acCOMICating Science:
Larry Gonick's 'Cartoon Guides' as Models of Science Textbooks in Comics Form

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Abstract

This article argues for the use of the comics form in science textbooks to address the concerns that Thomas Kuhn (1996), Paul Feyerabend (2002) and Bruno Latour (1987 raise about science education. To effectively address those concerns, this article synthesizes the arguments that each of these philosophers of science address to situate the theoretical perspectives that inform the rest of this article. Afterwards, the article goes on to describe the theoretical perspectives of comics that inform how this form opens the problem of black boxes by showing science in action. Finally, three examples from Larry Gonick's (2005) *The Cartoon Guide to Physics* present the ways in which the comics form can enhance science education. While further research may be needed, this article seeks to lay the groundwork for a science textbook in the comics form that shows (visually) science in action and partially engages students' awareness of scientific development, including revolutions and the black boxes of paradigms.

Keywords: comics, scientific revolutions, black box, rhetoric, textbooks, education

Introduction

Simon Locke's 2005 article "Fantastically reasonable: ambivalence in the representation of science and technology in super-hero comics" describes the public understanding of science and technology as they are represented in the popular culture artifacts of superhero comics. On it's own, Locke's article is beneficial from a popular culture perspective and as an exploration of the effect comics have on the philosophy of science. What has been a concern for others (Naylor and Keogh, 1999; Perales-Pelacios and Vilchez-Gonzales, 2002; Solomon, 2002; Barnes, 2006) is how these popular culture representations affect scientific literacy and education. Since at least the 1979 publication of Bruno Latour and Steve Woolgar's *Laboratory Life*, a major concern for science education has been a conflict between popular culture representations and classroom representations in textbooks, generally.[1] In part, these popular texts inform how a general public understands innovations in science in magazines like *Popular Science* and *Discover*, which, as George DeBoer (2000) correctly identifies, is important when "scientific literacy becomes the goal of science education reform" (582). DeBoer's point, similar to Latour's (1987), is that science education should be organic (open-ended) instead of static (a 'black box'). However, textbooks in the science classroom tend to focus on 'facts' rather than the development of scientific theories historically. Despite these historical concerns and recent research on incorporating popular culture artifacts into science classrooms, little has been done to address the underlying concern: that science education needs to incorporate historical perspectives into current pedagogical practices, including the use of popular culture artifacts such as comics.

Larry Gonick's *Cartoon Guide to Physics*, the primary example for this article, addresses the ways in which comics can be used for formal and informal education (outside of the classroom). Gonick's work has been inadequately utilized in classroom settings, whether in secondary schools or universities. The questions that permeate this article are: Can science textbooks developed in comics form address and resolve the concerns that philosophers and rhetoricians of science (Kuhn 1996; Feyerabend 1993; Latour 1987) have raised? If so, in what ways can the comics form then be used in a scientific classroom to create, to use Thomas Kuhn's (1996) term, a revolution in the education of future scientists? In general,

[1] Latour and Woolgar discuss "genres" of article for lay audience as important for public relations, which "can be useful in the long-term acquisition of public funds" (72).

these concerns rely on the view that reforming science education requires a historical understanding of science fields.[2]

Kuhn (1996), Feyerabend (2002) and Latour (1987) are concerned about the use of textbooks in science education and how those textbooks are represented in textbook. For Kuhn (1996), science textbooks misrepresent the growth of each field by showing a linear progression of science; Feyerabend (2002) expresses his frustration with the desire of science to produce scientific work with consistency without questions about theoretical frameworks; and Latour (1987) claims that science education needs to be taught as an active practice ("science in action") and that science students learn textbooks, not science, in the classroom. Much like Feyerabend (2002), Latour (1987) describes science education by suggesting that the information in textbooks comes in the form of 'black boxes' – accepted paradigms in the sciences. To address each of these concerns, Gonick finds, and accommodates, those paradigms with the comics narrative form.

Jeanne Fahnestock (1986) explains that accommodations of science "celebrate rather than validate" scientific discoveries and adjust "to an audience's already held values and assumptions" with those scientific discoveries (279). Accommodation in this sense suggests translating scientific concepts, discoveries and innovation for an audience learning about science or that are unfamiliar with science as a discipline. Briefly referring to the "classic comics" of science, as a translation of science, Fahnestock (1986) cites *The Cartoon Guide to Computers* and *The Cartoon Guide to Genetics* as examples of accommodating science for non-specialist audiences as comics (277). The comics form does not, as Fahnestock (1986) claims of accommodation, celebrate (or validate) science. Rather, as we will see in Gonick's work, the comics form accommodation of science traces the development of fields over time. Gonick (2008) does not attempt to merely represent science or the processes of a scientist. Rather, the narratives of Gonick's comics include a beginning, middle and end (accommodations of a specific field from inception up to the most recent discoveries, not only those of a specific experiment). However, he believes that scientists' process only

[2] David Buckingham and Margaret Scanion's *Education, Entertainment and Learning in the Home* may be useful to look at home schooling and personal interest in science. For this article, this book is not applicable since it does not discuss the theoretical concerns raised by Kuhn, Feyerabend or Latour. Additionally, the book does not address the concerns this article attempts to deal with. It is, however, an effect investigation of the importance of parents' involvement in their children's education.

includes the middle (the experiment within the framework). (A similarity between this middle and Latour's desire for scientific transparency is addressed later in this article.) Gonick's work in comics indirectly addresses Fahnestock's (1986) concern that 'accommodators' "leap to results" (284) by explaining (visually and verbally) how science has developed over time.

Yet, Gonick's work was not meant for the science classroom. In a personal correspondence, Gonick (2008) intimated that his goal was to tell these stories from the point of view of the characters, shifting the perspective "towards thinking of objects as characters and seeing processes as meaningful events." In other words, the results are not quite as important to Gonick's work as the processes of science and the development of science over time, paralleling the concerns that Kuhn, Feyerabend and Latour express about science textbooks. Even though Gonick produced this work for a public audience, his approach can be applied in developing textbooks for science classrooms.

