The materiality of narrative spaces: A theatre semiotics perspective into the teaching of physics*

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Abstract

In this article we discuss the concept of "materiality" within a framework created by two apparently divergent fields, which, however, converge with regard to their pedagogical and communicative content. Theatre semiotics proposes forms and structures that shed light on such material aspects of learning environments related to physics as the instantiation of "narrative spaces." Our perspective focuses first on the modalities by means of which various sign-vehicles (i.e., verbal, visual, kinesic-corporeal or sound-related signs), being agents of narration, define spaces, and, second, on how such spaces as referents are linked with reality (i.e., on real, imaginary, and abstract spaces).

Keywords: *materiality; physics teaching; theatre semiotics; narrative spaces; science education.*

1. Introduction

The invasion of *materiality* into the world of meanings has shown that cognition is affected by the nature of the perceptive data of any event. Hence, the need arises for dealing with the (educational) environment as a synthesis of semiotic agents that interact, while producing meanings (e.g., Roth 2001; Pozzer-Ardenghi and Roth 2006; Tylén 2007). In the field of science education, the established contemporary view about teaching is that students' interpretations depend on their already constructed *mental world* (e.g., Giordan et al. 1994; Ravanis et al. 2008), on the *social dynamics* developed among interlocutors (e.g., Ravanis 2000), but also on the (*material*) *parameters-signifiers* of the environments of learning (e.g., Roth et al. 1999; Lemke 2003; Ravanis 2005).

With regard to the teaching of physics, a significant element that proves its materiality is that signifiers in the classroom have referents that can also place

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the student in "external" landscapes. Even a video of a cyclist going into a turn and leaning his body (appearance of centripetal force — start of precessional motion) is a signifier that requires the student to enter the respective space. The same occurs when somebody narrates the story of a star's transition from a red giant to a white dwarf, or hears the sound of the siren of a moving police car (change in the perceived frequency — Doppler effect). In all these instances, the signifiers that shape the materiality of the learning environment make spaces by "narrating."

Ochs et al. (1994) lay stress on how physicists build intertextual stories by journeying into worlds (narrative spaces) constructed through *grammatical*, *graphical*, and *gestural* elements. Thus, the speaker constitutes a subject engaged in generating activities for interpretation (an active narrator on stage), but, by journeying into the narrative spaces, he/she also becomes an object of interpretation. The same researchers emphasize the role of graphs in the construction of narrative spaces in intertextual stories, pointing out that graphs carry physical properties incorporated in the multimodal text. Thus, they refer to *boundaries that delimit conventionally defined spaces* (e.g., a graph representing an accelerated car depicts a motion confined in two dimensions), to the *visual aspects of the spaces themselves*, which actually frame narratives (e.g., a graph of the accelerated car has referents in the real world but is a line that is essential in related narratives: the words uttered necessarily describe the form of the graph), and to the *static quality of the graph that works against the dynamic nature of the stories these physicists tell.*

Pozzer-Ardenghi and Roth (2009) have recognized the dynamics of semiotic resources that act in order that spaces from outside should be generated into the science classroom. Analyzing science lessons, they discuss how changes in the position of the teacher's body as well as in body movements, the verbal markers (i.e., pronouns) and the prosodic markers (i.e., markers connected with the intensity, pitch, and speed of words uttered) are factors that make narrative frames. Actually, the aforementioned researchers shed light on how the function of the reference can lead students to imagine themselves as participating in activities in outer (narrative) places — different from the classroom's setting. In addition, Roth and Lawless (2002) mention that, when inscriptions are used, the emergence of gestures (usually iconic) can shift the listener from the locus of the inscription to a narrative space; the narrator usually co-defines this place by using gestures. However abstract, iconic gestures are in principle representational forms that communicate referents not located in the space where the event takes place (Roth 2001; Pantidos et al. 2008). Pozzer-Ardenghi and Roth (2008) have also investigated how gesticulations repeated in connection with the words uttered by the teacher over time can serve to conceptualize entities. They come to the conclusion that specific gesticulations repeated by the teacher in science narratives

function as anchors contributing, among other things, to the speaker's narrative style.

From this perspective, Pantidos et al. (2008) analyzed in terms of theatre semiotics how the body of teachers functions during physics lessons and how both the body and the words of the narrator can represent entities that define spaces; the speaker at the same time describes and performs kinesically the situation of a human being or a personified entity (e.g., a particle), either by taking the role of an external narrator, or by placing him/herself into the narrative space. In the latter instance, the narrator puts him/herself into a non-tangible space (i.e., "I am a neutron"), but also acts in the role of the personified entity (i.e., "I [i.e., 'me the neutron'] can cause nuclear fission").

