Reshaping the Language of Mathematics and Physics: Some Intersemiotic and Interlinguistic Issues

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Abstract

This chapter aims to analyze some of the transformations the highly specialized languages of mathematics and physics undergo when adapted in the production of cultural goods, namely popular television productions. On this basis, it explores new teaching methodologies which might render the languages of these disciplines more interesting and stimulating for young adult language learners. The chapter thus analyzes audiovisual materials which intersemiotically translate the language found in various specialized texts (articles, books, textbooks, etc.) and describes the use of these texts and television productions as teaching materials during two third-year courses taught at the University of Parma in Italy for students of modern languages. These courses – which were taught in 2015–2016 and 2016–1017 – provided a useful testing ground for an innovative approach to teaching and learning English for specific purposes (ESP) with the aid of popular culture. In particular, the classroom experiment focused on the language of mathematics and physics found in Mario Livio's *Is God a Mathematician?* (2009) and Stephen Hawking's *A Brief History of Time* (1988) on the one hand, and in documentaries such as *The Story of Maths* (2008), *Origins*: *Back to the Beginning* (2004) and *Stephen Hawking's Universe* (1997) on the other. Moreover, the chapter examines the transformations the specialized language of science is subjected to when inserted in popular television series such as *Numb3rs*, *The Big Bang Theory*, and *Supernova*, in order to demonstrate the extent of the role played by specialized discourses within cultural industries. The chapter therefore suggests that this phenomenon has important repercussion on the very notion of *needs analysis*, and it argues that ESP syllabi should acknowledge its existence, offering customized teaching materials.

Part of
Ennis, M.J., & Prior, J. (Eds.). (2020). *Approaches to English for Specific and Academic Purposes*. https://doi.org/10.13124/9788860461711

1. Introduction: A New Notion of Science and Scientific Discourse

Even though Languages for specific purposes (LSPs) originated from within restricted communities of specialists and have for a long time been perceived as elitist forms of communication, it has become apparent in recent years that many of the disciplines they find expression in make a profound impact on the life of ordinary people too.

This is particularly true in relation to the language of mathematics and physics on which this chapter focuses, and is partly due to the fact that, during the first decades of the twentieth century, the way traditional science was shaken by new theories such as Einstein's General Theory of Relativity and Quantum Mechanics profoundly changed the mode in which people thought about the universe, science itself and, ultimately, their surrounding reality and themselves.

By abolishing the old notions of absolute space, absolute time, and a flat universe, and by stating that no measurement is any more correct than another, Einstein's theory basically undermined the claims of science to discover universal and fundamental Truths in relation to any event. The notion of absolute concepts was thus destroyed, and time and space appeared to be the interdependent elements of what was then called space-time which, in 1915, Einstein suggested was curved by the distribution of mass and energy, thus giving birth to what is now called the General Theory of Relativity. In addition, the General Theory of Relativity also predicted that the notion of a static universe would be abolished, for the reason that, if it actually were so, it would soon start to contract and collapse under the influence of its gravitational force. This was also predicted by the Russian Alexander Friedman, and the three different models of the universe which obeyed Freidman's two fundamental assumptions (namely that the universe looks identical in whichever direction we look, and that it would look the same from wherever we looked at it), and which shared the idea that at some time in the past, before the universe began to expand, the distance between the galaxies must have been zero, and the density of the universe and the curvature of space-time infinite. This moment corresponds to what is popularly known as the Big Bang (which provides the title to both Hawking's book and one of the situation comedies briefly discussed below), at which the universe and time itself are considered to have begun. Because it was assumed that the early universe was infinitesimally small, the small-scale effects could no longer be ignored. It was on the basis of the so-called Quantum Theory, which Max Planck formulated in 1900, that in 1927 Werner Heisenberg formulated, in turn, the Uncertainty Principle. By demonstrating the impossibility of measuring precisely the present state of the universe, Heisenberg's Principle – whose ramifications, as suggested below, are innumerable – illustrated the lack of tenability of a deterministic notion regarding the universe.

On the basis of the Uncertainty Principle, during the 1920s Heisenberg, Schrödinger, and Dirac reformulated mechanics into a new theory called Quantum Mechanics, according to which particles and waves were considered to behave identically, and could not have separate or precisely defined positions and velocities. On the contrary, they were said to be in a quantum state, in which position and velocity were combined. Because Quantum Mechanics cannot calculate a single and definite result for an observation, but predicts a number of possible outcomes, it naturally contributed to introducing an element of unpredictability into science.

The acknowledgement of the undermining of the claims of absolute Truth in science obviously had multiple repercussions, and led to the abolition of concepts of absoluteness in many different arenas, from biology (where, for example, it naturally put into question the *inferior* identity assigned to Others on the basis of *race*), to medicine (which had to concede defeat in the face of various diseases). As a consequence, over time the language itself of these disciplines began to change, as the lack of absolute objectivity of scientific observation began to be expressed through linguistic means. For example, the very compact structures based on nominal phrases with pre-modifications, heavily relying on participles – and often identified as typical of specialized discourse (see Gotti, 2008) – began to be replaced by *mitigated* phrases that relied much more on post-modification. Furthermore, rather than adopting impersonal constructions through the exploitation of either impersonal subjects or passive forms, the author of scientific prose too began to be present in scientific discourse in the form of first-person *I* (see Glanville, 1998). Naturally, this tendency to make specialized language closer to ordinary language has raised various concerns about the declining standards of the language of science (see Mills, 1997). Yet, it has simultaneously helped to provide a minimal scientific education which, while not providing an actual proficiency in specialized fields, has enabled the general public to partake, at least to a certain extent, in these disciplines, equipping them with some of the terminology and founding notions. As such, these popular (and popularizing) products seem to point to the creation of a more democratic administration of knowledge which – as for instance in the case of the medical language of psychiatry – played an important role in the development of a new approach to (mental) illness (see for instance the Democratic Psychiatry Society founded by Basaglia in 1973).

As discussed in more detail elsewhere (see Canepari, 2013), this attitude – together with the increasing demands made by average members of society to take part more actively in many aspects of social life and the decision-making processes that involve them directly – has led to drastic changes not only in the structure of society itself but also in the language spoken by its institutions, leading, for example, to Plain English movements of different kinds (see Steinberg, 1991). Undoubtedly, these processes were facilitated by the advent of the new technologies which enabled the public to retrieve with minimal effort information once available only to professionals. Furthermore, the spread of television largely contributed to this phenomenon, thereby justifying the perspective adopted in this chapter and offering a tentative response to the need for what Italian researcher Giuseppe Testa (2014) calls an innovative logic, capable of leading to a "science increasingly inclusive of the needs of an increasingly aware society" (online).

