Imagination of Science in Education

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Imagination of Science in Education

From Epics to Novelization

Springer

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Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand.

(Einstein 1931, p. 97)

Preface

> Imagination is the beginning of creation. You imagine what you desire; you will what you imagine; and at last you create what you will
>
> (Shaw 1949, p. 9)

> Imagination (as a productive faculty of cognition) is a powerful agent for creating, as it were, a second nature out of the material supplied to it by actual nature
>
> (Kant 1952, p. 176)

This book is about imagination. As the exemplary quotes above illustrate, all great thinkers seem to agree about one aspect of imagination: It is at the root of how we modify our material world. It is not just a fancy way of daydreaming that leads to oblivion. On the contrary, the human world is created from its imagination: So is the world of science from imagination in education. Teachers, textbook writers, students, parents, and other folks collectively draw an image of science from their imagination. This process is fundamental to the way in which scientists, being the successful proponents of science education, actually create their scientific enterprise once they take up their professional life as scientists. It is therefore surprising, as we argue in this volume, that little empirical research has been done on the ways in which this imagination actually takes place and hence how science is being created in education. In this context, we present in this book a novel way of looking at imagination in science education. We show how in science education a dynamic balance exists between two forces related to imagination, known, from the literary philosophy of Bakhtin, as *epic* and *novel*. On the one hand, science education maintains an epic story of science in which heroes set the stage. This epic image, however, creates a kind of science that is by and large inaccessible to students since it remains situated in the past. This is in contrast to the wider aims of science education of bringing the world of science *closer* to the current generation of children. As we argue in this book, the other force, novelization, is a way of imagining science such that it is accessible to students.

This book is one of the outcomes of a fruitful collaboration that started in 2006 at the University of Victoria (British Columbia, Canada). At the time, we set up the Pacific Centre for Scientific and Technological Literacy, a center funded by the Canadian government for the study and innovation of science education. Both of us were very interested in the way in which images of science were constructed in schools by using powerful symbols from the culture of science such as pictures of scientists, common scientific graphs, and iconic drawings. As well, we were both intrigued by the finding that the scientific methods imagined in school science textbooks had so little to do with the detailed images of the scientific enterprise constructed by ethnographers from the social studies of science. Our mutual interest led us to study how imagination occurred in science textbooks and science classes. The results of these studies are presented in this book.

In this book, we use materials collected in a variety of research projects generally funded by grants from the Social Sciences and Humanities Research Council of Canada and the Natural Sciences and Engineering Council of Canada. Our ideas and understanding also developed as we attempted to articulate them in articles submitted to a variety of research journals. We attempted to communicate how scientists were portrayed in textbooks as heroes and how, in contrast, they go about in different ways in their professional lives. We also tried to understand how imagination takes place in the actual practice of education and how various levels of epic and novel emerged and disappeared in the process. The anonymous reviewers of various journals have pushed our thinking further and therefore deserved special thanks. The resulting publications in *Journal of Research in Science Teaching, Science Education, Cultural Studies of Science Education, International Journal of Science Education, Educational Research Review*, and *PLoS Biology* were important starting points for the ideas presented here. We reused some of the images and data but reworked our analyses so that they reflected our present-day understanding and constituted a cohesive whole with the remainder of this book.

Finally, a book like this could not be written without many people involved in all the constitutive processes leading toward its ultimate form as cover, pages, and text. We thank all the individuals in our research groups who supported in some way this work. Special thanks go to Pei-Ling Hsu for her contribution to the work represented in Chap. 6. We are also grateful to all the individuals and groups outside our research communities who made possible the research represented in this book. This counts in particular for the W̱SÁNEĆ First Nations communities and the Marine Conservation Society OceanHealth (pseudonym). Their support is constitutive to the work in Chaps. 7 and 9. We thank the editors of the Cultural Studies of Science Education book series for carefully reading the initial version of the manuscript and providing their profound feedback.

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Contents

Introduction: Imagination, Epicization, and Novelization in Science Education

Theaim of this book is to contribute to a better understanding of the imagination of science in science education in terms of *epicization*—the process of creating epics, great master narratives about the nature and history of a country or field—and its counterpart, *novelization*—the continued renewal of narratives that derives from the dialogical interaction and incorporation of many voices. The rationale for this aim can be traced all the way back to 1957, when the famous anthropologists Margaret Mead and her colleague Rhoda Métraux for the first time studied the image of the scientist among a representative sample of high school students in the USA (Mead and Métraux 1957). The images of scientists typically expressed by the students they interviewed were not unlike the images prevalent among recently studied representative samples of youth in countries worldwide (e.g., Sjøberg and Schreiner 2010). Scientists are imagined in an epic fashion, being white middle class elderly or middle-aged males, wearing glasses and white lab coats, working in solitude, and being surrounded by typical laboratory artifacts such as test tubes, flasks, and weird machines. Taking the two studies together, we cannot escape the conclusion that epic images of science remain to prevail among students.