This study approaches the concepts of *materiality* and *narrative spaces* with respect to the teaching of physics. Our main idea is how the material aspect of learning environments refers to spaces by "narrating." Actually, in dealing with the referential function of signs, we investigate how the construction of narrative spaces depends on the nature of the signifiers appearing during the teaching of physics. It should be stressed that the present study includes utterances as part of the concept of materiality. Considering that uttered words are sound waves that disturb a material medium (e.g., the air), it seems reasonable to assume that these particular waves become "vehicles of meanings" because their specific regularity arouses the hearing system of the receiver (listener). Hence, speech, like any other form of matter or energy that can stimulate the human senses, can be recognized as materiality.

The methodological framework for this study arises from theatre semiotics, which lays emphasis on audiovisual communication in theatre and can prove an appropriate field for analyzing the teaching of physics (e.g., Pantidos et al. 2008). The paradigm of teaching as theatrical performance is a fruitful research orientation, which allows us to explore learning as a sign-making process (e.g., Ochs et al. 1994; Pantidos et al. 1996; Tselfes and Paroussi 2008). What follows begins with a discussion of narrative spaces as they are approached by sociology, anthropology, and cognitive sciences; then, as far as the teaching of physics is concerned, theatre semiotics analysis is used for exploring *the semiotic resources of narrative spaces as well as the relation of narrative spaces with reality.* Thus, we show how such spaces are formed by *verbal*, *visual*, *corporeal*, and *sound-related* sign vehicles, and narrative spaces are finally classified as *real*, *imaginary* or *abstract*, depending on their content. Among the nineteen examples taken from physics lessons, seven were recorded from school classes of Fotis Vallinas, Vassilis Raissis, Nektarios Protopapas, and Spyros Sagias, eight were recorded from the personal teaching of the author Panagiotis Pantidos, and four were made up, in order to illustrate cases that theatre semiotics puts forth. Finally, descriptive examples of "space composed

by sound," "mythological" and "abstract spaces" do not appear as separate extracts, but are incorporated in the text.

2. Signifiers construct narrative spaces

As narrative spaces are generated by environments "narrating," that is, creating them by means of language or other semiotic resources, mental representations of such spaces (signifieds) are influenced both by the framework in which they are created, and by the nature of related signifiers (Donald 1997: 181). Actually, any form of description of space, whether it is based on story-telling or images, mentally shapes entities that are either present in or absent from the space of the action of speakers and listeners (e.g., Haviland 2000). Bruner (quoted in Pelletier and Astington 2004), considering that material semiotic vehicles entail mental representations of spaces, underscores the duality of each space represented as a tangible audiovisual *landscape of action* as well as a mental *landscape of consciousness*. Moreover, Kymäläinen (2003) mentions that the conceptualization of the spaces described by written word (*writing places*) cannot be seen independently of the text itself and the context within which it is presented. Usually, the landscapes constructed through written or spoken language are disclosed by a frame of reference in which spatial configurations correspond to linguistic expressions, such as the pointers "here," "there," "right," "left," etc. (Carlson 1999; Werner and Habel 1999). In addition, anthropologists emphasize the human body's ability to essentially form space (Pandya 1990), while a plethora of ethnographic studies lay stress on how the shifting and the orientation of the *human body* create spatial configurations (e.g., Rodman 1985; Kahn 1990), and Emmorey et al. (2000) study how the human body represents space through the American Sign Language (ASL). According to this research, the "speaker" adopts the *route perspective* when he/she is physically contained in the space gesturally defined, and the *survey perspective* when he/she is physically outside the space bodily represented. Emmorey et al. point out that ". . . a route perspective corresponds to experiencing an environment from within, by navigating it, and a survey perspective corresponds to viewing an environment from a single, external, elevated point, such as a tree or a hill . . ." (Emmorey et al. 2000: 158).

The material environment's capability of conceptualizing spaces is also identified by researchers in the fields of robotics and artificial intelligence: in this case, the focus is turned to the construction of artificial systems that can comprehend and produce verbal utterances, pictorial information, and gestures as spatial referents (e.g., Fröhlich and Wachsmuth 1998). Cussins strengthens this perspective arguing that ". . . representation is itself a physical object which has two kinds of properties; properties of the representational 'vehicle'

and properties of the representational 'content' . . . The representational vehicle is the medium that carries the representational content as its message . . ." (Cussins 1990: 369).