Because of this, the products on which this chapter focuses, and the research path outlined here, appear to acknowledge the evolution scientific disciplines and their languages have undergone, leading from the deficit model of *public understanding of science*, now outdated, to the notion of a *public engagement of* *science and technology*. The latter, in Pitrelli's words (2003), should engage "the publics of science, through… an open and equal-to-equal discussion between scientists and non-experts that would enable non-experts to become the actual protagonists in the scientific decisions producing social effects" (p. 5). Clearly, the approach suggested here is rather simple and unsophisticated. Nevertheless, it appears to be equally engaged in the construction of that "civic epistemology" Testa (2014) describes by stating that, since we live in a "knowledge intensive society," a civic exercise of confrontation and exchange is required, not only between scientists, but also between scientists and non-experts (online).

2. Mathematical Discourse and its Popularization: The Case of Pythagoras's Theorem[1]

As discussed in more detail elsewhere (Canepari, 2018), the relevance that disciplines such as mathematics and physics can assume in an individual's life is clearly stated in the opening theme of the pilot of the television series *Numb3rs* (Falacci, Heuton, & Jackson, 2015), where the voice-over emphasizes how we resort to the language of science every day in order to perform ordinary actions such as handling money or telling the time. Each episode of the series actually echoes the idea that the language of mathematics is at the very basis of natural phenomena, history, and human accomplishments since ancient history, a notion explored not only in other fictional products such as *Touch* (Sutherland, 2012), but also in the works by mathematicians such as Mario Livio (2002; 2009) and Marcus Du Sautoy (2003; 2007), on which the television shows seem to focus (see for instance: Kring, 2012, 00:00:01–00:01:09 and 00:28:51–00:29:44).

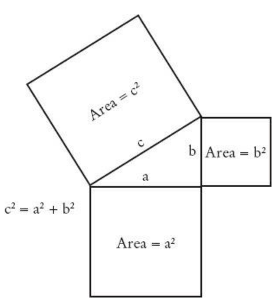
1 Some sections of this paragraph are partially based on a paper published in Canepari, M. (2018) *Reading Paths in Specialized Languages*, Parma: Athenaeum.

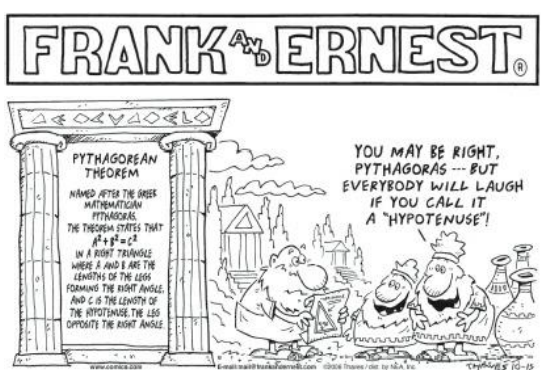
As a consequence, these products can become useful tools in a learning environment, in so far as they can be exploited to introduce some of the fundamental notions of these disciplines and their terminology, in order to train not only good students and/or translators, but also active members of society, able to interpret the signals that the contemporary world presents them when they perform ordinary activities. Moreover, these goods seem to work towards the transformation of science into that "collective enterprise" for which, for example, writer Antonio Giangrande hopes (2017). Indeed, since scientific knowledge can often be identified at the very basis of the decision-making processes entailed by society – for instance when individual citizens are called to vote in referendums regarding nuclear energy, assisted fecundation, genetically modified organisms, vaccines, etc. – it is important that all members of society (both experts and non-experts) can understand and assess its positive and negative value.

With this goal in mind, during the third-year courses I held at Parma University, I endeavored to focus my students' attention on some of the features of the language of mathematics and physics they are likely to have been confronted with during their school years. In particular, in order to reveal how the process of popularization which this form of intersemiotic translation entails might work in relation to the language of mathematics, the students were asked to read an extract from Mario Livio's book *Is God a Mathematician?* and compare it to the documentary *The Story of Maths* produced by the British Broadcasting Corporation (Du Sautoy & McGann, 2008) in collaboration with the Open University and presented by Marcus Du Sautoy.

Since it was necessary to take into consideration the different mathematical skills which students brought with them to the course due to their different educational backgrounds, they were also instructed on a mathematical principle that is taught in first grade, namely Pythagoras's Theorem. Students were therefore asked to read the second chapter of Livio's book *Mystics: The Numerologist and the Philosopher* and identify, on the one hand, those linguistic features that render its language specialized and, on the other, those elements which might be recognized as part of the popularization process evidently at work here:

> Even the ordinary numbers encountered in everyday life have interesting properties. Take the number of days in a year—365. You can easily check that 365 is equal to the sums of three consecutive squares: $365=10^2 + 11^2 + 12^2$. But this is not all; it is also equal to the sum of the next two squares ($365=13^2 + 14^2$)!… [T]he Pythagoreans had a way of figuring numbers by means of pebbles or dots. For instance, they arranged the natural numbers 1, 2, 3, 4,…as collections of pebbles to form triangles. In particular, the triangle constructed out of the first four integers (arranged in a triangle of ten pebbles) was called the Tetraktys (meaning quaternary, or "fourness"), and was taken by the Pythagoreans to symbolize perfection and the elements that comprise it.… The square numbers associated with the gnomons may have also been precursors to the famous Pythagorean theorem. This celebrated mathematical statement holds that for any right triangle (Figure 3), a square drawn on the hypotenuse is equal in area to the sum of the squares drawn on the sides. The discovery of the theorem was "documented" humorously in a famous *Frank and Ernest* cartoon. As the gnomon in Figure 2 shows, adding a square gnomon number, $9 = 3^2$, to a 4 × 4 square makes a new, 5 × 5 square: $3^2 + 4^2 = 5^2$. The numbers 3, 4, 5 can therefore represent the lengths of the sides of a right triangle. Integer numbers that have this property (e.g., 5, 12, 13; since $5^2 + 12^2 + 13^2$) are called "Pythagorean triples."