Following the groundbreaking study of Mead and Métraux, several research programs contributed to an improved and refined understanding of images of science in science education. Much of this research has come to be known as research on the nature of science (NoS) in science education. From this research, we know, for example, that students' epic images of science are akin to the images expressed by the majority of science teachers. That is, the epic image of science is widespread among various participants and stakeholders in science education rather than among students only. Other research programs revealed that epics not only concern the image of the processes of science itself but also concerns more generally what in science education has come to be known as science–technology–society (STS). All such research programs and individual studies confirm that epic images of science are persistent, universal, and widespread in science education.

Despite the substantial body of research on students' images of science, little research has been done on why precisely the epic nature of the image of science is so persistent, widespread, and universal. Most studies in the field are based on questioning large samples of students with a focus on mapping images of scientists among students. Such studies only confirm the persistent, universal, and widespread nature of epic images of science in science education but do not further dig into its causes, let alone provide solutions to overcome these causes. Few studies, however, focus on the processes by which epics of science are shaped in the practice of science education itself. Even fewer studies focus on the representational resources that are at the center of shaping epic images of science such as textbooks and other curriculum materials that literally *represent* science. Because of this gap in the literature, one is left puzzled why students' images of science are persistently epic and how this might be countered in science education itself. This book aims to fill this gap in the literature.

In this book, we commit ourselves to sociocultural perspectives on representation and imagination. In other domains—such as media studies and the social studies of science—these theoretical frames have widely proven to be useful for understanding how particular images are shaped by means of representations. In our research on images of science, the very same sociocultural perspectives appeared to be useful to understand why epic images of science are so persistent in the domain of science education and how this persistence can be countered in science education itself. More specifically, as a guiding thread in this book, we use the concepts *epicization* and *novelization* to shed light on the process of imagination. The rationale of this book follows from the fact that those two aspects are at the core of the imagination of science in science education but are simultaneously off the radar of science education research. To further introduce the reader to the rationale and the pivotal frame of reference of this book, thus, we illustrate sociocultural perspectives on imagination in general and epicization and novelization in particular with some typical cases of representation practices in science education.

In this introductory chapter, we lay the groundwork for this book as a whole. We begin by exhibiting an example from the biology curriculum, which we suggest contributes to the production of a particular view on and image of science. We introduce two sets of key concepts: epic and epicization, on the one hand, and novel and novelization, on the other hand. We conclude this introductory chapter with an outline of the four parts that constitute this book.

The Case of Harvey

This illustrative case is a common representation in science textbooks: a reproduction of a scientist's original drawing. This case exemplifies what we have found in our studies on the representations of scientists in textbooks. In this study, for ten different scientists, we collected in four different high school and college science textbooks all excerpts in which scientists' actions were described, yielding total number of 415 excerpts for all ten scientists. In 95 of these 415 excerpts, we found that artifacts typical for scientists' actions in research were represented. The case of

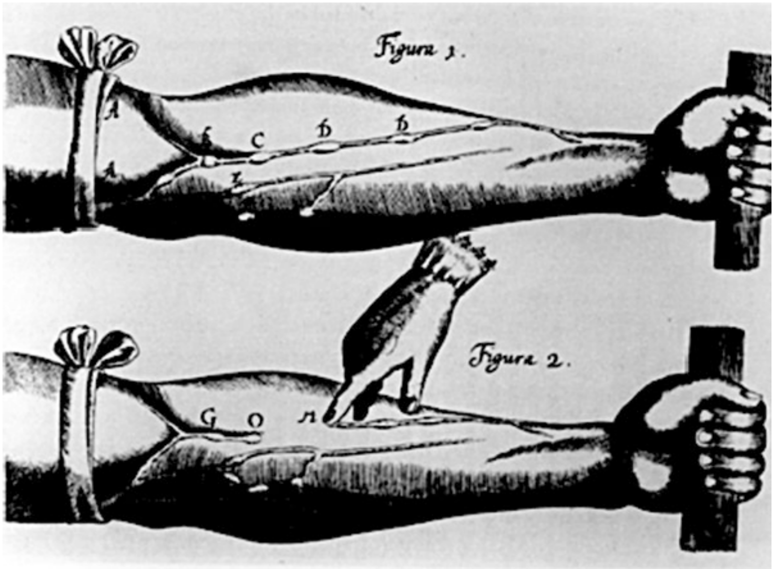

Fig. i.1 Harvey's original drawing as represented in a science textbook (Used with permission from Ritter 1996, p. 725)

Harvey below is one typical example, thus showing representational features common in science textbooks (Fig. i.1).

The drawing represents Harvey's experiment by means of which he illustrated the working of the valves that regulate blood flow. One can observe two lower arms of which the bloodstream is interrupted by a tie at the elbow resulting in observable veins and valves (the latter indicated by letters). A hand is pushing against one of the arms' veins, resulting in the part of vein until the next valve becomes invisible. In this book, the figure is accompanied by a caption title saying "Figure 29.7 Valves" and a caption text saying "The one-way valves direct blood flow back to the heart. William Harvey's teacher, Hieronymus Fabricius, had already discovered the valves, but he did not fully investigate their function. He, like many others, still believed in Galen's ebb-and-flow theory."

From Embodied Concepts ...