This article suggests that the use of Gonick's narrative comics form not only addresses some rhetorical concerns of science, but also has educational possibilities in the science classroom. In other words, Gonick's work attempts to visually illustrate scientific revolutions (see Kuhn 1996) by historically documenting the progression of scientific innovations that have become 'black boxes' and, in doing so, opening those boxes (discussed later; see Latour 1987). After discussing how comics can open these black boxes, this paper will describe how comics can be effective as an educational tool. Additionally, some information design perspectives on textbooks and pedagogy will support how the comics form can potentially enhance scientific education. Finally, by exploring how effectively Gonick's work addresses the concerns of Kuhn, Feyerabend and Latour, we can begin to move towards the comics form as a pedagogical tool for science textbooks. While a significant amount of research have been done using these three philosophers of science, this article concerns the problems they have identified that has been addressed minimally since their work has been published in relation to perceptions of science in formal (and informal) science education. Also, as discussed later, the comic-strip that Latour includes in the introduction of *Science in Action* offers an initial introduction of comics into science education and offer a conceptual starting place (*topos*) for beginning this conversation.

The Black Box of Scientific Revolutions

In *The Structure of Scientific Revolutions* (1996, 3rd edition) Kuhn describes a paradigm (in the introduction) as "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners" (x). To clarify, a paradigm includes a set of accepted premises that inform further research. When these paradigms shift a revolution occurs, which scientists are generally reluctant to accept (see Kuhn 1996). A revolution, for Kuhn (1996), is not a violent reaction towards a new theory. Rather, scientists become concerned with the work that has been done under existing paradigms. In other words, a revolution in science consists of supplanting a former theory (or theories) under which scientific achievements have been made. After a revolution, questions arise about the work that was done under the former paradigm and whether they can be brought into the new paradigm since "scientists are responding to a different world" (Kuhn 1996, 111). For Kuhn (1996), the lack of education about these revolutions in science textbooks needs to be rectified. As Bernadette Bensaude-Vincent (2006) argues, building on Kuhn, they disguise the procedures in favor the accumulation of data and are powerful tools in stabilizing disciplines by perpetuating paradigms and denying changes in scientific knowledge (669).[3]

Textbooks, as a pedagogical tool for future scientists, should trace the history of science instead of eliminating sections that do not fit in with the current paradigm. Otherwise, science enters what Latour calls a 'black box' – a set of principles that scientists use within the accepted paradigm. Truncating the history of science adds to the perception that science develops linearly toward a specific objective from the beginning, which creates a problem for scientific research by disguising that "science has reached its present state by a series of individual discoveries and inventions that, when gathered together, constitute the modern body of technical knowledge" (Kuhn 1996, 140). However, in the black box of a textbook, the information "is devoid of any trace of fabrication, construction or ownership" and while we know the work that scientists are currently doing, "we don't know" how they do that work (Latour 1987, 15). This lack of ownership creates what Feyerabend (2002) refers to as the "*consistency condition*" (24), which, in scientific work, hides the methods and knowledge that informs how scientific work is done in laboratories.

[3] *Science and Education*'s special edition "Scientific and Technological Textbooks in the European Periphery" (Vol. 15, Is. 7-8) contains some discussions of Kuhn and textbooks. However, those discussions are only tangentially useful for this article.

For Feyerabend (2002) the "*consistency condition*" requires that new hypotheses agree with accepted theories and preserves an older theory in favor of a newer, potentially better theory. The *consistency condition*, however, becomes a problem for science when scientific work shifts to a new paradigm. Scientists who work within paradigms that contain an incommensurable foundation of new knowledge inhibit scientific growth after these scientific revolutions (see Feyerabend 2002). For Feyerabend (2002), the *consistency condition* "contributes to the preservation of the old and familiar not because of any inherent advantage in it but because it is old and familiar" (25). The old and familiar here represents a black box that favors consistency. Feyerabend (2002) argues,

> *Unanimity of opinion may be fitting for a rigid church, for the frightened or greedy victims of some (ancient, or modern) myth, or for the weak and willing followers of some tyrant. Variety of opinion is necessary for objective knowledge. And a method that encourages variety is also the only method that is compatible with a humanitarian outlook.* (31-32, original emphasis)

The method that Feyerabend (2002) suggests, however, is not *a method*; rather, Feyerabend (2002) asks for a plurality of methods with a multiplicity of theories. While this may address aspects of the old and familiar, Feyerabend's (2002) proposal does not address the problems that arise from black boxes or from revolutions. Competing theories and methods would result in a new *consistency condition*, one in which science is continually involved in a revolution. Additionally, the new *consistency condition* may open some black boxes, but only to form new ones for each of the competing theories and methods. Instead of a single "*rigid church*," science will only develop multiple, competing denominations of a single field. Students, then, learn from the stance of the educators, as supporters of each 'scientific denomination'.

How educators' knowledge develops in a laboratory and then transfers to a textbook for the scientific classroom can be seen in an example from Latour (1987) in which he sketches a textbook paradigm through a comic strip (on the following page):

> We start with a textbook sentence which is devoid of any trace of fabrication, construction or ownership; we then put it in quotation marks, surround it with a bubble, place it in the mouth of someone who speaks; then we add to this speaking character another character *to whom* it is speaking; then we place all

of them in a specific situation, somewhere in time and space, surrounded by equipment, machines, colleagues; then when the controversy heats up a bit we look at *where* the disputing people go and *what* sort of new elements they fetch, recruit or seduce in order to convince their colleagues; then, we see how the people being convinced stop discussing with one another; situations, localizations, even people start being slowly erased; on the last picture we see a new sentence, without any quotation marks, written in a text book similar to the one we started with in the first place. (15)