(Livio, 2009, pp. 8–16)

The analysis enabled the students to categorize certain unmistakable features such as the presence of numerals, special symbols, graphic representations, words of classical origin, etc., words which, during Pythagoras's time, were considered neologisms as belonging to the specialized language of mathematics. However, although Livio's text appeared rather specialized to students reading modern languages, the narrative the author construed in the text, the structures he opted for, the graphic representations of particular notions, the use of punctuation (for instance the insertion of exclamation marks), and the insertion of a cartoon, clearly demonstrated that the text was meant to offer a "popular" version of the main notions set forth by Pythagoras and his disciples.

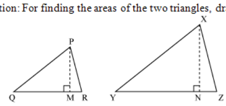
In order to help students appreciate this aspect to the fullest, they were asked to read (and if possible find by themselves) other explanations of the theorem, as presented in specialized textbooks and articles. Afterwards, students were required to analyze some of the documents from the small corpus they had compiled (an example is given in Figure 1), and identify the intralinguistic and intersemiotic procedures adopted in Livio's book first and, later, in the documentary that translates it intersemiotically[2]:

2 In fact, the examples provided in this chapter represent those rare occasions when the reference to the notion of intersemiotic translation in the field of specialized languages seems perfectly appropriate. Indeed, as maintained elsewhere (Canepari, 2013), most of the time, in such contexts, the source text can be identified with a more general notion and understood as a text which is intertextually composed of different extracts originally belonging to other texts. In the specific circumstances addressed in this chapter, however, the target texts represented by the documentaries under study are the intersemiotic translations of Livio's and Hawking's books.

Given: Two triangles PQR and XYZ such that $\Delta PQR \sim \Delta XYZ$

To prove: $\dfrac{ar(\Delta PQR)}{ar(\Delta XYZ)} = \left(\dfrac{PQ}{XY}\right)^2 = \left(\dfrac{QR}{YZ}\right)^2 = \left(\dfrac{RP}{ZX}\right)^2$

Construction: For finding the areas of the two triangles, draw $PM \perp QR$ and $XN \perp YZ$.



Proof:

$ar(\Delta PQR) = \frac{1}{2} QR \times PM$ and $ar(\Delta XYZ) = \frac{1}{2} YZ \times XN$

[Area of triangle = $\frac{1}{2} \times$ base $\times$ height]

$$\therefore \frac{ar(\Delta PQR)}{ar(\Delta XYZ)} = \frac{\frac{1}{2} QR \times PM}{\frac{1}{2} YZ \times XN} = \frac{QR}{YZ} \times \frac{PM}{XN} \qquad \ldots(1)$$

In ΔPQM and ΔXYN,

$\angle Q = \angle Y$ ($\Delta PQR \sim \Delta XYZ$)

$\angle PMQ = \angle XNY$ (Each is equal to 90°)

$\therefore \Delta PQM \sim \Delta XYN$ (AA similarity criterion)

Thus, $\dfrac{PQ}{XY} = \dfrac{PM}{XN}$ ...(2)

Figure 1 – Proof of Pythagoras's theorem (http://www.simages.org/similar-triangles-formula)

On the basis of the students' results, it became apparent that, in addition to numerous instances of faithful rendition,[3] procedures of omission, shifting, and dramatic synthesis are exploited from the very beginning of the documentary. As a consequence, the television program *A History of Maths* refers to the Greeks' interest in *proof* and some of the legendary aspects of Pythagoras's life at a later stage, and whereas Livio's written text dwells on specific details of the mathematician's life (for example his travels), the documentary is much more concise. This appears particularly true in relation to some of the specific and more specialized notions presented in the book (for instance the relationship between intellectual and sciential numbers, the notion of gnomon, the reference to the celestial *harmony of the spheres*, etc.), which tend to be omitted in the documentary. It is actually fairly easy to understand the motivation behind such choices, in so far as – temporal constraints aside – the documentary (precisely because it is a product directed to a mass audience) could not present notions bound to be considered too difficult and specialized by the general public. In spite of this, the omission of the references to the Chinese yin

3 For instance, both the written and the filmic text emphasize the fact that none of Pythagoras's works survived and that he was born in the early sixth century B.C. on the island of Samos.

and yang or to British author Arthur Conan Doyle, which are present in Livio's book, was deemed rather surprising, since these elements could have contributed to rendering the topic alive for, and accessible to, an audience of laymen, by creating a connection with the reality they inhabit.

At the same time, however, the documentary occasionally lays more emphasis on particular aspects simply mentioned in the book, which are amplified and diffuse in the filmic text. Consequently, particular elements – such as Pythagoras's theory of music – are rendered more incisive in the audio-visual product, in that the latter can provide the audience with an actual performance of a string quartet, demonstrating how the theory works in real life. This exploitation of the audio element typical of documentaries also becomes extremely relevant on other occasions, for instance when the text suggests that the discoverer of irrational numbers might have been drowned by Pythagoreans. In this scene, in fact, both the close shots of the breakers and the dramatic use of music are certainly bound to render the film more appealing to a mass audience.

In an analogous fashion, the visual aspects of the documentary become extremely useful and effective on many occasions. For example, rather than showing, as Livio does in his book, a static representation of the theorem, the documentary first offers a shot of some t-shirts sold as souvenirs at the market of Samos which reproduce the famous theorem (Du Sautoy & McGann, 2008, 00:40:45–00:40:58), thereby creating once again a strong connection between the theorem and the daily life of spectators. In addition, it subsequently exploits animations in order to draw, literally in front of the viewer's eyes, the triangle and the squares built on its sides (Du Sautoy & McGann, 2008, 00:41:26–00:41:56).

However, students were encouraged to notice how, as with any form of translation, any change (in terms of omission, variation, expansion, and addition) might have consequences which reflect on the ideological stance of the text, thereby resulting in the presentation of a different version of reality. Thus, the fact that Livio's book refers to the Pythagoreans' veneration of numbers and, in a later chapter, to their "numerical religion" (Livio, 2009, p. 45), whereas the filmic text repeatedly suggests that they were an actual "sect" (Du Sautoy & McGann, 2008, 00:40:09–00:40:25), clearly has important consequences. Indeed, the strategies of variation, shifting, and dramatic synthesis adopted here by the director create a different scenario and by adopting a term which, in mass culture, is negatively connoted (being often associated with dangerous practices, murders, sacrifices, etc.) presents the Pythagoreans under a different light, exploiting the emotive charge of such a term.

In actual fact, this kind of change in the perspective from which information is put at the audience's disposal corresponds to a further difference between written and filmic texts. Indeed, whereas *Is God a Mathematician?* is written and *narrated* by one single viewpoint, namely the author's, who tends to adopt an impersonal style, in accordance with one of the general features of specialized languages, the documentary is narratologically much more complex, with different *voices* taking over the narrative at different moments.