Past perspectives on imagination have approached representations such as those of Harvey as embodiments of concepts, thus articulating a fixed and universal meaning. In this tradition, representations such as those in Fig. i.1 can be considered a kind of container transferring Harvey's ideas on the closed blood circulation to any other reader. In a tradition of growing appreciation of constructivist perspectives on knowing, however, it is now widely recognized that representation and meaning coevolve in a reflexive process. As a result, the meaning of a particular representation cannot be reduced to the sender, the representation itself, or the learner–reader attributing the meaning to the representation. Hence, as the case shows, the message exchanged by such signs as Harvey's drawing is not a straightforward, linear process from sender to recipient. Rather, it is vital to "recognize that the discursive form of the message has a privileged position in the communicative exchange (from the viewpoint of circulation), and that the moments of 'encoding' and 'decoding', though only 'relatively autonomous' in relation to the communicative process as a whole, are determinate moments" (Hall 1980, p. 129). Here, both "encoding" and "decoding" refer to the processes by means of which the "contents" of the message are realized twice, depending on the particular discourse through which the message is either packed or unpacked in/from culturally meaningful signs. Once immersed in a scientific discourse, for instance, we may decode Harvey's drawing as the representation of a scientific experiment rather than a piece of art.

The majority of constructivist studies on representation practices in science education centers on the process of decoding. There is a wealth of literature focusing on the gap between the meaning students construct when decoding scientific representations (signs, symbols, etc.) and the meaning commonly attributed to those representations in scientific practices. From this body of literature, one might learn that identifying Harvey's drawing as a scientific experiment to illustrate the working of the blood circulatory may be a rather complex activity for students. To understand this complexity and to anticipate it in education, researchers working within the constructivist paradigm generally contrast the construction process by means of which students attribute meaning to representations such as Harvey's drawing with the common knowledge constructed in the sciences. Accordingly, the focal point in this tradition is the behavior students express when they are supposed to construct knowledge by using particular scientific representations, artifacts, symbols, or models characteristic to ready-made science, and from which the contrast between scientific and "student" epistemologies (conceptions) becomes evident.

. . . to Sense-Making Through Representations

Mainly because of their particular focus on science content, constructivist approaches in science education generally fall short of recognizing the nature of the discursive frame within which meaning is generally attributed to (scientific) representations. The fuzziness of science in the making recognized by the social studies of science since the 1980s, for instance, shows that epistemic and behavioral characteristics common in representations of ready-made science are invalid for interpreting processes of scientific knowledge construction. Hence, the presence or absence of such characteristics really is irrelevant for understanding students' ability to construct scientific meanings in the process of attributing meaning to (scientific) representations. Recent sociocultural studies in science education suggest that the specific discursive norms along which meaning is attributed to particular representations are more relevant in this case. For instance, one study examined specifically how underrepresented urban students responded to epistemic, behavioral, and discursive norms during their first experience with high school science (Brown 2006). The outcomes of this study indicate that students experience relative ease in appropriating the epistemic and behavioral norms of science, whereas they express difficulties in appropriating the discursive norms of science. In other words, students have difficulties decoding the signs that make sense in scientific discourse and in which "scientific messages" are packed. But this is not so much the result of either misunderstanding the epistemologies of science or being incompetent in expressing the appropriate scientific behavior required for decoding scientific representations. Rather, students' decoding problems generally result from resisting buying into the language of science. Hence, prior to problematizing the construction of particular images of science from representations, a discursive perspective would urge us to problematize first of all *why* students have problems using the linguistic tools by which they can construct particular scientific images from the drawing of Harvey.

Unitary Language

At the heart of all representation is language, the primary system for humans to constitute their reality. The language we use may be open to multiple ways of understanding or it may be unitary, that is, admitting only single forms of understanding. Research in the sociocultural tradition has shown that the problem of (not) buying into the language of the sciences is a universal problem in . For instance, one study conducted in the 1990s focused on the reform of science curricula for the purpose of making these accessible to Aboriginal peoples in Canada. In this study, it was shown that Aboriginal students experience issues of social power and privilege in science classrooms that lead them to more easily drop out of the trajectories that lead to science-related careers (Aikenhead 2001). The theoretical construct of cultural border crossing developed in that study described how students move between their everyday lifeworld and the world of school science and how students deal with cognitive conflicts between those two worlds. Because students generally reject assimilation into the culture of Western science, they tend to become alienated in spite of it being a major global influence on their lives. However, these attempts of assimilation and the resulting alienation appeared not to be exclusively experienced by Aboriginal students. The construct of cultural border crossing was equally applicable to "mainstream" students to describe the complicated cognitive trajectories that students experience from the subcultures of their peers and family into the subcultures of science and school science. Rather than being exclusively a problem experienced by Aboriginal students, it appeared that this alienation is only more acute for Aboriginal students whose worldviews, identities, and mother tongues create an even wider cultural gap between themselves and school science.