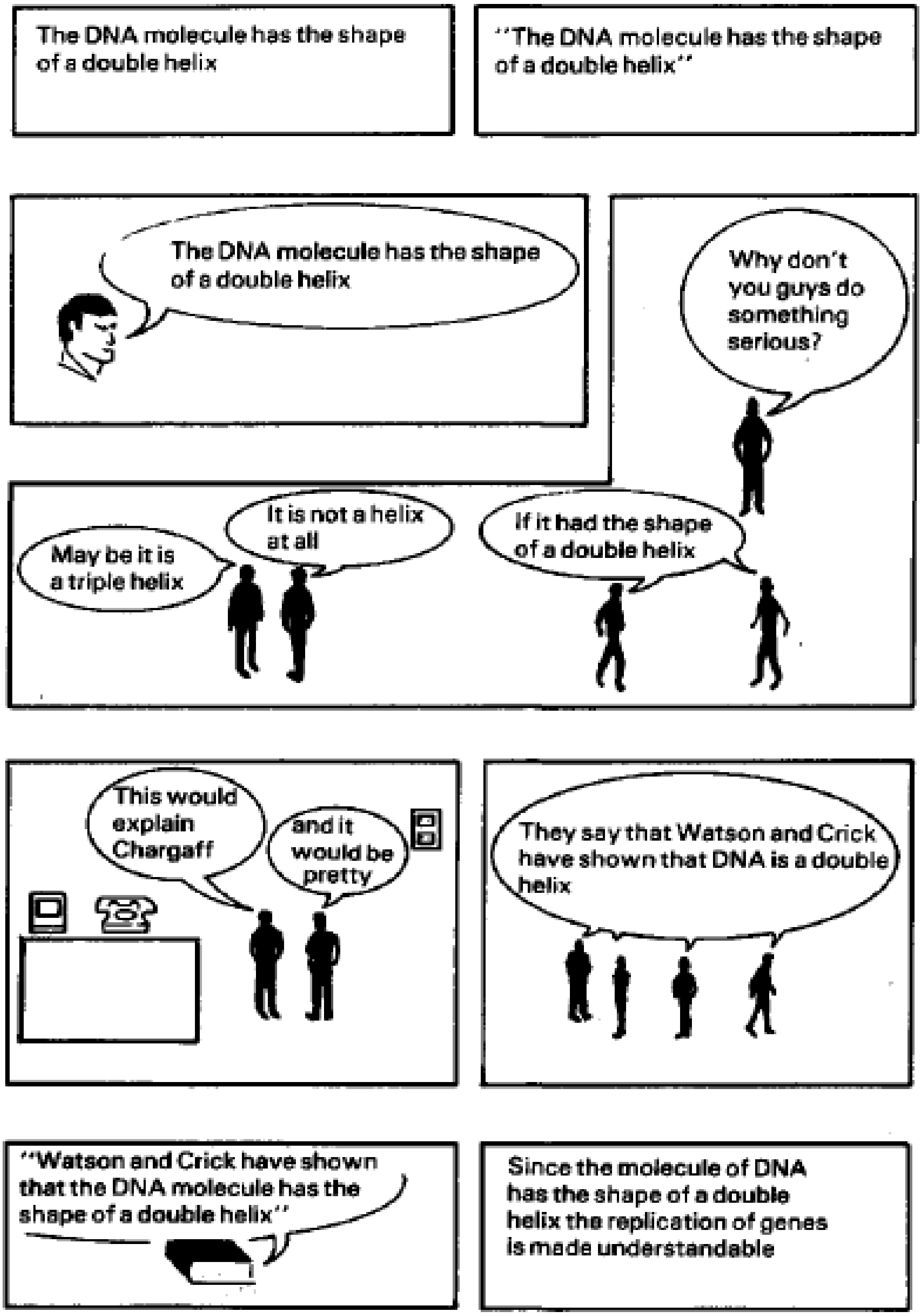

Figure 1: *Latour's (1987) diagram of textbooks, from* Science in Action *(14)*

Latour's (1987) sketch touches on the concerns that Kuhn (1996) and Feyerabend (2002) have about science. First, Kuhn's (1996) revolution happens through the discussion of theories from a variety of opinions, but ends up with a similar paradigm structure, a consistent outline of scientific revolutions. Second, to open black boxes, within Latour's (1987) description, requires the sharing of opinion for discovery; however, opening a black box and exploring the assumptions and premises that informs further discovery only leads to another black box. Feyerabend's (2002) claim that a variety of theories and methods can help 'humanize' science can only work if the conversations between each of the theories and methods continue (see Latour 1991, 1-12).

As Kenneth Burke (1969) writes in *A Rhetoric of Motives*, "Any such 'unmasking' of an ideology's limitations is itself made from a limited point of view. But each such limited perspective can throw light upon the relation between the universal principles of an ideology and the special interests which they are consciously or unconsciously made to serve" (198). Thus, Feyerabend's (2002) suggestion only works to develop science if students of scientific fields are taught to continue these conversations from a multiplicity of viewpoints; otherwise, we remain in a revolutionary state of discovery that yields little, if any, practical results or we enter into another paradigm. Latour's (1987) example, then, offers an opportunity to address each of these three concerns through simulated conversation (see Eisner 1985, 26[4]). The comic strip, a shortened version of the comics form, allows students to see science in action. In addition, students receive more than 'just the facts'; through the narrative of scientific development, they are provided with an understanding of the progression of science over time as well as how current scientific knowledge works. In other words, comics, as a visual narrative form, have the ability to address scientific revolutions, a multiplicity of theories and methods, and open black boxes by showing science in action. Before continuing to explore Gonick's examples, we need to understand what elements of the comics form can attend to these concerns in textbooks and how students can benefit from seeing science in action.

[4] Eisner writes: "The balloon is a desperation device. It attempts to capture and make visible an ethereal element: sound. The arrangement of balloons which surround speech – their position in relation to each other, or to the action, or their position with respect to the speaker, contribute to the measurement of time. They are disciplinary in that they demand cooperation from the reader. A major requirement is that they be read in a prescribed sequence in order to know who speaks first. They address our subliminal understanding of the duration of speech" (26).

Comics as a Pedagogical Tool

Defining Comics Accommodation

To begin, there may be some resistance to using the comics, a form traditionally associated with children's entertainment and non-serious subjects, within a science classroom. However, traditional comics-narrative perspectives can inform how comics demonstrate 'science in action': how science functions in, and outside, of the laboratory. Addressing this concern requires that we explore some empirical research about the use of textbooks in the classroom, as well as how effective comics can be in the classroom and, specifically, the science classroom. Understanding how a textbook in the comics form can address the concerns stated above and inform the discussion of how the comics form can be used as an effective pedagogical tool.