Consequently, in one of the activities introduced at a later stage of the courses, students were asked to categorize the various narrators in the filmic text, with a view to identifying: Du Sautoy himself, who produces a much more subjective narrative and actually creates a *plot* and a *story*, projecting himself as an auto-diegetic narrator; various expert witnesses, who generally are quite impersonal as they are consulted so as to create the impression of higher objectivity, and can thus be identified as homo-diegetic narrators; the voice-over, which connects the various parts in a rather impersonal style and which, by not being physically *present* in the story, could be identified as a hetero-diegetic narrator (Genette, 1972). Furthermore, through such analysis, it became evident that both voice-over and Du Sautoy remain at a first-degree level, whereas the various scholars who intervene as experts are placed on a second, intradiegetic level relating thematically to the first.

The students were then urged to connect the variety of voices represented within the documentary, and their different registers and levels of specialization, to the very idea of popularization and the notion of *need* it implicates. Moreover, they were encouraged to observe that, in the documentary, the relationship between the visual and the verbal text could be described in terms of both redundancy (generally speaking, images and voice "say" the same thing) and complementariness (in that, even when the images and the voice say different things, they nonetheless complete each other). Naturally, these relationships came as a further confirmation of the user-friendly format typical of the popularization process analyzed here and to which specialized languages have to adapt on the basis of various factors. First, obviously enough, the function, which in a popular product such as a documentary is not simply informative-referential, or, as Halliday (1994) would say, "ideational," but much more interpersonal and conative (in that it tries to attract viewers and give them reasons to continue watching the whole documentary). Secondly, the target audience is clearly not only specialists, but a much wider audience of laymen. Indeed, the target audience does not even necessarily include viewers who are merely interested in mathematics, but also distracted home viewers zapping through the various channels who were successfully seduced by the documentary. This includes those who are neither students nor specialists simply wanting to learn but, as in the best tradition of *edutainment*, want to be entertained too.

This aspect becomes more evident when we approach the even more popular cultural goods which were subsequently introduced in the courses: television series which employ the language of mathematics. For example, in order to help students appreciate how the language of mathematics is treated in such products, examples were found of how the Pythagorean theorem is used in the situation comedy *The Big Bang Theory* (Belyeu, 2007). To this end, the thirteenth episode of the tenth season (Lorre, Prady & Cendrowski, 2017) offered a clear example of how some of the pillars of science inserted in this extremely successful series are turned into typical elements of popular culture.

Naturally, to fit the televised format of the situation comedy, specialized discourse needs to undergo a further intralinguistic translation and be made more "popular" in order to be accessible to the masses. In this specific case, Norrick's (1993) theory of humor – according to which sitcom writers rely on the fact that viewers capture the comic effect of verbally-expressed humor thanks to the common lexical, general, and cultural knowledge they share –

was presented to the students. Consequently, the class expected that products such as these could provide spectators with the fundamental information necessary to familiarize them with the topic and help them understand (and enjoy) the various jokes. In point of fact, since humor in sitcoms is often based on mechanisms such as misunderstanding and hyper-understanding, in the case of *The Big Bang Theory* (Belyeu, 2007) humor stems from word-play which exploits polysemy, homonymy, near-homonymy, or literalization. Naturally, if it is true that rather often the humoristic effect of the sitcoms depends on the viewer's recognition of particular notions and lexical items, it is undeniable that in this particular series it is elicited by other characters' incapability to understand specialized discourse (in particular, the character Penny's, with whom the extra-diegetic receiver identifies, frequent inability to understand her physicist neighbors and their friends). Because the very format of situation comedies usually provides a reading key to these polysemiotic texts (through the canned laughter and clap track inserted in the audio-visual products, which work in synergy with visual, non-verbal language), it seems important for spectators to understand the various elements of the discourses represented on screen. Yet, as students were encouraged to notice in class, this is not always the case. For instance, in the episode introduced above, the character Sheldon applies the Pythagoras's theorem to a very informal speech event (two male friends discussing their love life), by comparing the difficulties his roommate Leonard experiences in his relationship with Penny once the initial excitement wears off, to the change he experienced in relation to the Pythagorean theorem: "[when I first encountered the Pythagorean Theorem] I was blown away that the square of the hypotenuse was the sum of the squares of the opposite sides. Yeah, but now I'm just like 'eh'" (Lorre, Prady, & Cendrowski, 2017, 11:04:13–11:16:01).

The same Theorem is also referred to in various episodes of the television series *Numb3rs* (Scott & Scott, 2005). For example, it is implicitly mentioned in the third episode of the second season (Falacci, Heuton, & Behring, 2005), where viewers are confronted with the following dialogue:

DAVID: We have something new for you to look at. It's related to the same case. Now, we don't have an address, but we're trying to find out where this place is. I noticed that the basketball hoop was casting a shadow. I thought I read somewhere that you can calculate a location based on shadows.

CHARLIE and LARRY: Spherical astronomy.

AGENT SINCLAIR: What's that?

LARRY: Well, it's a way of looking at the cosmos to define one's location on the earth.

CHARLIE: Sailors use it when they're lost at sea.

LARRY: Cosmologists use it when we're just plain lost.

CHARLIE: And it just happens to be the same math used with sundials…. We need to measure the length of the pole as well as the shadows.

AGENT SINCLAIR: Well, the basketball hoop looks like it's regulation height.

LARRY: Yeah, and those are bricks on that driveway.

CHARLIE: Right.

AGENT SINCLAIR: Bricks? How does that help?

CHARLIE: Well, they're the same size. It allows us to measure the movement of the shadows. By measuring the length of the shadows against the bricks and then factoring in the exact times that these two images were snapped, the equation can then determine the altitude of the sun on a grid. Then by mathematically overlaying these images, I can provide to you, with certainty, latitude and longitude down to a hundredth of a degree.

