foreground to reflect on events, reorganize and reconstruct knowledge in explicit scientific terms initiated by the teacher, by the pupils in the audience or by the pupil presenting.

The interactive construction and reconstruction of scientific knowledge on the social plane, in a sense, shaped a kind of preliminary "draft" towards the production of the actual revised report individually. The pupils imposed a generic structure expected inexplicitly in science class (i.e. by the teacher) on the text they produced individually, in the report genre. That is generic conventions were used by pupils as a resource both to reshape elements from written resources and from the multimodal communicative events. It seems that the pupils internalized, consciously or unconsciously, the teacher's implicit expectations to structure a long-term exploration assignment on topics theoretical in nature in the form of a report.

The analysis shows that the communicative events described can constitute what Hand, Lawrence & Yore (1999) describe as prewriting steps to be taken to enhance scientific writing. In this process the teacher's active role might be crucial for pupils. This is exemplified in this chapter by Jordan's case (case study one). The teacher's active role is evident in the way she transformed Jordan's multimodal presentation into spoken ideas in explicit scientific terms on the skeleton and motion system; how she posed challenging questions and by that reframed, reorganized, reconstructed the topic and made implicit notions in her presentation explicit. In doing so the teacher revealed points of strength in her presentation, provided her a scaffold and challenged her thinking within her "zone of proximal development" (Vigotsky, 1987, p. 209). Although the teacher's scaffolding was not aimed specifically to enhance Jordan's writing, though not in a conscious fashion, her communicative actions generated semiotic material Jordan could draw upon in the revised report. However, it must be recognized that it is the individual learner that reorganizes and reconstructs scientific understandings from social to personal planes (Vygotsky, 1978, 1987; Mortimer & Scott, 2000, 2003) as revealed in the ways pupils integrate their understandings in a holistic way in the texts they produce/revise.

CHAPTER 7

CONCLUSIONS

> Learning, and more especially educational learning, is essentially a process of creating meaning; and it is meaning of more than one kind.
>
> (Halliday, 1994b, p. 34)

INTRODUCTION

The aim of this thesis was to describe and better understand the different ways in which pupils use resources made available in the science classroom to represent and communicate scientific knowledge, from the pupil's perspective. In particular the different ways in which pupils use resources in the rhetorical process of presentation events and in the production of texts were exemplified.

The rhetorical analysis of presentation events exemplified in this thesis is, to the best of my knowledge, an initial attempt in research to deal with the rhetorical aspect of communication in the science classroom in elementary school from the pupil's perspective. The multimodal framework applied throughout this study opened up the possibility to reveal a wide range of resources pupils deploy and realise their function in the rhetorical process of presentation events and in the expression of scientific knowledge in texts they produce.

The descriptions in this thesis are based on existing teaching and learning practices in fifth grade classes in the regular setting and environment of the science classroom observed through a multimodal "lens". Looking at learning practices through a multimodal "lens" reveals a spectrum of the resources made available to and deployed by pupils in the process of science learning wider than the common view in education observed through a linguistic "lens". This does not suggest that the linguistic realization of meanings is no longer important. It however suggests that visual and actional realizations of meanings are important in meaning making processes in the science classroom.

The multimodal analysis in this thesis is developed on the foundation of other studies, discussed in more detail in the previous chapters. The thesis extends the language based line of analysis in previous studies (such as Lemke, 1990; Ogborn, Kress, Martins & McGillicuddy, 1996; Mortimer & Scott, 2000, 2003). It also contributes to the multimodal line of research in earlier studies (such as Kress & van Leeuwen, 1996, 2001; Van Leeuwen, 1998; Lemke, 1998a, 1998b, 2000; Ogborn & Kress, 1998; Kress, Jewitt,

Ogborn & Tsatsarelis, 1998, 2001). This thesis stands in line with the mentioned studies in the sense that it contributes to the ongoing international research interest in the various meaning making processes in science classrooms. Nonetheless this study makes a distinct contribution to research knowledge in focussing on the ways in which pupils orchestrate a range of communicative modes in the science classroom rather than, for example, the teacher. Furthermore the study is located in the context of Israeli schooling, at the primary level, with its distinctive cultural setting, which to the best of my knowledge has not previously undergone this kind of multimodal and rhetorical analysis.

The intensive multimodal and rhetorical analysis carried out in this thesis required a number of case study examples of the practices explored. Nonetheless some general questions and messages can be derived from the findings, concerning learning, assessment, teacher education and pedagogical implications.