Marilyn J. Chambliss and Robert C. Calfee (1989) write, "lecturing children[5] about science has little effect, whether delivered by the teacher or presented in a textbook" (311-312). Science textbooks, to echo Kuhn (1996) and Latour (1987), merely present facts and how those facts fit into the paradigms (and black boxes) currently being taught; however, "effective instructional strategies must eradicate the naïve conceptions by relying on models, analogies, empirical reasoning, and discussion to help children connect their reality with the scientific understanding. The well-designed textbook exemplifies this approach both in content and structure" (Chambliss and Calfee 1989, 312). It is here that the comics form begins to make its use viable, in relation to models, analogies, and developing a personal connection to the information in textbooks. If we may translate Chambliss and Calfee's (1989) "conceptions" into a comics vocabulary, eradicating the naïve connections they speak to become clearer: models can be seen as the visual content in each comics frame; analogies become simplified, abstracted characters and stories; and the personal connection to the information develops through engaging and making the connections between the comics frames. As Will Eisner (1985) writes, "comprehension of an image requires a commonality of experience. This demands of the sequential artist[6] an understanding of the reader's life experience if his message is to be understood" (13). To make these connections, a textbook writer needs an awareness of the audience's common experience. In general, a student

[5] Where Chambliss and Calfee write "children," they are also speaking of 'students' in the classroom.
[6] A sequential artist, for Eisner, equates to a comics artist, such as Gonick.

audience is not an audience well versed in the intricacies of the field. Rather, a textbook attempts to prepare students for more concentrated study in the subfields.

More recent studies have explored similar trends in using popular culture artifacts to teach science, such as cartoons. For example, Perales-Palacios and Vilchez-Gonzalez (2002), in an empirical study comparing textbook information to cartoon television shows like *The Simpsons*, concluded that using a comparative analysis to dissuade students' misconceptions of physics – which they claim parallel "incorrect physics in cartoons" – can be pedagogically effective in learning the (now) basic laws of physics (405). However, to assume that cartoons and comics portray scientific concepts incorrectly would be inaccurate. While Locke (2005) has demonstrated that superhero comics tend to push the believability of scientific concepts, that one genre does not represent comics as a whole. Others, such as Joan Solomon (2002), suggest that introducing images into science education may introduce an empathic element to integrate the full "scope of the human mind" (103). Comics can certainly introduce the empathic (emotional) part of the human mind, but it accounts for the logical mind – after all, to use a cliché, 'seeing is believing.' The obstacle cited most often is that these visual media are problematic because of their lack of understanding of the fields. Still, if authors/artists work with scientists closely, as Gonick does, that obstacle can be circumvented, and those media can accommodate science appropriately.

As Fahnestock (1986) says, "the true accommodation involves finding the points of interest in the topic that will appeal to readers who are not apiologists [honey bee scientists] or even specialists in any life science" (280). Similarly, the comics form requires that these points of familiarity present an easily identifiable image for the audience. In Eisner's (1985) words, "the skill of the rendering and the universality of form chosen is critical" (14). While Fahnestock (1986) discusses accommodating science for public consumption, her argument applies to how we begin to accommodate science for the classroom[7]. Generally, scientific textbooks, according to Kuhn (1996), Feyerabend (2002) and Latour (1987), produce a linear perspective of science. However, for Eisner (1985), "universality" means to produce a general understanding of how the comics form constructs stories. As it applies to science,

[7] When discussing science textbooks and 'universality,' we are discussing early science education, either in secondary schools or in first-year collegiate courses. Otherwise, if we wait for advanced courses, students may have gained paradigms of science that may be difficult to discard. Addressing the concerns that Kuhn, Feyerabend and Latour express requires that students be taught about science at an early age.

then, Eisner's (1985) description suggests that the science textbook (in the comics form) should accommodate the content in such a way that the "drawings are a mirror reflection, and depend on the reader's stored memory or experience to visualize an idea or process quickly" (Eisner 1996, 17) and [the drawings] are not, as Punyashloke Mishra (2004) claims, a direct representation of reality (181) – whatever that would be. The power of comics to illustrate science in action, as well as other concerns of science education, comes from, as Gonick (2008) claims, a "primal identification with the simplified face that goes back to the perceptual apparatus of newborn babies, who see any circle as the face of a caregiver."[8]

Identifying with the Comics Form and Content

Scott McCloud (1994), in *Understanding Comics*, suggests that the power of comics come from the designer's ability to abstract an image in such a way that the viewer/reader can identify with characters and the action. Indeed, comics, as 'the invisible art,'[9] create a world of information that students can easily identify and engage with through abstraction by "de-emphasizing the *appearance* of the *physical* world in favor of the *idea* of form, the cartoon places itself in the world of concepts" (McCloud 1994, 41; original emphasis) – the concept of 'amplification through simplification (McCloud 1994, 30). While the purpose of science is to discover facts – not invent facts – in a specialized field, the education of students relies on situating the concepts and paradigms in context, a task the visual aspect of comics is well suited to accomplish. By paring down to the specifics in science education, students are provided, in Latour's words, "the right path [to scientific discovery with] *a sound mind and a sound method*" (184; original emphasis) that clears "away the distorting beliefs" (185) surrounding scientific discovery. The concepts the comics form focuses on can help students of science to develop sound methodologies 'free from prejudice' (see McCloud 1994; Latour 1987, 185) that muddles scientific discoveries. However, to achieve this freedom, science instructors can enhance student education by abstracting the "social and cultural conditions" (Latour 1987, 185) that distort scientific research.

McCloud (2002) argues that comics strip away the specifics of the social and cultural to focus on content, an approach to accommodation that can help science education free itself from

[8] This comes from a personal email cited in References. Also, see McCloud (1994).