(Falacci, Heuton & Behring, 2005, 00:31:57–00:33:38)

Within the show, no explicit mention of Pythagoras's name is made. However, Charlie's reference to spherical astronomy implicitly recalls astrometry which, as illustrated in Figures 2 and 3 below, fundamentally rests on Pythagoras's theorization:

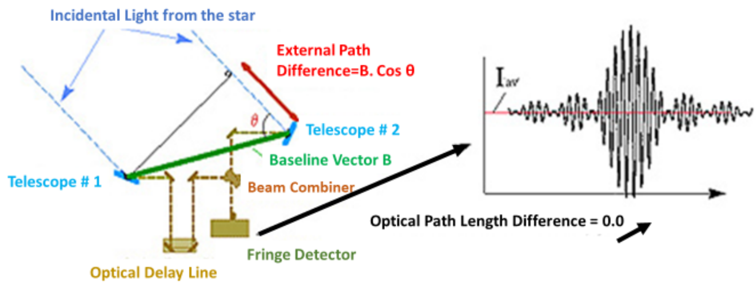


Figure 2 – Optical interferometric measurements (https://www.revolvy.com/page/Astrometry, © NASA/JPL-Caltech)

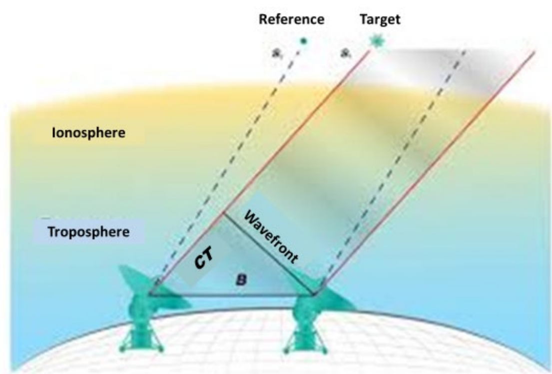


Figure 3 – Radio astrometry measurements (http://www.gisopen.hu/eloadasok/2019/cs10.pdf, p. 14, © M. Reid)

In the fifth episode of the third season (Falacci, Heuton, & Miller Tobin, 2006), the filmic text openly quotes the Pythagorean theorem and references the law of cosines which, while pertaining to trigonometry rather than pure geometry, clearly rests on the theorem and is equally used in triangulations:

> CHARLIE: Hey. Pythagorean theorem, law of cosines, metrics.
>
> LARRY: Equivalence principle.
>
> CHARLIE: Back to basics. (Falacci, Heuton, & Miller Tobin, 2006, 00:16:25–00:16:35)

Thus, although the general expectation was to find simplified versions of scientific notions in more popular products, in reality in both television series, the theorem, which is explained at length by Du Sautoy, is to a certain extent taken for granted and not explained at all. This is particularly true in relation to the situation comedy, which, as a genre, is generally characterized by an even more "incidental" educational value (Dash, 2013), although even the explanations offered by the protagonist of *Numb3rs* (Scott & Scott, 2005) partially rest on the assumption that the spectators will be able to activate their knowledge of the theorem and apply it to the current situation. This is particularly evident in the second episode mentioned above, and it can be justified by referring to the cohesive devices which hold the entire series together. Indeed, having introduced the theorem in more detail in the previous season, producers probably assumed that viewers had already had the chance to "revise" the mathematical principles on which the theorem rests and therefore felt they could consider it shared knowledge.

This is the reason why a product such as *Numb3rs* (Scott & Scott, 2005) could become a useful teaching and learning tool for both specialist and non-specialist students. This is actually the approach investigated for example by Hudson (2009), who focused some of the activities she prepared for her students of mathematics on the television show, in order to encourage them to investigate how the relationship between A^2 + B^2 and C^2 is affected by the measurement of angle C. Naturally, within a course in modern languages, these products are particularly interesting from a linguistic perspective, and they can become useful to demonstrate how sentences are constructed, which types of verbs and verb tenses are mainly adopted in scientific language, etc.

Although it is obviously necessary for them to understand "the language of mathematics" as well, the primary aim of these students was not to become mathematicians or physicists. Therefore, the knowledge (and its teaching) of this specialized language should in such cases be adapted to their needs. To this end, some of the exercises which can be used with mathematical students in order to stimulate them to use this variety of English properly are equally useful in a modern languages class. In particular, providing students with a glossary and asking them to complete simple exercises in order to learn the meaning of mathematical terms and symbols (following the footsteps of the HM Learning and Study Skills Program, while adapting it to the University context)[4] proved to be a valid tool and helped students avoid becoming frustrated, while encouraging and stimulating their curiosity.

Furthermore, by watching the same filmic extracts in both the original language and their dubbed versions, these audio-visual texts can become a useful tool also in terms of translation practice, helping students raise their awareness in relation to the way specialized languages work in different cultures and encouraging them to think about the translation strategies that might prove helpful when approaching such texts. With this aim in mind, a series of extracts were selected from different episodes both in the original and the dubbed versions of the shows, from which students were asked to complete activities such as *find the (translation) mistake*. These exercises proved very stimulating for them, and by focusing on theories and notions they were familiar with, enabled them to recognize whether the translation of the filmic text respected the use of the specialized language of math normally made in the Italian translations.

3. The Language of Physics

Because the discipline of mathematics is closely connected to physics, often the specialized languages of the two fields are simultaneously present and work in synergy within the same product. Indeed, as Galileo stated,

> this grand book, the universe… cannot be understood unless one first learns to comprehend and read the letters in which it is composed. It is written in the language

4 The program was elaborated by the HM Group in order to meet the needs of adolescent learners and encourage the development of their capacity for abstraction. The program is geared for grade levels and teaches the skills students need in order to be successful (organizing, use data, etc.). The publications of the group had an immense success, as they teach students to exploit and put to use their specific learning style.

> of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it. (Galilei, 1623/1957, p. 238)

In fact, Boyer sustains that mathematics and physics have been interwoven since ancient Greece, when mathematicians (as Du Sautoy suggests in the documentary briefly introduced above), had to resort to mathematics in order to overcome the difficulties they encountered

> In their attempt to express their intuitive ideas on the rations and proportionalities of lines, which they vaguely recognized as continuous, in terms of numbers, which they regarded as discrete. (Boyer, 1949, p. 4)

This is actually the same notion Sheldon reminds spectators of in *The Big Bang Theory* (Belyeu, 2007), when, in an attempt to teach Penny some of the basic notions of Physics, in order to enable her to understand Leonard's work better, he repeatedly states:

> What is physics? Physics comes from the ancient Greek word "physika."… Physika means the science of natural things. And it is there in ancient Greece that our story begins.… It's a warm summer evening, circa 600 B.C. You've finished your shopping at the local market or agora. And you look up at the night sky. And there you notice some of the stars seem to move so you name them "planets" or wanderer.… This is the beginning of a 2600-year journey we're going to take together from the ancient Greeks through Isaac Newton to Niels Bohr to Erwin Schrödinger to the Dutch researchers that Leonard is currently ripping off.… As I was saying, it's a warm summer evening in ancient Greece… (Lorre, Prady, & Cendrowski, 2009, 00:10:17–00:11:38)

As mentioned above, on many occasions viewers of this situation comedy are not provided with an explanation of the various notions and theorems the filmic text introduces. This became perhaps even more evident during the discussion of the language of physics, when it was possible to appreciate an important difference in relation to the other television show succinctly discussed above, namely *Numb3rs* (Scott & Scott, 2005).