With regard to the nature of the signifiers that make up narrative spaces, de Souza e Silva (2006), addressing the traditional distinction between *physical* and *digital* spaces, explore how modern mobile technologies have eliminated the dividing line between these two genres. Indeed, she mentions *hybrid spaces*, which occurred from the moment cell phones incorporated the Internet. Thus, human communities that were used to communicate privately in so-called cyberspace can now, thanks to the mobile Internet, meet digitally, even in urban/public spaces. Hybrid spaces constitute a blending of physical and digital ones, and have their own social dynamics.

Concerning the relation between spaces and reality, in her study of environments developed in four video-games, Schwartz (2006) refers to textual and visual signifiers that create spaces characterized by *realism* or related to *fantasy*. Ryan (2003) recognizes a similar distinction in examining how cognitive maps contribute to the construction of narrative spaces, and explains that the places developed by such maps are either *real* or *imaginary*. Especially in the case of fantasy spaces built through virtual reality, it makes more sense to focus on the distinction between landscapes related to *realistic fantasy*, and landscapes related to *unrealistic fantasy* (Schwartz 2006). In the former case, the environment constructed, for example, in a video game, consists of realistic entities entangled in imaginary action and space in terms of a story or myth (e.g., the hero of the game might find himself in the Middle Ages yet be using a cell phone). By contrast, an unrealistic fantasy landscape comprises unreal elements (e.g., the hero is confronted with aliens on a starship).

3. The concept of space in theatre

Elam (1980: 99) aptly argues that the world (and space) of theatre is a temporal-spatial *elsewhere* reconstructed in the *here and now* of the time and space of the performance. The so-called *performance space* (otherwise theatrical, or scenic, or physical space or setting, cf. Kuntz 1993: 153–155; Valakas 1997: 285, 286), namely, the particular material space in which the theatrical event is physically carried out by performers before an audience, can serve for our purposes as a parallel to the science classroom. As far the theatrical phenomenon is concerned, the performance space materially "narrates," communicates, and, thus, mentally constructs *narrative spaces*. They are usually marked in the text of a play by means of references that specify them either as the spaces in which the dramatic action of personages is set (as the same authors explain), or as other places of interest for the personages. So, Ubersfeld (1981: 56–58)

suggests that the performance space is the starting point that supplies and finally defines all forms of spaces of reference in a play.

With regard to *the semiotic resources used for the construction of narrative spaces* in theatre, Pfister (1988 [1977]: 267–275) points out that spaces can be generated by *verbal* and *nonverbal* signs. The latter case had already been shown by Honzl (1976 [1940]: 75), who, commenting on the transformability of signs, had made clear that the world of theatre could be based on *gestural signs*[1] (as, for example, in pantomime), *visual constructions*, *speech* or other *sounds*. Thus, every audio-visual semiosis on stage "narrates" — and invites the audience to — particular places of "otherness."

According to the degree of abstraction they convey, narrative spaces in the theatre are referents either for real material entities or imaginary ones (e.g., melancholy feelings can be evoked by "a spring shedding tears of sorrow"). By analogy, in our following attempt to exploring theatre semiotics in the analysis of narrative spaces in physics teaching, apart from semiotic resources, it will be also important to consider whether signifiers refer to spaces which *exist in reality or to unreal spaces.*

4. Introducing the theatrical aspects of narrative spaces into physics teaching

4.1. *Semiotic resources used for the construction of narrative spaces*

In what follows, we deal with the *verbal* and *nonverbal (co-)definition* of narrative spaces in physics teaching, taking into account the parallel from theatre.

4.1.1. *Verbal definition.* In most traditional genres of theatre, the spoken word alone can construct a space in detail (Pfister 1988 [1977]: 267; Valakas 1997). In Example 1 from the teaching of physics the teacher also constructs a setting purely verbally:

(addressing a student)
"You're in a bus and suddenly the driver steps on the brakes. Which way do you move?"
(tenth grade, Panagiotis,[2] example 1)

However detailed it can be, the verbal definition of space may convey a varying degree of abstraction. In examples 2, 3, and 4 the utterances denote landscapes, but increasing the amount of related information decreases the degree of their abstraction.

"A 'body' moving along a 'horizontal plain' collides with another" (tenth grade, Panagiotis, example 2)

The "body" refers to anything, as might the "horizontal plain," while both may be contained anywhere. As soon as properties of these objects are given, the narrative space takes on a more concrete form:

"A 'ball' moving along a horizontal plain at a speed of 2 m|s collides with an immobile ball" (tenth grade, Panagiotis, example 3).