[9] "The Invisible Art" refers to the subtitle of McCloud's *Understanding Comics* (1994). Others, such as Thierry Groensteen have also written extensively about abstraction and reader-identification, McCloud's and Eisner's perspectives permeate throughout more recent scholarship. Additionally, the recent view of comics as art (cf. Molotiu, *Abstract Comics*) adds credence to McCloud's and Eisner's descriptions.

these conditions. He writes, “The cartoon is a *vacuum* into which our *identity* and *awareness* are *pulled*… an *empty shell* that we inhabit which *enables* us to travel in *another realm*. We don’t just *observe* the cartoon, we *become* it” (McCloud 2002, 36; original emphasis). In relation to Latour’s (1987) argument that we need to open black boxes, comics allow students to become actors in the social and cultural life of scientific discovery. By identifying with the cartoon, students engage with a methodological approach in context, although not engaging in the discovery process. Still, the importance of the ‘vacuum’ and becoming the cartoon allows the content to matter more than the writer (McCloud 1994, 37), similar to what traditional science textbooks accomplish. While the comics form can be manipulated to disguise prejudices in methodology and opinion, comics also have the ability to clearly communicate a contextual understanding of how science is performed, enabling students to travel in the realm where those methodologies are socially and culturally applicable and constructed. Further, since students can see, when using the comics form, where and how science develops, they are more likely to connect that contextual learning to their own experiences.

Information designer Richard Saul Wurman (2001) writes of education: “Comparisons enable recognition. […] We recognize all things by their relationship to other things, by the context in which they exist” (270). As we saw in Latour’s (1987) comic strip, textbook information develops through discussions outside of the textbook, where science happens, not in textbooks, where scientific discoveries are recorded. However, when we place the conversation of scientific discovery in a textbook, a contextual and social understanding of science in action results. While the comics form creates a space for this conversation to take place within a textbook, the power of comics, as we see through McCloud (1994), resides in abstracting the concepts and procedures so that students begin to recognize their role as a “scientist” through the characters and action represented in the visual and verbal progression of discovery. Additionally, students also see the black box of discovery as they internalize the role of a scientist. Still, the concept of this role depends on the educator; as Locke (2005) says, there “are ways of *thinking about* science” (42; original emphasis), which echoes Fahnestock’s (1986) claim that “there is no ‘body of knowledge’ without bodies of knowers and these are multiple” (293). Further, as students learn the work of science in the contextual and social paradigms under which discovery happens, they must also learn the multiplicity of ways scientific discovery happens and how science develops over time. By juxtaposing several images to create a temporal narrative, the comics form can achieve what a single image and text-only textbooks have failed to accomplish.[10] The next section explores how comics compose time in such a way to address the concerns raised above.

Action in Comics & Seeing Science in Action

While there are various definitions of comics, the most appropriate for the purposes of a science textbook, as described above, comes from McCloud (1994): “juxtaposed pictorial and other images in deliberate sequence” (9). Other definitions of comics that include single-panels instances, photo-realism, non-textual, etc… McCloud (1994) acknowledges that his definition is limited, but for his purposes, and ours, this definition serves the most appropriate function.

A single image, even one that includes text, in science can be referred to as a diagram that visually communicates a single thought to an audience. By juxtaposing images in sequence, however, the comics form creates a temporal narrative that enhances the story of science and how science works in action. As Eisner (1985) notes in *Comics and Sequential Art*, “In the universe of human consciousness time combines with space and sound in a setting of interdependence wherein conceptions, actions, motions and movement have a meaning and are measured by our perception of their relationship to each other” (25). McCloud (1994) goes further to say that “between those frozen moments – between panels – our minds fill in the intervening moments, creating the illusion of time and motion” (94) which we can complete “based on past experience” (63). In contrast to text-only descriptions, the comics form not only allows students to see the work of science visually, but also temporally in context, which, according to Wurman’s (2001) discussion on learning, enhances students’ ability to learn. Additionally, as Eisner (1985) writes, this temporal aspect of comics “enables us to deal with the real business of living” (25); for the science classroom we can rewrite this to say that the temporal aspect of comics enables us to deal with the real business of science.

This ‘real business of science’, according to Kuhn (1996), Feyerabend (2002) and Latour (1987), is the performance of science and scientific discovery over time, not separate from time. As we see above in Latour’s (1987) mini-comic strip, the science occurs between the

[10] Film also does similar work, but is beyond the scope of this argument – in comics the most obvious participation is when readers fill the spaces between each frame in a traditional structure.

evolutions of the textbook descriptions (in the 'gutters'; see McCloud 1994). If we think of current scientific work as the textually transcribed stories of performed experimentation developed within a paradigmatic structure, the comics form can contextualize experimental development over time while preserving the content of that scientific work. In contrast to Fahnestock's (1986) description of popular accommodations of science[11], accommodating science in the popular comics form for the classroom can open the black boxes of discovery, rather than close them even further, by exposing the contextual, social and temporal development of specific fields and sub-fields. Using Gonick's (2005) *The Cartoon Guide to Physics* as a model may offer a potential solution to enhancing student comprehension contextually, socially and temporally as well as avoiding the problem Jorge Cham (2008) points to in the following webcomic called *PHD Comics*: passive science, instead of active science.

Figure 2: *Cham's* PhD Comics *from Feb. 22, 2008*

Gonick's Cartoon Guide as a Model

Example 1: a revolution in action

The example on the following page from Gonick's (2005) book is one that addresses what Kuhn (1996) refers to in an example as the 'emergence of a scientific theory': " Galileo's contributions to the study of motion depended closely upon the difficulties discovered in

[11] "Science accommodations […] replace the signs or data of an original research report with the effects or results, once again increasing the significance and certainty of their subject matter" (284)

Aristotle's theory by scholastic critics" (67). Further, those difficulties resulted in what Kuhn (1996) calls a revolution. Gonick (2005), in tracing the history of motion, shows the shift in paradigms, which, from Kuhn's (1996) perspective, we understand as a scientific revolution. Still, Gonick's trace of this version of history in the following image shows the pre-revolutionary paradigm (there is more about Aristotle's understanding of motion in the preceding pages) and the shift into a revolution with a idiosyncratic "So buzz off!" (19). The revolution, as Kuhn (1996) understood it, takes place in the shift before the new paradigm becomes accepted into scientific theory. As Gonick (2005) continues to trace out this history, he moves into the work of "normal science" – "research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice" (Kuhn, 1996; 10). Two pages later, Gonick (2005) writes, "Isaac Newton (1642 – 1727) summarized Galileo's idea as Newton's First Law […]" (21). In this record, Gonick's work addresses the Kuhnian scientific revolution, but continues to validate the work of science (which Kuhn does not argue against). To show how this can be done, the rest of this article will briefly touch on three examples from Larry Gonick's (2005) *The Cartoon Guide to Physics*. As the previous pages shows, the development of science does not necessarily follow a linear progression, as Tho Sprat (2003) suggests in *History of the Royal Society: For the Improving of Natural Knowledge*[12]. Rather, Gonick demonstrates visually (and humorously) that the development of science occurs when no further progress can be made in a field with the accepted paradigm. However, as Gonick continues his narrative of physical science[13], he also shows the validation of post-revolution science. Still, this validation is not one that claims scientific knowledge to be completely accurate, but, rather, as continually developing, defining and re-defining