More generally, according to the perspective we elaborate in this book, the aforementioned sociocultural studies illustrate that a *unitary language* is maintained in science education, that is, a "system of linguistic norms" (Bakhtin 1981, p. 270), frustrating students who do not buy into these norms to enter the discourse of science. From this linguistic perspective, the preceding becomes only a first level reading. The issues are more complex because Mikhail Bakhtin suggests that any word belongs both to the speaker and listener, author and reader. Similarly, across his entire work, Jacques Derrida (e.g., 1985) emphasizes the role of speaker and listener, author and reader, in the saying/writing of what is said/written. Finally, in speech act theory, the speech act is distributed across speaker and recipient so that it always belongs to both. All of these approaches therefore agree that no piece of text is unitary in itself. In fact, the title *Monolingualism of the Other or the Prosthesis of Origin* (Derrida 1998) explicitly attributes monolingualism to "the other," which, from the perspective of the author, is the reader. Hence, the reason for adopting the specific linguistic perspective is to include the question about the strategies some texts use to delimit readings such that they appear to be unitary/monolingual. Semiotic analyses of scientific texts have indeed identified such strategies, the purpose of which is to exclude alternative readings and, therefore, to exclude a multiplicity of readings. Thus, a Bakhtinian perspective that elaborates such linguistic features allows a better understanding of why epic images of science are so persistent, universal, and widespread in science education.

Epic in the Novel

Throughout this book, we show that it is not just language humans use to constitute reality but that there are a variety of genres that give rise to *forms of* text. In this book, we focus on two of these genres: epic and novel. Together with his colleagues Pavel N. Medvedev and Valentin N. Vološinov, collectively known as "the Bakhtin circle," Bakhtin theorized the relationship between the everyday social/material world that we inhabit and how it comes to be reflected and refracted in literary texts such as the novel or epic. The resulting literary theory appeared to be reflective in the sense that Bakhtin's later studies on the development of literary genres since ancient times pertains to the cultural–historical development of human languages more generally. Recent work in the analysis of narratives shows that the ideas of the Bakhtin circle with respect to the novel and other poetic forms are useful to rethink everyday language and the particular forms in which the natural and social world comes to be represented.

The linguistic perspective of the Bakhtin circle recognizes that the signifying features of a language cannot be thought apart from the ideological nature of the discourse in which it is used. Hence, a unitary language is not "an abstract minimum of a common language, in the sense of a system of elementary forms (linguistic symbols) guaranteeing a *minimum* level of comprehension in practical communication" (Bakhtin 1981, p. 271). Rather, a unitary language is taken "as ideologically saturated, language as a worldview, even as concrete opinion, insuring a *maximum* of mutual understanding in all spheres of ideological life" (p. 271). In an analysis of the language used by the French author François Rabelais, Bakhtin (1984b) shows how those with institutional power—the church, the king, and the state—enforced unitary language, among others, by allowing a polyvalent language during carnival and some other feasts. This permission to use a polyvalent language served as a relief, which, while questioning unitary language also reinforced its use during the remainder of the year. From a recent study of laughter in an Australian science classroom, we learned that the same shifts between unitary and ambiguous language operate in science education.

The Bakhtin circle developed a detailed understanding of how the linguistic norms constituting a unitary language are maintained. Key to this understanding is the notion of *heteroglossia*, the coexistence of distinct varieties within a single linguistic system of representation. Any language, in the view of the Bakhtin circle, stratifies into many voices: "social dialects, characteristic group behavior, professional jargons, generic languages, languages of generations and age groups, tendentious languages, languages of the authorities, of various circles and of passing fashions" (p. 291). The linguistic norms constituting a unitary language, in turn, are "generative forces of linguistic life, forces that struggle to overcome the heteroglossia of language, forces that unite and centralize verbal-ideological thought" (p. 271). The operation of these forces are illustrated by the cultural–historical process of the maintenance of the epic, a unitary language*pur sang*, as opposed to the novel, of which the power lies in the coexistence of, and dialogical conflict between, multiple different voices: the voices of characters, the voices of narrators, the voice of the author, and the voice of the reader ("we ourselves participate in the [narration], as listeners or readers" [p. 255]):

> Whatever its origins, the epic as it has come down to us is an absolutely completed and finished generic form, whose constitutive feature is the transferral of the world it describes to an absolute past of national beginnings and peak times. The absolute past is a specifically evaluating (hierarchical) category. In the epic world view, "beginning," "first," "founder," "ancestor," "that which occurred earlier" and so forth are not merely temporal categories but valorized temporal categories, and valorized to an extreme degree. This is as true for relationships among people as for relations among all the other items and phenomena of the epic world. In the past, everything is good: all the really good things (i.e., the "first" things) occur only in this past. The epic absolute past is the single source and beginning of everything good for all later times as well. (Bakhtin 1981, p. 15)

Epicization in the Case of Harvey's Drawing

The *epicization* of a language is a way of overcoming the heteroglossia of language by means of concrete verbal and ideological unification and cultural centralization. Thus, we argue throughout this book that epicization constitutes the main force for reproducing the unitary language in/of . Concerned with question of how scientific texts restrict different readings to a centralized one, a process denoted as "the channeling of sense" (Bastide 1985, p. 142), the author suggests that both scientific illustration and scientific articles work in the same way: they are "constructed like a military strategy, an ambush without an escape route: Each time that a reading of the results differs from that of the authors could possibly be made, the bifurcation is barred by an adequate argument" (p. 142). That is, "scientific illustration aims at the same absence of freedom in possible readings as the text" (p. 143). In the case of Harvey's drawing, one can observe how this works in the most mundane form of language use in science education, especially when taking the following main text given by the drawing:

> VeinsCapillaries merge and become progressively larger vessels, called **venules**. Unlike capillaries, the walls of venules contain smooth muscle. Venules merge into **veins**, which have greater diameter. Gradually the diameter of the veins increases as blood is returned to the heart. However, the very return of blood to the heart poses a problem. Blood flow through the arterioles and capillaries is greatly reduced. The passage of blood through incrementally narrower vessels reduces fluid pressure. By the time blood enters the venules, the pressure is between 15 and 20 mm Hg. These pressures, however, are not enough to drive the blood back to the heart, especially from the lower limbs.
>
> How, then, does blood get back to the heart? Let us return to William Harvey's experiments to answer that question. In one of his experiments, Harvey tied a band around the arm of one of his subjects, restricting venous blood flow. The veins soon became engorged with blood, and swelled. Harvey then placed his finger on the vein and pushed blood toward the heart. The vein collapsed. Harvey repeated the procedure, but this time he pushed the blood back toward the hand. Bulges appeared in the vein at regular intervals. What caused the bulges? Dissection of the veins confirmed the existence of valves.
>
> The valves open in one direction, steering blood toward the heart. By attempting to push blood toward the hand, Harvey closed the valves, causing blood to pool in front of the valve. The pooling of blood caused the vein to become distended. However, by directing blood toward the heart, Harvey opened the valves, and blood flowed from one compartment into the next. (Ritter 1996, p. 725)

In the text, William Harvey is represented as the founder of the blood circulation, which is reinforced by the addition of his original drawing from the past. His drawing becomes a unifying icon of scientific discovery and pretentions to be scientific.

Epicization in the Classroom

Epicization occurs not only within textbooks but constitutes a form of teacher–student–textbook relation from which emerge the images of science as epical endeavors. From all media used in the curriculum, textbooks have the most authoritative role. This counts for the science curriculum as well. Indeed, "more than any other single aspect of science, that pedagogic form has determined our image of the nature of science and the role of discovery and invention in its advance" (Kuhn 1970, p. 143). It is well documented that science teachers over-rely on textbooks when planning lessons. The selected textbook determines the scope, sequence, and depth of the lessons implying that a textbook's inclusion of content, in part, also legitimizes its inclusion in the curriculum. It is reported as well that teachers hold ideas of scientific practice based on the views expressed in science textbooks. Therefore, it is likely that teachers regularly discuss representations of the kind exemplified in the Harvey's. In our developmental research how the working of the cardiovascular system is taught (van Eijck 2006), we monitored a science lesson in which epicization with this drawing and text actually happened in situ. In the beginning of this lesson, as a 20-min assignment, students have read a 500-word text comparable to that of the first case on Harvey's discovery of the blood circulation as a closed circuit, including Harvey's original drawing. In the following excerpt, we enter the point in the lesson at which the teacher starts a discussion of Harvey's discovery:

1	T	I take out Harvey here since he is actually the one who . . . well his theories . . . actually, we still assume that today they are as even sound as he has presented in those days. [. . .]
2	T	What did Mister Harvey say?
3	S1	Blood is streaming in one direction.
4	T	Blood is streaming in one direction. How did he discover that?
5	S2	He discovered that because there are valves in the heart.
6	T	How can one observe from the valves that the blood is streaming in one direction?
7	S2	Well, because the valves open in one direction only.
8	T	Who knows, for example, how in the heart . . . how in the heart things are occurring with the valves? [silence]
9	T	If you know what the heart is used for – I hope you have written down several things next to another – what requirements should the heart meet?

Here, one can observe how the teacher, perhaps unwittingly, reinforces the epic stature of Harvey: "we still assume that today they are as sound as he has presented in those days" (turn 1). Thus, Harvey's epic from the past is the single source and beginning of everything good for all current times as well. Reinforcing and recalling the past in which it emerged while mitigating any attempts to change it by our present knowing thus maintains the linguistic unity of the representational system at stake. Typical for these forces, the time–place dimensions of author and audience, on the one hand, and that of the hero and his time, on the other hand, are completely separate and impenetrable (Bakhtin 1981). Typical for the epic, the two worlds, the one that creates the text and the one represented in the text are "set off by a sharp and categorical boundary" (p. 253). This is the very reason for presenting an original drawing of Harvey's experiment that can only confirm what is already being expressed through verbal symbols. Indeed, in the epic, "it is memory, and not knowledge, that serves as the source and power for the creative impulse. That is how it was, it is impossible to change it: the tradition of the past is sacred" (p. 15). Furthermore, the case shows that the students play their part in the reproduction of the unitary language. The turn-taking routine that the teacher and his students enact has been described as IRE, whereby the teacher *I*nitiates an exchange by posing a question (e.g., turns 2 and 4), a student *R*esponds (turns 3 and 5), and the teacher *E*valuates (turns 4 and 6). Such turn-taking routines are at the very heart of the linguistic construction of knowledge, that is, at the construction of science as a unitary system.