The "body" is now a "ball" (hence it can roll), which is moving at a certain speed. The denoted parameters offer the listeners more specific material properties as structural elements that can illuminate the meaning of the narrative space. When the properties of the objects referred to are revealed, or when more objects are added, the narrative space becomes even more specific:

"A 'red' ball moving on a 'billiard table' at a speed of 2 m|s collides with an immobile ball" (tenth grade, Panagiotis, example 4).

The "billiard table" is more specific than a "horizontal plain" and more powerful in terms of the information conveyed than the "red" color of the ball. Hence, it puts forth a space that is more complex (e.g., a room with many billiard tables, music at the background, smells, specific people around). Of course, if the narrative space is familiar to the listener he/she tends to conceive it with greater ease.

The very nature of the content of physics teaching, i.e., the study of the natural phenomena, usually entails a projection upon the outside world. For example, with regard to teaching in the form of an experiment Newton's second law about the motion of a wagon, the verbal signifiers used in the process as well as those that refer to the properties (shape, color, movement) of the wagon create signifieds outside the classroom (e.g., a car begins to accelerate from the moment the traffic lights turn green).

In example 5 (cf. figure 1), the teacher refers to a space outside the classroom (the classroom next door), inviting the students to "move" to it.

The phrase "by going to that classroom" transfers the "code" in another space. The reference could be supported by supplying images of the new environment, that is, the classroom next door. But this does not happen — perhaps because the new environment is already familiar to the students.

4.1.2. *Nonverbal (co-)definition.* The visual dimension of narrative spaces is traditionally realized in the theatre by the painted scenery, which, in modern

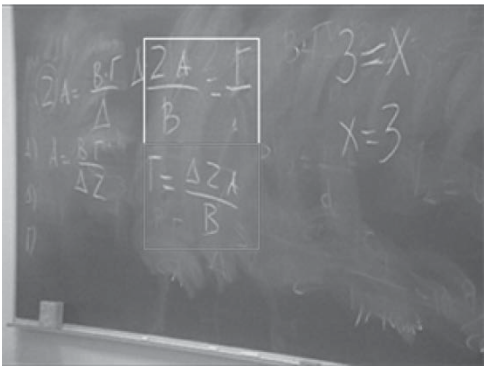

Figure 1. *Verbal definition of space outside the classroom. The teacher defines the spaces of the blackboard and the classroom, but also of the next classroom, through the utterance: "Don't worry with the left or right* [i.e., part of the equation on the blackboard]. *If you can't see it there on the right, you can look at the same equation from the classroom behind, by going to that classroom. In that case you will see it as if in a mirror, like you're used to, with the unknown factor on the left* [he writes the content: cf. frame below]. *It's simply a matter of habit" (eighth grade, Vassilis, example 5).*

theatre, has gradually moved away from the representation of landscapes and has been replaced by three-dimensional constructions (Fischer-Lichte 1992 [1983]: 102).

According to Appia (1981 [1960]), especially the kinesic function of the actor as a dramatic figure on stage is a prerequisite for the form of the scenery. The actor's movements, his pace, and moving about on the scenic space create patterns of spatial style. Moreover, Zich (1931: 226) mentions that landscapes can be defined not only by the spoken language and the tangible constructions in the performance space, but also by other sign vehicles such as the actor's body. Typical of this is the dramaturgy introduced by Beckett, whose plays emphasize on the visual image and the scenographic perspective prompted by the actor's corporeal function. Such an approach demonstrates the scenographic role of the dramatic figure and the dynamics of the actor's body, on par with language (Garner 1994: 54). Additionally, as Prazákova (quoted in Quinn 1995: 104) suggests, narrative spaces can be solely generated with the help of sounds as a kind of acoustic scenery similar to the one used in radio plays.

In conclusion, the nonverbal (co-)definition of narrative spaces in drama is either achieved *visually* and *kinesically (corporeally)* or by means of *sounds*.

4.1.2.1. *Visual definition.* Architectural, pictorial or sculptural artefacts, theatrical scenery and lighting are meant to signify spaces visually. As far as the design and the construction of the setting in theatrical genres is concerned,

in different periods we come across all possible tendencies, with technology and various materials constituting useful tools for "narrating" spaces (e.g., Bentley 1968).

Landscapes of physics in the classroom are also defined by *pictures of material entities*, *three-dimensional objects* or even the *moving image*. Depending on the form and structure of such representations, landscapes can be made more or less distinct. Example 6 (cf. figure 2), illustrating the conservation of mechanic energy, is the drawing of a skier preparing to go down a hill.