[12] See pages: 61-62; 111-116

[13] Gonick's (2005) *The Cartoon Guide to Physics* creates a linear narrative of science beginning with chapter two of the book. However, as Gonick's (2005) narrative follows physics across time, the narrative of science does not necessarily develop in a similar way.

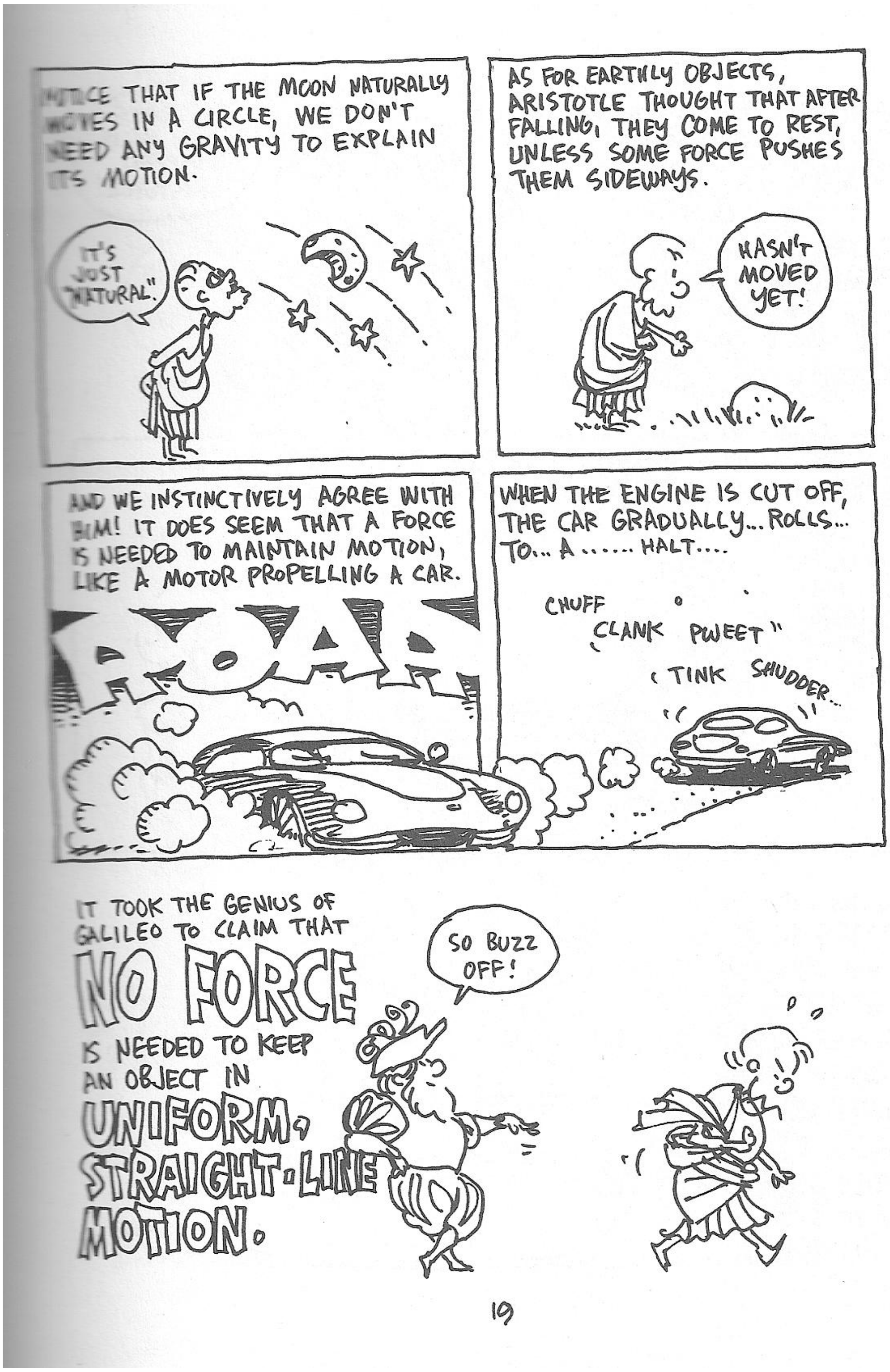

Figure 3: *from Gonick's (2005)* The Cartoon Guide to Physics, page 19

scientific, paradigmatic facts. In other words, Gonick’s (2005) work, in this example (including the previous and proceeding pages), demonstrates how comics can address Kuhn’s (1996) petition to disclose the development of scientific knowledge that does not always follow a linear path to knowledge. Rather, that science, at times, folds upon itself to achieve a more accurate understanding of facts before continuing with further experimentation (as Galileo returned to Aristotle, and Newton to Galileo, in order to refine the concept of gravity). In relation to Feyerabend's (2002) desire for a break from the *consistency condition,* this example also addresses the context in which the paradigm of motion developed. The views of Aristotle and Galileo conflict; the revolution (paradigm shift) shows the change from one previously accepted perspective to another. While science, currently, agrees with Galileo's assessment of motion, the inclusion of Aristotle's perspective not only addresses a multiplicity of perspectives, but also how and why some perspectives are rejected in favor of others.