LEARNING

The multimodal framework applied in this study is informed by a multimodal and social semiotic view of learning as a dynamic transformative process of sign making influenced by the pupil's interest and the context of learning. The analysis of texts and presentation events exemplified in this thesis illustrates this view of learning. When asked to produce written assignments in response to the teacher's lesson and a writing task she gave them, the pupils were actually engaged in the transformation of the teacher's multimodal communicative actions into two dimensional texts. In addition to the teacher's lesson pupils were expected to draw elements from other resources she made available (i.e. textbooks, handouts, maps, models). This involved transformation and integration of elements from different available resources in the new produced signs/texts. In the process described the pupils transformed aspects of content presented in one mode (i.e. by speech) or in co-operating modes (i.e. by model, gesture and speech) into a different mode (i.e. writing) or into a different combination of modes (i.e. image and writing). They transformed aspects of content presented in one form of text (i.e. report) into a different form of text (i.e. flowchart).

The analysis shows that texts produced by the pupils in response to the same lesson, the same task, and the same resources made available to them, vary remarkably within and across a number of dimensions including: mode, genre, aspects of content and organization of content. With respect to mode, although the teacher clearly set the task as a written assignment, pupils used different combinatorial possibilities of visual and

linguistic resources in a variety of genres to convey scientific knowledge. They deployed differentially representational possibilities of the interplay between the visual and linguistic elements in the text to resolve representational problems (i.e. representing the motion entity; invisible vibrations, the process of inhaling and exhaling) or as constrained by generic conventions.

With respect to genre, the written assignment was framed in terms of content, whereas the form of the text to be produced usually remained open to the pupil's choice. Nonetheless pupils deployed a small number of existing genre types or mixed genres, to give scientific knowledge an outward material structure and shape, which was not in each case in congruence with the forms of text anticipated by the teacher in science class. The teacher's expectations were projected in her actual responses to the texts pupils produced which may have been crucial in apprenticing pupils in conventions of recontextualized genres developed in the subject of science at school. At times the pupils packaged scientific knowledge in recontextualized genres anticipated by the science teacher. At times they mixed conventional with non-conventional generic structures outside the conventions of writing science at school (i.e. a scientific report framed in a guided tour). The analysis shows that pupils can use generic conventions differentially even within the possibilities and the constraints of the same genre type (i.e. flowcharts). Pupils' choices of the different genre conventions, often of mixed generic structures, provided possibilities to focus on different aspects of content from the teacher's lesson or from other resources (i.e. other lessons, textbook, and handout material).

The different ways in which these pupils integrate scientific knowledge in generic structures available to them can reveal their serious efforts to give scientific knowledge shape and their differential understanding of key notions and aspects of content of the topic in the lesson, even when packaged in non-conventional and unexpected forms of text (by the teacher) in the science classroom. This is indeed evident from the different ways they transformed resources made available to them in the science classroom to realise expression of scientific knowledge in a variety of genres. Using de Beaugrande's (1997) terms the pupils did not just "reproduce the subject matter" (p. 425) they transformed resources and integrated scientific knowledge in the visual and written mode in generic structures available to them in an innovative fashion, influenced by their interests and the context of learning, which is indeed the nature of learning. From a pedagogical point of view, looking at the interests the pupils encode in the texts they

produce it is significant to take into consideration that "interest is not fixed but is the expression of a temporary configuration of socially and culturally produced internal representations" (Kress, 1993a, p: 172).

When asked to present a topic independently explored or report on an experiment to the class as the audience the pupils could act as rhetoricians in a conscious or unconscious manner, although they were not instructed or apprenticed in any direct form regarding the task of presentation. It seems that from the pupils' perspective they are habituated in the practice of presentation intuitively, by reading the teacher's habitus of communication or other classmates' communicative actions. The analysis shows that pupils' communicative actions can reveal their understanding of the rhetorical situation of presentation, which sets different epistemological and rhetorical demands than the written reports to be read by the teacher. This is projected in the choice of different aspects of content presented to the class than those represented in the written report to be read by the teacher. The analysis shows that the pupils understood, consciously or unconsciously, how to exploit semiotic resources for the rhetorical task and situation. This is projected in the rhetorical process of the presentation, which points backwards to epistemological and rhetorical decisions in the process of design. Pupils' engagement with design processes, is evident in their pre-designed rhetorical means (i.e. models, images, OT, 3D experimental objects), in the sequence in which the rhetorical means were presented, in the manner in which these were interwoven with rhetorical strategies (i.e. demonstration, creating difference, explanation) and communicative modes (i.e. action, visual, speech).

The analysis highlights the epistemological work involved both in the design and the rhetorical process of presentation events. This is evident in the different ways pupils took into consideration the nature of the specific phenomenon or issue explored, and in their transformation of aspects of content appropriated so as to communicate scientific knowledge accessibly. Thus, at times their rhetorical effort was focused on making an everyday phenomenon into a case to be explained in scientific terms (i.e. the pitch level of notes on the xylophone) or on the contrary making a complex phenomenon accessible (i.e. introducing the function principle of the electric circuit through a model construction; the move from simple to more complex organisms e.g. fish-frogs-mammals).