The epic nature of the representational system of science education is not unique for the cases presented. In the science education literature, several studies have described the epic nature by means of which scientists are represented in science education. For instance, one study, which we discuss in greater detail in Chap. 1 of this book, concerned representations of ten scientists who are pivotal to almost every biology textbook, such as Darwin and Mendel. This study found that scientists' actions are presented in a highly epicized way that does not allow students to reconstruct how they arrived at their conclusions.

Epicization in/of Contemporary Representations

One may argue that not only famous scientists and their past actions are represented in science textbooks. However, epicization also works in other forms of representation. Take, for example, the practice of graphing, a representation practice common in science textbooks and quintessential to scientific endeavors of representation. Our studies on graphing in both the domains of ecology and blood transport revealed that graphs, although observable less frequently in science textbooks than in scientific journals, are important types of representations comprising a substantial part of all representations in textbooks. Moreover, graphs are typical for school science in the sense that interpreting them can be considered an aim of all science subjects. In the same studies, we found that a particular kind of graph is most frequently observable in science textbooks. This kind of graph constitutes graphical models representing outcomes of mathematical simulations in an iconic way, without scaling the axes or adding units of measurement. For instance, of the 58 graphs found in ecology sections of three science textbooks frequently used in Canada, 45 graphs were of this type. More or less the same counts for the section on human transport of two science textbooks frequently used in the Netherlands; of the 37 graphs found, 28 graphs were of this type. One example of this type is a representation from a textbook that is commonly known as an electrocardiogram (Fig. i.2).

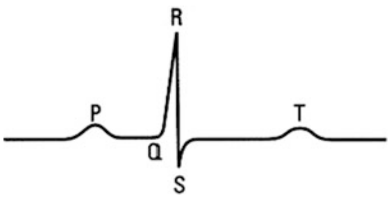

Fig. i.2 Electrocardiogram as represented in a common Dutch science textbook (Used with permission from Maier and Van Wijk 1999, p. 109)

In the graph, one can observe a non-straight line with letters above and beneath its particular features. In the textbook, the graph is accompanied by a caption saying "**31** Electrocardiogram." Accompanying the figure and its caption is the following main text:

> Heart graph – A physician can register the electric activity of the heart on the electrocardiograph with electrodes on the skin. Source 31 gives schematically the result: an ECG (electrocardiogram). During one heartbeat, the ECG of a healthy person shows three peaks. The P-peak reflects the electrical activity in the atria. Due to dissemination of the impulse over the ventricle walls the QRS-peak emerges. Refraction of the ventricles causes the T-peak. (Maier and Van Wijk 1999, p. 109, our translation)

This representation brings us right into the present where ECGs can be observed in hospitals and in television series. However, even in this case, the representation is contributing to the maintenance of a unitary language through epicization by "the work of framing and contrast that is in operation during the production of scientific images aims at generalizing and *reducing* the signification to the single 'message' given in the scientific text it accompanies" (Bastide 1985, p. 142, our translation, emphasis added).

To develop our understanding how this graph of an ECG exemplifies epicization, we draw on the notion of a *chronotope* developed by the Bakhtin circle, which defines a narrative's linguistic unity in relationship to an actual reality. Accordingly, space and time, as they appear in forms of representation, should not be taken as some reality external to the articulated account of human life. Rather, they should be perceived as constitutive moments of theme, story, and plot that have organizational and constructive function in the narrative—as spatial and temporal categories of human thinking. Thus, "the object of representation—the natural or historical phenomenon – is now evaluated in terms of ... its constructive role in the closed unity of the work, in terms of its constructive expediency" (Bakhtin and Medvedev 1978, p. 47). Hence, Bakhtin, while rethinking the recounting of space and time in the novel from a dialogical perspective, refers to the idea of the space–time continuum as chronotope, a unit that defines the relation of the unit of the narrative and the world we inhabit. This unit ties and unties the "knots of narrative" (Bakhtin 1981, p. 250). Each point of view is chronotopic, which is to say, that it is co-inclusive of time and space:

> We cannot help but to be strongly impressed by the *representational* importance of the chronotope. Time becomes, in effect, palpable and visible; the chronotope makes narrative events concrete, makes them take on flesh, causes blood to flow in their veins. An event can be communicated, it becomes information, one can give precise data on the place and time of its occurrence. It is precisely the chronotope that provides the ground essential for the showing forth, for the representability of events. And this is so thanks precisely to the special increase in density and concreteness of time markers – the time of human life, of historical time – that occurs within well-delineated spatial areas. (p. 250)

The case of graphing features a chronotope commonly used in science education. The chronotope is what allows us to connect the line and accompanying texts—the linguistic unity of the narrative—to the actual changes in the potential difference between different parts of the heart occurring over time of about 1 s—an actual reality in scientific terms. This chronotope is deeply rooted in a particular ideological discourse of the biophysical sciences. Only from and within this discourse can one understand that this line is used to express the relationship between two sets of measurements of time and voltage. In this sense, the chronotope that allows us to connect this graph to a physical reality is fundamentally different from those that can be found in narratives featuring pictures and naturalistic drawings, which share with readers' everyday lifeworlds, the nature of spatial relationships. Graphs, on the other hand, create new spatial relationships that may have little to do with the spatial relationships of our experience. That is, the graph (Fig. i.2) profits from the exploitation of two particular dimensions. However, through the superposition of arbitrary labels, these dimensions are no longer spatial but can refer to anything that a scientist deems relevant—for example, in this particular case, time and voltage.