Example 2: contextualizing science

Contextualizing information, for the purpose of learning, has to do with more than just where knowledge is discovered. Memory, one of the five canons of rhetoric derived from Aristotle's *On Rhetoric* (2007), has come to include the written word/text. However, Aristotelian memory focused on fostering the ability to remember information and then being able to apply it in practice. How well a science textbook, as they are currently constructed, accomplishes this goal is questionable. A major problem (one which we will not expound on in this article) is the ability of students to learn in the way that Aristotle conceptualized memory. However, as we saw Wurman (2001) explain above, "[we] only learn something relative to something [we] understand" (257); thus, "In teaching or communicating anything, we have no choice but to make connections between a new idea and that which is already known" (Wurman, 2001; 260). Asking students to memorize the information in a textbook without an understanding of the context in which that scientific knowledge has been discovered or where it is applicable becomes an exercise in futility. However, as we see in the selection from Gonick (2005), students are provided, in the first frame (the ball on a string), a contextualized relationship to a previous part of the historical narrative ("Recall the accelerometer ball we hung from Ringo's roll bar?") where new knowledge applies outside of the laboratory.

The commonality of the experience that Gonick (2005) describes in the selection on the following page (acceleration in a car), combined with McCloud's (1994) description above of becoming the character by way of abstract design, creates an experience that allows the student reading and seeing the page to associate personal experiences of a car ride to that character's experience. In other words, a student understands what Ringo (see Figure 4) experiences through the common experience of a car ride and that familiarity of experience allows, in Wurman's (2001) words, 'learning through connection to the personal' (257-260). Unlike a traditional textbook, in the way that Latour (1987) defines it, a comics form textbook can address these and develop this familiarity.

In addition to this familiarity of experience, this example addresses Feyerabend's (2002) claim of contaminated evidence (in discussing the Copernican theory):

> Consideration of all these circumstances, of observation terms, sensory core, auxiliary sciences, background speculation, suggest that a theory may be inconsistent with the evidence, not because it is incorrect, *but because the evidence is contaminated*. The theory is threatened because the evidence either contains unanalysed [sic] sensations which only partly correspond to external processes, or because it is presented in terms of antiquated views, or because it is evaluated with the help of backward auxiliary subjects (52).

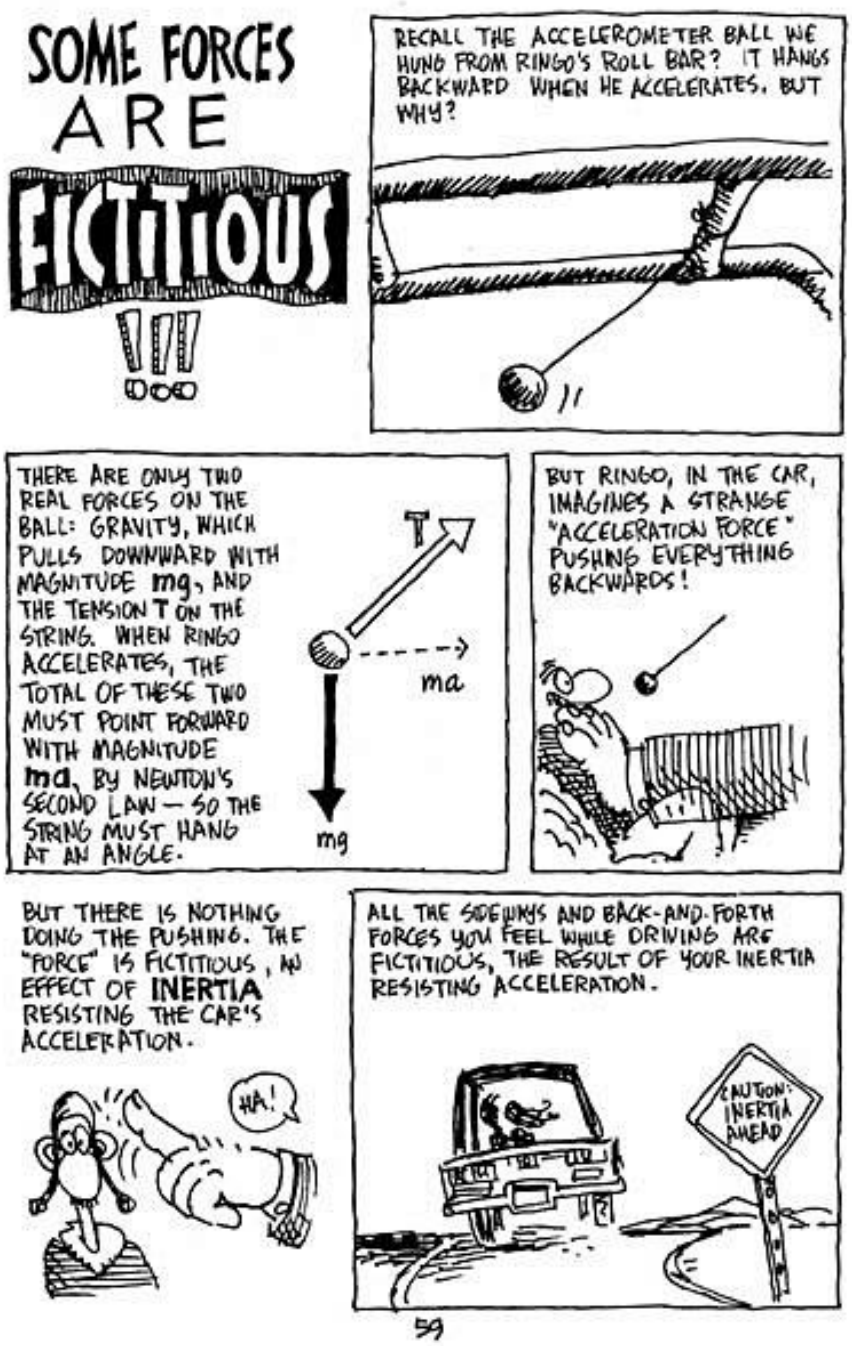

Figure 4: *from Gonick's (2005)* The Cartoon Guide to Physics, *page 59*

Specifically, in relation to the previous example, the comics form contextualizes the scientific theory in two ways: 1) as if it were to appear in a traditional textbook (see the second closed-panel); and 2) how the actual theory works in practice and can be applied to a familiar situation (a car ride). Ringo, the character, experiences the action; the reader, through identifying with Ringo, connects the scientific theory to his personal experiences of being ‘forced’ back in his seat by inertia. The student, then, experiences the sensations of the theory described within the paradigm of ‘force’ in an external process. Here, Feyerabend’s concern about contamination is addressed through a commonality of experience between scientist, student and science. While this does not address necessarily ‘contaminated evidence,’ the visual/verbal action of the comics form across panels allows students of science to point to sections where the evidence of the scientific theory could have become contaminated. However, these concerns can only be addressed through the next example: science in action across the panels of the comics form.