In presentation events pupils could rhetorically orchestrate modal ensembles to communicate scientific knowledge on phenomena and topics explored. This they realized

by spatial, bodily, visual, and actional resources in combination with speech. At times one of the modes, speech, action or the visual mode was in the foreground while at other times the rhetorical power lay in the integration of communicative resources from different modes. The analysis shows that in the overall presentation actional and visual resources are not just illustrations of speech; they are rhetorical resources; they are mediums of thought; they are resources to present scientific content, to construct scientific explanations (i.e. explanation of the function of distinctive joints by action with the body) to clarify abstract complex notions (i.e. reciprocal relations between systems in the human body depicted by images); and they generate semiotic matter pupils can draw upon in writing science.

The analysis shows that pupils used writing as a modal resource to transform scientific meanings they had communicated multimodally in communicative events comprising the overall presentation, which they integrated into their revised report following the presentation. In certain instances, the revised report was better organized, lengthier, more elaborate and explicit, better positioned the reader in relation to the topic and better conformed to the task framework than the first version of report. In other cases the revised report was reduced and was rather produced as complementary to the first report with respect to content and the task framework.

However, in each of the revised reports reviewed, pupils dealt with aspects of content concerning complex abstract notions (i.e. interrelations between organs as structures within a system in the human body; reciprocal relations between systems in the human body), which they left out in the first version of the report, even though it was required in the task framework. That is, constructing knowledge from different resources independently on complex aspects of content of the curriculum, which were not yet studied at that time in class, and transforming them into written reports was problematic for all the fifth grade pupils observed. In contrast clarifying the same complex notions and constructing explanations multimodally (i.e. by model, image, body, action, gesture, speech) and interactively in communicative events enhanced understanding and writing.

The teacher and the class as an audience contributed to this process by taking the role of a responsive audience and community. In certain cases the teacher led the class to reflect on presentation events from the aspect of content. These reflective events contributed to reconstructing scientific knowledge in explicit scientific terms, to

clarifying key notions of the topic and to reorganizing the presentation event as intuitively constituting a kind of spoken "draft" which pupils were able to reshape into a revised report. The analysis shows that in response to presentation events pupils in the audience directed challenging questions to the pupil presenting, which mainly related to or were derived from the headings demanded by the teacher. This contributed to the extension of scientific knowledge and the construction of explanations on the topic presented. In turn this process generated semiotic matter which pupils were able to draw upon and transform into writing in their revised report with conformity to the headings demanded. However, the effectiveness or ineffectiveness of rhetorical resources used by pupils in the overall presentation (i.e. model, image, poster, demonstration, OT, text, guiding question, position, orientation, talk) was not articulated in the reflective discussions.

ASSESSMENT

From the pupil's perspective the production of texts, as evidence of science learning, seemed to carry ambiguous expectations and messages from the aspects of mode, genre and assessment. With respect to mode, it seems that there is constant tension between the ways contents of the science curriculum are presented to pupils multimodally and the manner in which their representation of scientific knowledge is assessed primarily from a linguistic point of view. The analysis shows that images representing scientific knowledge were usually not controlled, evaluated or assessed as a written representation of knowledge; and image-dominated texts (i.e. comics) were generally construed in terms of creative expression if produced in an unexpected form of text.

With respect to genre, on the one hand the expected form of text to be produced was not framed, hence pupils could make free generic choices. On the other hand, if the choice of genre seemed to match the expected structure in the science classroom, the pupils were not informed of what in the text made it appropriate for the topic and the subject of science. On the other hand, if the choice of genre did not meet the expectations of a scientific text form the pupils were also not informed of what in the text made it inappropriate for the topic and the subject of science. At the same time the teacher's uniform response to the various arrangements of texts pupils produced within the same genre type anticipated in science class (i.e. flowcharts) may have obscured pupils' differential conceptualisation of phenomena indicated by variation of content with variation of form encoded in the variety of arrangements of the text elements. Since the criteria for assessment were not articulated, pupils had to independently decipher why a text was accepted or unaccepted as an assignment accomplished successfully.

Design processes surrounding a chosen experiment or topic presented to the class were commonly not articulated, recognized and evaluated as the productive process of the presentation event, although design involved production of a variety of artefacts; for example, pupils transformed the experience of an experiment (i.e. experimenting with vibrating objects) into various artefacts such as models, images, OTs, written experimental reports. They transformed a theoretical innovative idea discussed in a small group into a model construction (i.e. translating the idea of an invention of an alternative door-bell for people with hearing problems into a model). They transformed written resources, and/or interactions with 3D objects, into images, models and written texts.