The chronotope featured in the case of the electrocardiogram—tracing its origin to the origins of modern science in the work of Galileo and Descartes—is rooted deeply in biophysical scientific discourse (ideology). That is, in the graph, we observe the complete absence of any axes and labels for units and quantities that shape the chronotope for someone who is not familiar with the biophysical discourse. Students are not familiar with this discourse at all. Indeed, being part of a textbook, this text's aim is to familiarize students with this discourse in the first place. The result is that the physical reality represented in the case of the electrocardiogram is in fact inaccessible to students. Indeed, a study that used this graph and its accompanying text shows that students, who had previously used the textbook in a course on the blood circulation, could not identify the nature of its Cartesian plane as defined by its two particular dimensions representing voltage and time. Thus, the graph features a form of epicization that is of a different order than in the previous cases. In this case, the maintenance of a unitary language works chronotopicly, by limiting access to forms of space and time required to enter the discourse that places the representation into a signifying relation with other things. Alternatively, entering the discourse of science requires high levels of familiarity with this discourse in order to establish the signification of the forms of time presented in the graph. In any case, the establishment of connections between the represented physical reality and students' present knowing is mitigated by the chronotopic features of the linguistic unity of which he graph is part. The graph itself becomes part of an epic—an epitome representing various scientific narratives related to the heart but not longer granting access to these narratives in terms of the physical reality it represents. Accordingly, the stability of the unitary language in science in textbooks is maintained at the cost of limited possibilities for students to read the texts using this language and to contribute to a scientific discourse with their own voice, let alone to question or refute it. Along these limited possibilities for decoding and contributing to the discourse, linguistic norms in science education work toward concrete verbal and ideological unification and cultural centralization. Although this chronotopic process of maintaining a unitary language is featured in this single case, it is certainly not unique. For instance, the above-cited textbook study of graphs in the domain of ecology in six representative high school biology textbooks, it has been found that chronotopic resources to facilitate graph reading and to establish connections with a physical reality were in all cases limited.

Novelization

In the previous sections, we show how epic features of the most mundane forms of science education, as featured in the cases, contribute to cultural centralization through the reproduction and maintenance of a unitary language. But in this book, we do not only aim at showing how epicization underlies the persistent problems related to imagination. To overcome these problems, in response, we propose a new approach to understanding valuing and keeping cultural diversity in science education. Pivotal in our approach is the rethinking of science curricula as constituting the novelization of representation practices of science. According to the Bakhtin circle, the process of novelization is the counterpart of epicization. Novelization refers to the process of continuous discursive stratification that defines the novel as a genre in the making. Characteristically, internalized in the novel's discourse is a dialog between more or less established literary genres and everyday "folk" languages. Such dialog actually develops ideas rather than allowing them to become reified and set in stone (Bakhtin 1984a)—as this would be typical of classical scientific language. It is precisely the internalization of this dialog that makes the novel such a powerful genre since it is the source of and the power behind the creative impulse it reflects.

Epicized as they are, current science curricula, in contrast, mainly allow for the *reproduction* of one prominent discursive layer through the maintenance of a unitary language. As featured in the case materials, it is the scientific discourse from yesteryear that is to be "transferred" to students. From a curricular perspective, it is the unifying discourse that ought to provide purpose and signification to the educational activities and the scientific terms to be "used" by the students (although the students may not experience it as such). After all, these cases reflect daily business in science education. Without this discourse, terms such as "QRS," "venules," and "electrical activity" would not have their common sense in the context of science and science education. Accordingly, pertaining to the linguistic characteristics of science education, the discourse of science of yesteryear brings about a centralizing tendency from which scientific words obtain their very particular significations. It is precisely epicization that maintains this centralizing tendency at the cost of cultural diversity.

In the Christian churches, we may actually find a suitable analogy for the point we make here. Prior to reformation, the Bible was available only in Latin, and, therefore, the priests were the only ones that could read it. Even part of the mass was read in Latin. This constituted a centralizing tendency toward a dominant discourse, which was determined, according to Bakhtin, by the church. On the other hand, during Reformation, Martin Luther translated the Bible into vernacular, thereby making it possible for any literate person to read and interpret the book. This has led, as history shows, to a proliferation of interpretations and a large number of organized protestant churches along the lines of specific readings and interpretations of the Bible.

Another discursive layer—the one on which the language of science education unfolds in its own typical way—is creeping out of the cracks of what is linguistically kept together by the dominant literary genre of the natural sciences. Characteristic of this discourse is that it must allow for students' "folk" language at least to some extent, in the way it has happened to the reading of the Bible during Reformation. Accordingly, in the process appear intermediary languages by which concepts share sense and signification from both the scientific discourse and students' vernacular. From a scientific perspective, the use of these intermediary languages may lead to the use of words and significations that do not exist in the discourse of science. Indeed, as any science teacher will admit, using the language of the natural sciences *as is* will not help much in engaging students in the discourse of science. Students may even resist the discourse of science actively, despite their ease in appropriating its epistemic and cultural behaviors. Thus, in the typical discourse of science education, there is already a decentralizing tendency as well—one that attempts to disrupt the dominancy of linguistic characteristics from the natural sciences.