In order to help students elicit these differences, it was decided to focus on one of the basic principles of physics which, as anticipated in the initial paragraphs of this paper, revolutionized the mode in which people thought about the universe and about science itself, namely the principle of uncertainty elaborated by Werner Heisenberg in 1927. To this end, students were initially required to read the fourth chapter from Hawking's best-seller *A Brief History of Time*, from which the following passage is extracted:

> In order to predict the future position and velocity of a particle, one has to be able to measure its present position and velocity accurately. The obvious way to do this is to shine light on the particle. Some of the waves of light will be scattered by the particle and this will indicate its position. However, one will not be able to determine the position of the particle more accurately than the distance between the wave crests of light, so one needs to use light of a short wavelength in order to measure the position of the particle precisely. Now, by Planck's quantum hypothesis, one cannot use an arbitrarily small amount of light; one has to use at least one quantum. This quantum will disturb the particle and change its velocity in a way that cannot be predicted. Moreover, the more accurately one measures the position, the shorter the wavelength of the light that one needs and hence the higher the energy of a single quantum. So the velocity of the particle will be disturbed by a larger amount. In other words, the more accurately you try to measure the position of the particle, the less accurately you can measure its speed, and vice versa. (Hawking, 1998, pp. 54–55).

This explanation of the Principle was then compared to an extract from the second episode of the first season of *Numb3rs*, where the same notion is introduced by Charlie, in an attempt to help his brother and his FBI colleagues catch a group of robbers:

> CHARLIE: Heisenberg noted that the, uh, the act of observation will affect the observed. In other words, when you watch something, you change it. And, uh for example, like, an electron. You know, you can't really measure it without bumping into it in some small way. Any physical act of observation requires interaction with a form of energy, like light, and that will change the nature of the electron, its path

of travel… you've observed the robbers. They know it; that will change their actions.
(Falacci, Heuton, & Guggenheim, 2005, 00:13:28–00:14:02)

As hinted at *above*, in this rather sophisticated series, the language adopted often responds to the requirements of specialized language as such (to the extent that also the various equations spectators are confronted with during the opening titles and on many occasions throughout the different seasons, are actually mathematically sound), and in each episode, one or more fundamental theorem is presented. Nevertheless, because there is always at least one character in the series who plays the role of the learner, the viewer generally finds an explanation of the theories presented, and s/he is therefore enabled to follow the episode, enjoy it, while learning something new.

Because of the rhythm enforced by the genre of the sitcom, on the contrary, in *The Big Bang Theory* (Belyeu, 2007) – where Sheldon explains specialized notions for the benefit of Penny, his fellow scientists and, as a consequence, the extradiegetic audience, only occasionally[5] – the didactic explanations typical of *Numb3rs* (Scott & Scott, 2005) are replaced by much shorter illustrations and/or mere definitions of the theorems the filmic text refers to.[6] Thus, during

5 See for example the seventeenth episode of the first season, where Sheldon posits the experiment of Schrödinger's cat as an analogue for Penny and Leonard's potential relationship before they actually start dating. On this occasion, Sheldon tells Penny: "In 1935, Erwin Schrödinger, in an attempt to explain the Copenhagen interpretation of quantum physics, he proposed an experiment. A cat is placed in a box with a sealed vial of poison that will break open at a random time. Now, since no one knows when or if the poison has been released, the cat can be thought of as both alive and dead.… Just like Schrödinger's cat, your potential relationship with Leonard right now can be thought of as both good and bad. It is only by opening the box that you'll find out which it is" (Lorre, Prady, & Cendrowki, 2008, 00:15:04–00:16:06).

6 This is for example the case with the Doppler effect, which Sheldon, despite the obvious difficulty that other characters have in understanding it, simply defines without any form of amplification or exemplification: "It's the apparent change in the frequency of a wave caused by relative motion between the source of the wave and the observer' (Lorre, Prady, & Cendrowki, 2007, 00:0726–00:07:32).

the twenty-third episode of the second season, Sheldon introduces the uncertainty principle by stating:

> SHELDON: Well, now, here's a peculiar e-mail. The president of the university wants me to meet him at his office at 8 a.m.
>
> LEONARD: Why?
>
> SHELDON: Doesn't say. Must be an emergency. Everyone at the university knows I eat breakfast at 8 and move my bowels at 8:20.
>
> LEONARD: Yes, how did we live before Twitter? I guess you'll find out what it is in the morning.
>
> SHELDON: That's 14 hours away. For the next 840 minutes, I'm effectively one of Heisenberg's particles. I know where I am or how fast I'm going, but I can't know both.
>
> (Lorre, Prady, & Cendrowski, 2009, 00:00:50–00:01:22)

Naturally, the function of the situation comedy is patently to elicit the audience's laughter and, in reality, the comic effect depends, for example in this case as well as many others, on the viewers' partial understanding of specific notions. Subsequently, the educational purpose is rather thin. However, within the same series, spectators do actually come across a "popularized" version of the Principle and can perhaps better understand Sheldon's comment in the second season retroactively. Indeed, in the fourth season ("The Herb Garden Germination") spectators meet theoretical physicist Brian Greene, who participated as a star guest on the show, playing himself, in the twentieth episode of the season. On this occasion, Professor Greene – who is famous for his popularizing efforts in actual life – is giving a conference at a bookstore, presenting his book *The Hidden Reality: Parallel Universes and the Deep Laws of the Cosmos* (2011). Sheldon and Amy attend the conference and when Professor Greene refers to the special-order menus of Chinese restaurants in order to explain the uncertainty principle, the two protagonists ridicule him (Lorre, Prady, & Cendrowski, 00:00:45–00:01:01). Certainly, the explanation seems far too "popular" to be appreciated by the two scientists, but it still provides a useful exemplification for the general public watching the series.