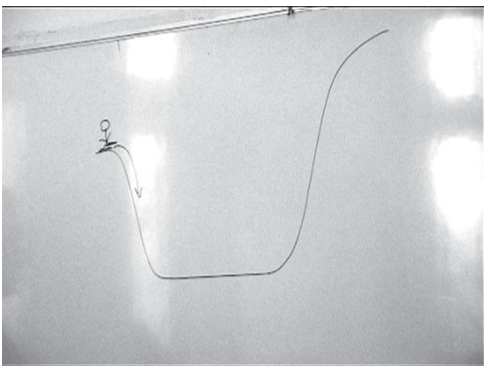

Figure 2. *Visual construction of a narrative space (ninth grade, Spyros, example 6)*

Moreover, spatial entities may contain a higher degree of abstraction (cf. figure 3, example 7).

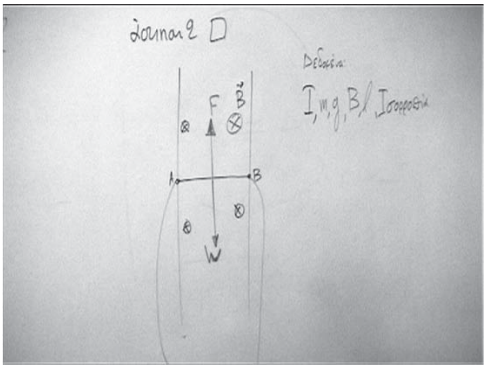

Figure 3. *An abstract visual construction of a narrative space. The horizontal conductor slides along two other conductors. The system exists within a magnetic field. At the two ends of the conductor a potential difference is created due to induction (eleventh grade, Fotis, example 7).*

Indeed, in figure 3 a conductor moves and is supported by two other conductors (drivers). Compared to the landscape created by the skier and the hill (cf. figure 2), that is, a landscape that can be linked with the real life of the students, this one is depicted as highly abstract: a conductor sliding down two others and the space where they are, cannot be part of human experience and can only be represented by symbols. In fact, such symbols as, for example, the arrows that indicate forces in figure 3, form specific conventional codes that students are required to know in order to understand the narrative entities and spaces of physics (Pantidos 2008).

Comparably conventional environments can also be denoted by *three-dimensional objects*. In example 8 (cf. figure 4), objects such as a lamp, a thermometer, and a glass of water take up a "performance area" to represent the function of an electrical circuit.

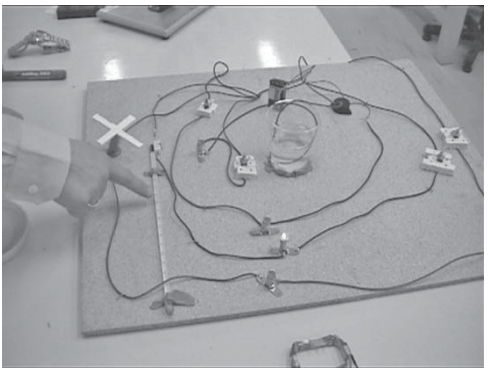

Figure 4. *Visualization of a space by means of three-dimensional objects. An electric circuit shows the thermal, magnetic, and other effects of electric current in suggested spaces (eleventh grade, Fotis, example 8).*

Apart from depicting the electrical circuit as a laboratory "world," objects in figure 4 can also evoke other narrative spaces of related interest: the thermometer and the increase of temperature may suggest spaces like a house where people use, for example, an electric heater.

Thus, objects and depictions of objects in the teaching of physics are usually combined with the spoken word so as to signify narrative entities and landscapes in material forms. While "narrating" such entities, their shape and properties, teachers and students can also manipulate them and make them act roles in different scenarios and spaces.

4.1.2.2. *Corporeal co-definition.* In example 9 (cf. figure 5), the teacher represents a space by using his body, and the whole image is supported by his

verbal description. What is being "constructed" is a swing, perhaps in a playground. As the swing "moves," it shifts from positions of maximum potential energy to positions of maximum kinetic energy and vice versa.

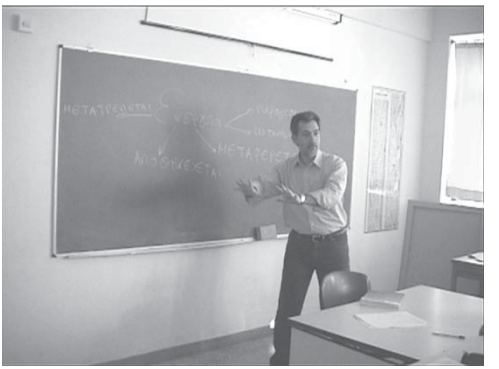

Figure 5. *Corporeal co-definition of narrative space. The teacher pretends to be pushing a swing during a discussion about the conversion of energy (ninth grade, Fotis, example 9).*

Accordingly, figure 6 includes corporeal signifiers of specific spatial referents.