The struggle between these two tendencies, one centralizing and another decentralizing, results in "linguistic stratification" (Bakhtin 1981, p. 67). Once dominant literary genres and "folk" languages are woven together in novelized discourses, new literary genres with their own specific linguistic characteristics may emerge. Thus, internalized in the discourse of science education, there is already some kind of a dialog between the language of the natural sciences and students' "folk" language as a result of which the language of science education develops another discursive layer with its own literary genre. Yet, this dialog, as the featured cases show, is severely limited, resulting in serious problems with appropriating cultural diversity. What is more, such a limited dialog between science and students' "folk" language is remarkable given the very ends that are to be achieved in *both* science and science education.

There are many studies of science, philosophical and empirical, leading to as many theories of scientific development. Yet, all these theories agree upon the phenomenon that scientific development depends on the continuous renewal of ideas underlying the ways in which scientists approach, observe, and ultimately understand the natural world. Since new scientific ideas come with their own typical discourses (paradigms), inherently a process of discursive novelization is going on in the natural sciences continuously. Indeed, in the process of science, established scientific discourses are deconstructed and replaced by new discourses, giving way to entire new languages, concepts, practices, technologies, and ideologies. Science education, in turn, aims at providing students an understanding of this process of scientific development. Any contemporary curriculum document prominently features the aim to let students understand that our current knowledge of the natural world is not eternal at all and may be subject to refutation, criticism, renewal of ideas, and, in short, change. As well, students are expected to learn that our current knowledge of the natural world is the result of a long human endeavor during which many different paradigms existed and that no single paradigm has shown to be eternally true. Thus, the cultural centralization in the discourse of science education, as featured in our case materials, is inconsistent with both the aims of science education and the development of science more generally.

In response to this inconsistency, we propose abandoning the dominant notion of science curricula as *resembling* the scientific discourse of yesteryear, since this notion comes with its maintenance of a unitary language and hence cultural centralization that does not allow for valuing and keeping cultural diversity in science education. Instead, in this book we propose to rethink science curricula as *constituting* the novelization of representation practices of science itself. That is, in line with the very aims of science education and the development of science, science curricula can be thought of as avenues along which students engage in the ongoing novelization of scientific discourses—with the ultimate goal of making these relevant to the daily lives of the students. Accordingly, these avenues should help rather than withhold students in rupturing established discourses and replacing these with new discourses based on their own "folk" language, thereby giving way to new languages, and inherent ideologies (ideas). This notion of science curricula as *constituting* the novelization allows for a science education as a continuous genre in the making capable of appropriating increasing cultural diversity.

Outline of This Book

In the preceding sections, we sketch two central sets of concepts—epic/epicization and novel/novelization—that we see as lying at the heart of the images of science that students form in/through their participation in current science education. In the remainder of this book, across its four parts, we gradually elaborate how we understand the imagination of science in science education in terms of *epicization* and *novelization*. In Part I, we provide more flesh to the process of epicization of science in science education. We do so by taking a close look at the work of scientists. On the one hand, we dig deeper into the issue of the images of scientists in science textbooks, going beyond the snapshots provided in this introduction. On the other hand, we compare these images with the work of scientists in real life. Accordingly, in this part, we provide solid evidence of an epicized image of science in science textbooks. In Part II, this epicized image of science is contrasted with the need of today's science education to appropriate contemporary images of science. Particularly in today's globalized world, there are more forms of knowing than the scientific alone, which has already been appropriated in science itself. Simultaneously, scientific practices are increasingly dynamic, interdisciplinary, and reflexive and continuously merging with other practices in society. Accordingly, in this part, we elaborate the need for novelized images of science in science education—an imagination capable of appropriating the dynamics of today' scientific practice. This need brings us to Part III of this book, in which we describe some first conditional steps in the project toward novelized images of science in science education. In each of these steps, we describe how fundamentals of science education are to be rethought to take us from epicization to a novelizing discourse. We scrutinize several key concepts in science education research such as scientific literacy, students' images of science, and the connection between students' lifeworlds and science education. Taken together, these examples provide a methodical base for rethinking imagination in science education. Drawing on these methodologies, we sketch in Part IV the contours of a science education that aims at the production of images of science through novelizing discourse. As it turns out, this science education is radically different from traditional science education to which epicization is central. This science education targets the construction of images of science from the connections with students' lifeworlds. Moreover, the epistemologies of science education need to be rethought to allow for such a production of novelized images of science. In the tradition of Bakhtin's literary theory on imagination, we allow a novelizing discourse to emerge from this volume—one in which science education itself becomes the target of irony and receives an entirely new meaning. Such a science education, as it turns out, allows learners to ridicule epicized images of science through the lens of the fullness of their own life instead of the usual other way round, that is, a science that ridicules its learners' lives by the fullness of its epicized images.