The analysis shows that within the entire outcome of the transformative work surrounding a chosen experiment or topic (i.e. poster-map, model, OT with schematic diagrams, written report) only the written text was controlled, assessed and recognized as the real serious means for representation and communication of scientific knowledge. Seen from the pupil's perspective the written text was assessed as an evidence of science learning in isolation rather than one sign/product of the entire outcome of the process of learning, experimenting, exploring a topic, issue or phenomenon. From a pedagogical point of view, it seems that the assessment of the written text in isolation within the entire outcome of the process of learning involved in the design and presentation of a topic explored belonged to contrasting pedagogical orientations.

The findings raise a question for further contemplation and exploration. That is, from a multimodal view, how should we articulate, evaluate and assess the various material outcomes produced by pupils in the process of science learning in ways that correspond to the characteristics of representation of knowledge in school science? This is a challenge for researchers in social semiotic theory, for teacher-educators and for science teachers.

TEACHER EDUCATION

As the work of teachers involves constant reflection on their practices and assessment of learning, they need to be given the means to be consciously attentive to the communicative modes available as resources for reflection on teaching and learning practices.

A multimodal and social semiotic theoretical framework can open up the possibility to do so. It can contribute to science teachers' training, further education and praxis. A major objective in inquiry is to develop praxis (Lemke, 1995). That is, to use theory as a tool for analysis and reflection on the ways that things are done in the present and to critically rethink new ways in place of the present self-evident ways that might be constraining. A multimodal framework as exemplified in this thesis can be used as a tool to reveal the range of transformational resources pupils differentially introduce in science learning practices and provide a means of scaffolding their further apprenticeship into the world of science. This could replace the common pattern of using purely linguistic tools, which can be pedagogically misleading because they cannot account for the wide range of resources through which children can express scientific knowledge, that is, what thinking might have been. In contrast, a multimodal approach can stimulate a pluralistic conception of knowledge. A multimodal framework does not require new materials, equipment and other resources from the science teacher. The approach is what is different and the approach is informed by a multimodal and social semiotic view of learning.

PEDAGOGICAL IMPLICATIONS

From a pedagogical point of view a multimodal approach and framework as exemplified in this thesis raise several messages and implications regarding science education and teacher-education. These include the need to:

- Develop awareness of the multimodal landscape on a macro and a micro level of communication in the science classroom environment;
- Reconsider the conception or misconception that language as speech or writing is the central and primary mode for representation and communication of scientific knowledge, reasoning and explanation;
- Consciously pay attention to the range of semiotic resources made available to pupils and deployed by pupils in the science classroom;
- Take into consideration the benefits of consciously habituating pupils to the rhetorical task of communication and articulating the use of communicative modes for rhetorical purposes;
- Reconsider how to frame the production of texts and the performance of presentation events in terms of form and not only in terms of content.
- Develop awareness of the contribution of operating modes in communicative events in generating semiotic matter for writing;

- Consciously reflect on the effects of teaching and take into consideration pupils' interests when responding to their artefacts or other outcomes of the process of learning;
- Approach the differences between pupils' texts/events as reflecting their subjective interests rather than being the result of individual differences or their failure to follow the lesson or the framing set in the science classroom;
- Develop reflective practices in teachers' education on the relation between mode and representation of aspects of content;
- Develop mode specific criteria to assess pupils' expressions of learning and not only content specific criteria.

The multimodal analysis exemplified in this thesis highlights aspects of representation and communication (i.e. the use of action, image, model, demonstration, or experiment to represent scientific knowledge) in the science classroom, from the pupil's perspective. Some of the aspects discussed are subject specific or more salient in the subject of science than in other school subjects. Nevertheless, the application of a multimodal framework, on a principle level, should be considered as a tool to explore the range of meaning making resources made available to and deployed by pupils in learning practices in other school subjects. This is particularly relevant in light of the increasing shift in the conceptions of communication in general from the unique focus on language to a range of communicational resources.

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APPENDIX

TIMSS = Third International Mathematics and Science Study

Science Curriculum Framework

Doc. Ref. ICC 307/NPC 080 May 1992

The TIMSS frameworks were designed to characterize curricular materials, content specific pedagogical approaches, and student performances. This is an international enterprise. The frameworks were developed in a process of negotiation seeking consensus between multiple countries. The frameworks also intended to represent not only what countries currently do with regard to instruction in these subjects, but also to anticipate the reform efforts in these subjects currently under way in many of the participants countries.

The frameworks included the following document analysis:

1. Curriculum guidelines
2. Curriculum textbooks

DECLARATIONS

I confirm that the word length of the thesis is: 82,807

I confirm that the word length of the bibliography is: 2,815

I confirm that the word length of the appendix is: 105

Furthermore, I hereby declare that the work presented in this thesis is my own work.

Zahava Aurika de Beer

Zahava Aurika de Beer