Figure 6. *Corporeal version of a "downhill road" where a "car" is to move up and down (tenth grade, Panagiotis, example 10).*

The students can see in front of them the bodily semiosis representing (aspects of) spatial referents, while the spoken word describes these visual signifiers.

4.1.2.3. *Composition by means of sounds.* In a theatrical performance (as also in films and other performing arts), sounds serving the function of denotation define environments in terms of space and time (e.g., the clashing of swords would define the space of a battle in the past, Fischer-Lichte 1992 [1983]: 117–120). Thus, the whistling of a kettle may specify the space as the kitchen, and the geographical area as England or Russia, if it is a signal for teatime; the sounds of running water and dishes can denote that someone is standing at the kitchen-sink, etc.

Sounds, especially those connected with technical artefacts, denote aspects of the — natural or technological, external or internal — space in which they function, and the science teaching process can incorporate sounds produced by animate or inanimate entities in order to define narrative spaces. For example, the sound of roaring, galloping, fluttering, the sound of the northern wind, the crashing of waves, the eruption of a volcano, a storm, a hailstorm, a typhoon, etc., denote respective spaces: the sound of waves may denote the sea and the coast, the sound of an explosion may denote a goldmine, etc. Moreover, it is possible to use any sounds produced in a physics lab or specifically by technological means such as the sound of a clock, the siren of a police car, the screeching of brakes, the sound of two cars crashing. In all such cases, sounds produced by appliances and machines suggest respective natural phenomena and laws. The whistling of a steam engine can evoke a space (e.g., a rail station) and the function of boilers according to the first law of thermodynamics, and so on; the sound of an airplane "narrates" the space through which it flies, and is linked to accelerated motion, the Doppler effect, sound waves, etc. Even in the "sonic scenario" of a typical car chase the sound of the police car siren "fading" in the distance, the screeching of tires, the slamming of brakes, and the sound of the crash, all these signifiers "narrate" a landscape that communicates natural phenomena, respectively the Doppler effect, static friction (as centripetal force), decelerating motion and impact.

Given that the development of technology with regard to machines is accompanied by an evolution in terms of sounds, the quality of sounds can also denote the era of related (technological) environments. Thus, the sound of a steam-engine whistle places the scene in the nineteenth or early twentieth century, while the sound of a jet turbine places it in the post-war era. Yet both sounds can be used as joints in a teaching scenario in which science and technology are interconnected.

4.2. *Narrative spaces and reality*

4.2.1. *Real spaces.* Narrative spaces in physics teaching regularly signify *real referents*, namely, existing in natural or technological environments, but it

is not always possible for the viewer or listener to touch them physically. In the classroom, such *real narrative spaces* are constituted by any kind of "narration" or "scenery" and can be tangible or intangible.

In example 11 (cf. figure 7), by means of the spoken word and a quite realistic illustration, the teacher defines a landscape in which someone is exerting a force on a crate.

Figure 7. *Visual construction of a real narrative space. The verbal text co-defines the generated space: "In order to pull a crate with a rope the two bodies have to come in contact" (ninth grade, Nektarios, example 11).*

This landscape, whatever mental image the student makes out of it, is tangible for the student, as is any other space that forms a part of the mesocosm.

Conversely, real narrative landscapes that are part of the microcosm or megacosm deprive the student of the possibility of any such contact. In example 12, the teacher refers to nuclear fission and verbally defines the respective landscape in the following way:

"In a nuclear reactor a neutron collides with a nucleus of uranium-235" (twelfth grade, Panagiotis, example 12).

As the schematic illustrations in example 13 shows, this landscape from the microcosm, the exact space where the nuclear fission takes place — in contrast with the building housing the nuclear reactor — is obviously not palpably accessible for the students (or anyone else; cf. figure 8).

A similar remark can be made when the referent entities of real narrative spaces come from the megacosm (cf. example 14).

"A neutron star revolves" (tenth grade, Panagiotis, example 14).