Thus, despite the priorities of television series such as those briefly commented upon *supra*, it is certainly true that, albeit "incidentally," spectators might learn some of the basic notions of physics and its language (or they might feel encouraged to learn more). Consequently, it is my contention here, if adopted by teachers, a situation comedy too might become a useful learning tool. For instance, in order to achieve a fuller understanding of the pragmatic uses of language made in the series, students might be asked to search for more information about some of the notions introduced. Likewise, they might be encouraged to ponder over the translation strategies that the dubbing or subtitling of these episodes entail, thereby acquiring – if only indirectly – a higher level of competence in both languages. In particular, on the occasion of Heisenberg's principle above, it is essential for students to realize that, even though in ordinary language the term *uncertainty* is generally translated into Italian as *incertezza*, within the specialized field of physics, Heisenberg's principle has acquired a different form (*Principio di indeterminazione*), and, on the basis of a strategy of divergence, it should be translated as such. In this sense, it might be interesting to draw students' attention to the fact that the title of the second episode of the first season of *Numb3rs* – which in English reads, precisely, "Uncertainty Principle" – is rendered in Italian as *Il principio di Heisenberg*, in an attempt to understand the motivations (and the consequences) behind this translation choice.

Indeed, when dealing with such popular products as *The Big Bang Theory* (Belyeu, 2007) or *Numb3rs* (Scott & Scott, 2005), which have been translated in many different languages, the activities can be based on contrastive analyses and *find the mistakes* type of exercises. In this context, then, it would be equally productive to exploit other documentaries which, due to the notoriety of their producers and/or presenters, have been translated in other languages as well. Among the various products available, the documentaries *Origins: Back to the Beginning* (Levenson, 2004), introduced by physicist Neil de Grass Tyson – who is famous all over the world for his efforts in popularizing science – or *Through the Wormhole* (McCreary, 2010), hosted by American actor Morgan Freeman, not to mention the mini-series *Stephen Hawking's Universe* (Sobel, 1997) or *Into the Universe with Stephen Hawking* (Foster, 2010), presented – at least in part – by Hawking himself, appear particularly useful. Indeed, these specific filmic texts focus on the same notions introduced in Hawking's book. Thus, it was very stimulating for students to reflect on how the same "raw" material (namely the physical world itself and the laws of physics which regulate it) is treated in the various products introduced and how the documentaries attempt to render it more "popular" through processes of intersemiotic and intralinguistic translation.

Thus, on this occasion too, students were required to identify the various intersemiotic strategies adopted in the rendition of Hawking's book, which, in a similar way to Livio's book before, was defined as the source text as the basis not only of the two documentaries actually written and presented by Hawking himself, but also of at least some of the episodes from the other two programs. Hence, students were able to identify strategies of amplification, explicitation, omission, and dramatic synthesis, which emphasize the way the visual and audio aids the medium puts at the producers' disposal were exploited.

Moreover, students were once again asked to provide a narratological analysis of the texts, after which it naturally became apparent that the same structure which was identified in relation to *The Story of Maths* (Duke, 2008) (especially in terms of the way the different narrating voices are connected), could be recognized in these products as well. However, whereas the documentaries introduced by DeGrasse Tyson and Freeman actually appeared to adhere to the format rather closely, the other two distinguished themselves with their different organization. Indeed, during the analysis of these filmic texts, it was sometimes difficult to identify the main narrator, in so far as – for example in the first episode of *Stephen Hawking's Universe* (Hawking, 1997) – spectators are confronted with two intra-diegetic narrators (Hawking himself and, in this specific case, the headmaster of his college at Cambridge). In addition, the various expert witnesses do not actually appear visually on screen but enter the filmic narrative only as voice-overs. Spectators thus recognize that various narrators are contributing to the construction of the documentary simply because the voices sound different, without, however, being able to see who is speaking. This aspect therefore raises various issues in relation to the status that should be assigned to these narrators, in so far as they are obviously outside the narrative but – contrary to the expert witnesses – they often seem present at a first-degree narrative level.

Once this part of the course came to an end, students were required to approach some of the many documentaries retrievable from YouTube and the British television series *Supernova* (Freeland, 2005) namely products which, since they have never been translated into other languages, provided them with more challenging activities.

For example, during the courses, various extracts from the British sitcom were introduced. In particular, the second episode of *Supernova* ("God Are You Out There?") provided stimulating material at more than one level. Indeed, initially the episode – which focuses on the discovery of a wormhole almost fourteen billion years old, and which therefore "stretches back to the dawn of time" (Cripps & Lipsey, 2005, 00:11:24–00:11:52) – was compared to extracts from the first episode of the first season of the documentary series *Through the Wormhole* (Isser, Lund, & Sharp, 2010), in order to appreciate the similarities between the two products from both a visual point-of-view and in terms of the language used. In fact, although the television series, due to the genre it belongs to, presents a distinctive use of informal register, students were asked to identify the linguistic elements the two products share. Furthermore, students were required to complete a series of lexical cloze and multiple-choice exercises based on the script of the episode, and subsequently translate extracts from the script which presented particularly specialized notions, expressions, etc.

Finally, the class was encouraged to reflect upon the popularizing strategies exploited in this sitcom and compare them to those utilized in the products analyzed during the previous stages of the courses. Indeed, while sharing some aspects with both the documentaries and other television series taken into consideration earlier, it became immediately apparent that this product is rather different on various levels, thus providing yet other examples of popularization strategies. For instance, the entire second episode of the first season (Cripps & Lipsey, 2005), rests on fundamental references to British culture and the science-fiction television program *Dr Who* (Nathan-Turner & Lambert, 1963) produced by the BBC since 1963 and whose eleventh series is scheduled to be released later in 2018 (Chibnall, 2018). In particular, during the episode spectators are confronted with very swift visual references to the third Time Lord, whose role was played by British actor Jon Pertwee (Sherwin, 1970). Naturally, while being a British production, *Dr Who* has actually become such a cult series for science fiction fans all over the world that the reference is bound to be appreciated by many spectators. However, whereas the various references to science fiction identifiable in *The Big Bang Theory* (Belyeu, 2007), by belonging to American top-grossing comics, films, and TV series, are bound to be easily recognized by an international audience, the visual intertextual references to *Dr Who* more likely appeal to a niche public. Thus, the scenario these references activate and the function they perform can be appreciated by a more restricted audience. This holds true also in relation to the ironic comments made in relation to the Doctor's role, which, in *Supernova* (Freeland, 2005), is fundamentally that of God. Indeed, the whole episode is actually based on the fundamental misunderstanding sparked by a failure in the equipment the protagonists use at the Royal Australian Observatory that serves as the main setting to the situation comedy. By analyzing the wormhole they discovered, Dr Paul Hamilton believes in fact he has beheld God's face, thus proving His existence. As Figures 4, 5, and 6 demonstrate, however, at the very end of the episode the scientists (and, with them, the spectators) realize the image that appeared among the nebula was created by a crossing of signals between the astronomical equipment and the television broadcast featuring *Dr Who*:


Figure 4 – Standstill (00:15:45)


Figure 5 – Standstill (00:19:25)

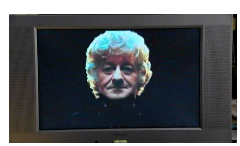


Figure 6 – Standstill (00:26:14)

In addition, the (often surrealistic) narrative this television show composes equally strikes viewers for its "Britishness," whereas the tendency to avoid important amplifications of the specialized notions introduced appears even more marked.