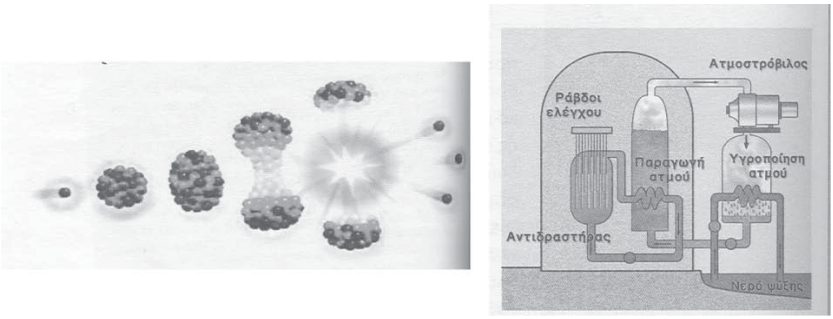

Figure 8. *Schematic depictions of the inaccessible space of nuclear fission and the accessible space of a nuclear reactor (twelfth grade, Panagiotis, example 14; Georgakakos et al. [2002: 90]; N. Antoniou et al. [2002: 328]).*

The semiosis of narrative spaces and the forms of related sign vehicles is a major theme in theatrical theory and practice. Antoine (1858–1943, cf. Braun 1982: ch. 2), a French actor and director, and a pioneer of theatrical Naturalism in Paris at the end of the nineteenth century, held that the performance and the setting had only to depict the tangible world of reality by means of almost photographic realism; in 1906 he staged Ibsen's *Wild duck* with a scenery of real Norwegian fir trees. By contrast, advocates of theatrical Symbolism in the early tweentieth century (cf. Hartnoll 1968: ch. 11; Braun 1982: ch. 3–7), such as Appia (1862–1928), Craig (1872–1966), Reinhardt (1873–1943), but also the realist Stanislavski (1863–1938), came to believe that the theatre had to shift from the illusion of realism to a more abstract essence of things (cf. Dusigne 1997). In the aforementioned perspectives, all more or less realistic, schematic and abstract forms of sign vehicles and sceneries were legitimized to signify the "real" or "unreal" worlds and spaces of art and theatre (Fischer-Lichte 1992 [1983]: 102).

4.2.2. *Imaginary spaces.* In the teaching of physics, narrative spaces are often imaginary. The analogy from art and theatre is still helpful in that the hypothetical landscapes of physics and the sign vehicles that create them can evoke and, at the same time, distance themselves from the real world, by combining references both to real and to unreal, fictive entities and relationships (Elam 1980: 101–103; Fischer-Lichte 1992 [1983]: 102).

"Sergey felt the end as soon as the black hole that appeared before him was pulling his starship" (Invented, example 15).

The spatial set-up in question is a composition of real elements, such as the "starship" and the "black hole" existing in natural or technological environ-

ments, but it creates a non-existent world. A manned starship cannot travel into space and approach a black hole; hence, no environment can contain both these entities at the same time. Nevertheless, the construction of such unreal spaces is necessary for the purposes of scientific research, and is exemplified by the spatial set-ups in thought experiments of Einstein.

Example 16 describes a landscape that also clashes with logical rules and with typical definitions of entities.

"How wonderful it is to travel on a ray of light! I have to remember to bring my stopwatch with me. It's incredible . . ." (Invented, example 16).

The "ray of light" and the "stopwatch" no doubt belong to the real world of matter and energy, but are combined in a dream landscape. The speaker enjoys the unique possibility to travel on a ray of light, taking measurements at the same time.

In the comparable landscape of example 17 (cf. figure 9) existing entities are put together with the ones that no longer exist in the real world.

Figure 9. *Visual representation of imaginary narrative spaces. Two constructed narrative worlds contain contemporary entities (i.e., an explorer, an airplane) engaged with prehistoric animals: the paradox is interesting (Walking with Dinosaurs, produced by the BBC, Kathimerini Newspaper 21 April, 2006 and 5 May, 2006, cd. 2, 4, Invented, example 17).*

It is clear both that the airplane and the explorer exist and that prehistoric animals once existed as characteristic entities of different periods in the world of matter and energy, but their combination under special conditions produces only imaginary landscapes and times.

In examples 15, 16, and 17 from physics teaching, elements retain their typical properties while "narrating" unreal landscapes: a starship is travelling, a ray of light is travelling with the speed of light, an airplane is flying, a diver is

swimming. An interesting question is what kinds of worlds can be constructed, if the properties of the entities comprised are perverted. In fact, we encounter such landscapes every day in science-fiction films, cartoons, shows of illusionists etc. In Example 18, the teacher makes a landscape of this kind by asking students to "hang from the ceiling like a bat" (cf. line 4) in order to solve an equation.