Thus, the analysis conducted in the final stage of the courses, gave students the opportunity to ponder about broader issues that fell outside strictly linguistic perspectives. First of all, it became apparent that when dealing with phenomena such as specialization and popularization, cultural knowledge remains paramount, and the metaphors specialized discourses resort to are bound to offer different interpretations and representations of the same reality.

Furthermore, the discussion of these differences emphasized the fact that cultural (neo) colonialism plays a major role in the depiction of the world in specialized contexts, which inevitably triggered a reflection on the role of English (usually in its American variety) as a *lingua franca* in specialized fields. As a matter of fact, as Lindsay (2011) maintains among many others, "English has become *de facto* the language of science" (p. 11). Through the work carried out during the courses on which this chapter is based, the fact that language-related issues have recently assumed a fundamental role in science therefore found a further confirmation, thereby helping students recognize the role language plays in our understanding of reality and nature. This was further substantiated by references to physicist Bohm (after whom the protagonist of the television series *Touch* (Sutherland, 2012) mentioned above is named),[7] who emphasizes the active role played by language in scientific domains, to the extent that in his opinion, particular uses of language might lead to a block in the scientist's creativity (Bohm as cited in Peat, 1987). Similarly, references were made to physicist Neils Bohr's epistemological theory, which attributes

7 The American physicist and the character played by Kiefer Sutherland share only the surname, the former being called David and the latter Martin. Given the main topic of the series, however, this intertextual reference appears very relevant.

a great importance not only to the object of observation but also to the observing (and describing) subject. As such, his theory assigns a fundamental role to language and communication, to the extent that the Danish physicist maintains in (1960) that "[i]t is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can say about nature" (online), thereby positing an intimate (if reversed) relationship between the world, science, and language. Thus, as Ford and Peat (1988) notice, the importance of language is such that "a change in the use of the word is indicative of a change in theory" (p. 1236), which leads to the patent consequence that understanding the way language works and the impact it can have is essential in any field of study and circumstance of life.

4. Conclusion

It is therefore possible to see how the products discussed in this contribution are actually conceived on the basis of some of the fundamental notions of the didactic perspective we refer to as needs analysis, since, in the case of the aforementioned television shows, generally one of the protagonists plays the role of what Dudley-Evans and St. John (1998, p. 13) describe as the ESP practitioner as teacher, whereas the co-protagonists or other characters occupy the position of the learners with whom the extradiegetic receivers can identify. As mentioned above, these products might become the focus of teaching activities within an English course for students of mathematics and/or physics only occasionally. On such occasions, they might in fact become useful when introducing notions which are bound to be further elaborated during the course, since their level of sophistication is not adequate to such specific courses.

Nevertheless, precisely because English – despite the controversy that surrounds this notion (Albert, 2001; Tardy, 2004) – is often considered the *lingua franca* of science, these goods prove that non-specialists, and non-native speakers, need to master the trends of this specialized language too (Wheatley, 2014). Thus, the need is very much felt for university and training courses (as well as publications) whose aim is to improve students and trainees' proficiency in scientific English.

Furthermore, students attending courses of study such as modern languages – who often envisage a career either in teaching or translating – are also required to have some knowledge of the specific uses of the language of science, on the basis of a syllabus specifically designed in accordance with needs analyses. Clearly, teachers cannot expect students from the humanities to "talk in mathematics" (Badyopadhyay, 2002) and/or "think in math" (Bing & Redish, 2007), and the evaluative stage of ESP courses should always take this aspect into consideration. However, in order to become functioning members of society, as well as good teachers and translators, students should be aware of some of the founding aspects of these disciplines as reflected in the language they rely on. It is precisely from this perspective that the products on which this paper has focused might become extremely valuable, enabling students to appreciate some of the basilar features of the language of science, not only in terms of, as illustrated above, the specific terminology typical of this field, but also in terms of more general mechanisms, such as the use of past and present participles and the highly evaluative lexis which, as Hunston (1993; 1994) and Cava (2010) for example recognize, are often essential in scientific writing and must therefore be comprehended, used, and translated appropriately.

In addition, these television series can become useful for illustrating other crucial features of scientific language too. This is for example the case with the recourse to metaphors, some of which, as Brookes (2003) suggests, represent the pillars of physics itself. Thus, these products can help illustrate how heat is discussed as a fluid (we talk in fact about *heat flow*), how the atom is compared to a solar system (and in fact we talk about *electron orbitals*), and how *electrons* are equated with *waves*. In this sense, the fourteenth episode of the third season of *The Big Bang Theory* (Belyeu, 2007) can be highly instrumental, as during the episode, Sheldon, while working at The Cheesecake Factory in order to stimulate his brain, drops a series of plates on the floor and has an epiphany:

> The interference pattern in the fracture. The motion of the wave through the structure. I've been looking at it all wrong. I can't consider the electrons as particles. They move through the graphene as a wave. It's a wave! (Lorre, Prady, & Cendrowski, 2010, 00:16:39–00:16:52)

Naturally, the various texts adopted should be diversified and associated to scientific articles and extracts from books and essays where possible.[8] However, if appropriately adapted by ESP teachers, these products provide useful tools to help students lower their affective filters, develop, as we have seen above, their higher order thinking skills (Bloom, 1956), encouraging them to ponder broader (philosophical, political, etc.) issues, and trigger their curiosity, which, according to Einstein himself, is at the very basis not only of scientific discovery but of life itself. According to Einstein, in fact, "the important thing is not to stop questioning" (Calaprice, 2000, p. 281).

8 The author is willing to share part of her material if contacted directly at the following e-mail address: michela.canepari@unipr.it.

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