"Therefore, we have to solve it in terms of D. What are we going to do? . . . (A student moves the numerator writing $\frac{E \cdot A}{B \cdot C} = \frac{1}{D}$*). That's your idea, eh? . . . And you want us to bring B·C here. And what'll be left on the right? And then? (discussion with the student). And then, you remember the bat, right? We hang from the ceiling like a bat and look at the equation upside down, right? Which means (he writes* $\frac{B \cdot C}{E \cdot A} = D$*) . . ."* (eighth grade, Vassilis, example 18).

By appropriating the alien property of "hanging from the ceiling like a bat," the students are able, in terms of this spatial fiction, to see the world upside down and solve the equation from the ceiling.

A comparable imaginary world is described in example 19 (cf. figure 10).

Figure 10. *Visual representation of an imaginary narrative space co-defined by the text: "Planet SDF-12687 was different. People stood, walked and lived at a height of 3m above the ground." This drawing as well as the text are not contained in Le Petit Prince by Antoine de Saint-Exupéry, although they were obviously inspired by it (Invented, example 19).*

The entities "planet" and "people" compose the landscape in Example 19. In that space, however, people have an added, imaginary property, that of hovering. One could claim that human organisms on that imaginary planet can interact considerably with some other force except from gravity and fly. For example, an appliance could be exerting on the little Prince an electromagnetic force opposite to his weight, or else the little Prince could be occasionally standing at such a distance between two planets as to be subjected to their equal gravitational forces, etc. Although such narratives seek for explanations of clearly imaginary situations, they can be very useful in the process of teaching as they can tend to emphasize on the possible existence and meanings rather than the non-existence of imaginary worlds. The appeal of science fiction on the public offers a telling — though extreme — example. Unreal entities in the context of science fiction generate landscapes that can be described as *"mythological" spaces*. For instance, verbal descriptions, even three-dimensional material objects in films or stage adaptations (e.g., a vehicle carrying a fusion micro-reactor, an appliance that can teleport humans and objects as shown in the TV series *Star trek* etc.) specify original entities and spaces with no referents in the real world.

4.2.3. *Abstract spaces.* In extraordinary cases of narrative spaces constructed either by ambivalent visual or kinesic-corporeal or verbal or other sound-related signs in physics teaching, no explicit correspondence can be discerned between the semantic content and material reality. Spaces that take shape in such cases are *abstract*. Verbal expressions such as "a body moving at a speed of . . ." or "a force exerted on a material point" contain terms that do not specify concrete material referents, but can evoke various existing entities. In the aforementioned examples, "body," on the one hand, can indeed imply entities that differ in terms of their properties: e.g., an eraser or a fire-extinguisher that are not self-propelled, as well as a car; on the other hand, "material point" can somehow relate to and replace either two- or three-dimensional objects, even though a material point is originally considered with no dimensions. Consequently, terms defining abstract narrative spaces involve a large degree of polysemy and can denote many referents at the same time.

5. Concluding remarks

The concept of *materiality* is constantly addressed when the material world is signified and interpreted. The essence of signs that emerge in any event is supplied and infiltrated by materiality. If materiality is one of the factors that construct a "descriptive language," then the semiotic approach to learning

environments in the context of the teaching of science seems not only to make a difference but also to take on a special dynamic. Besides, as it has already been mentioned, the teaching of natural phenomena in all grades is placed *de facto* in a material frame of reference that is based on the domination of the signifiers.

With regard to the aspects of narrative spaces that were analyzed, their semantic dimensions were primarily specified and examined in terms of their respective morphological modalities. Formal modalities have been considered on the intersection of theatre semiotics and the teaching of physics, but this approach may prove versatile enough to move between two apparently non-related fields. The cognitive aspect of the teaching of physics is thus approached from a very different perspective, by adopting a formalist point of view, while at the same time diminishing the aesthetic value of signs asserted in the theatre. Indeed, the study of signifiers can offer new orientations in the analysis of the teaching of physics, but also new prospects for the "engineering" of teaching practices, which normally follow the psycho-pedagogical paradigm (e.g., conceptual aspects, laboratory work, interaction, and discourse analysis). By describing the *material structure of events* within the specific context, a similar analysis can be applied to teaching approaches in other scientific fields such as biology and chemistry, and to research in scientific fields like artificial intelligence, robotics and informatics, which also deal with *descriptive languages*.

Notes

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1. Gestural signs involve the whole body, whereas gestures are linked exclusively with movements of the hands (Fischer-Lichte (1992 [1983]: 30).
2. The first name of the teacher and the grade are cited in each example.

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