Example 3: science and comics in action

To explore the ways in which comics develop action in and across panels, we will use a selection from Gonick’s (2005) work that addresses momentum. The following example also comes from *The Cartoon Guide to Physics*:

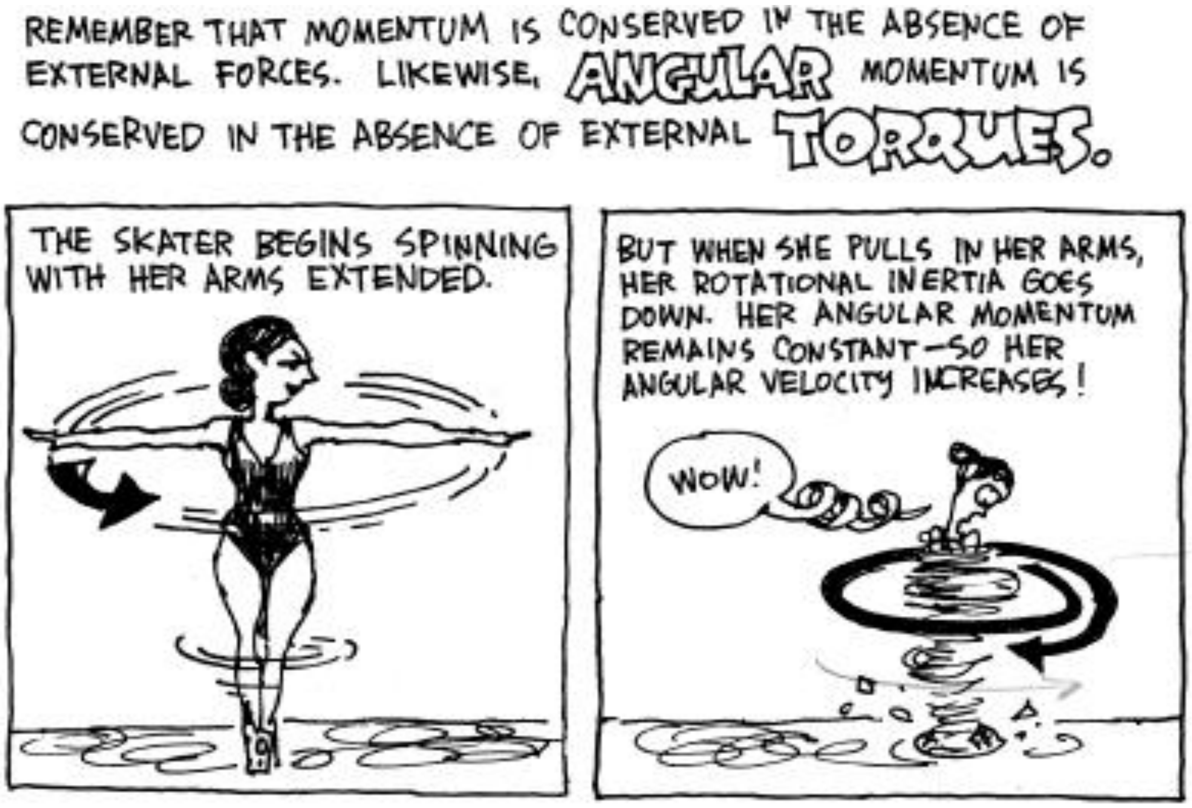

Figure 5: *from Gonick's (2005)* The Cartoon Guide to Physics, *page 95*

In the example above we see two things occurring: 1) our identification with the skater helps us to experience and understand the concept of angular momentum; and 2) we see a progression of speed from one panel to the other, which works as a synecdoche of how comics show science in action (since we have already explored how we may create a sense of identification, from the student's perspective, with the characters).

Through each of the previous examples, we have explored how comics can address the concerns that Kuhn (1996), Feyerabend (2002) and Latour (1987) express as problems with the educational practices that form future scientists. However, each of those concerns can be addressed through Latour's (1987) suggestion of studying science in action, in the laboratory. Yet, this last example suggests that the education of future scientists does not need to only happen in the physical laboratory; it can happen with an identification of science in action through the visual/verbal comics form as well (at least initially).

Just as a diagram in a traditional science textbook may use an image to show a singular moment of action, the juxtaposition of those images can create a sense of the temporal progression of how science is studied. If we look at the first panel in isolation, the skater spins slowly. If we then look at the second panel in isolation, we see the skater moving quickly. However, these two images together tell us nothing of how angular momentum works. Only through the juxtaposition of the two images do we get a sense of the action taking place to increase the speed. Additionally, the text, in this case, supplements the action by describing exactly what is happening in the images to develop motion. It is here, in this example, that we finally come to see the power that Gonick's (2005) "Cartoon Guides" can have in a science classroom: as Latour (1987) suggests, "Apart from those who make science, who study it, who defend it, there exist, fortunately, a few people, either trained as scientists or not, who open black boxes so that outsiders may have a glimpse at it" (15). Students, when entering a science classroom of any kind, begin as outsiders to science. However, by opening the black box of science in order to allow students to glimpse the ways in which science is performed we may be able to provide students with an effective introduction to scientific fields (and subfields). By seeing how science is performed ('in action') temporally and contextually, it also celebrates, validates, and exposes the black boxes of scientific research – namely revolutions, *consistency conditions*, multiple methodologies and how the scientific textbook knowledge has developed over time. How this is accomplished can be summed up in the Gonick's (2008) words: "I'm trying to find a compelling narrative thread that tells the essential story, not looking for ways to give a half-assed version to dummies."

Conclusion

As we have seen, comics have great potential for the science classroom. While Latour's (1987) comic strip offers an introduction to seeing science in action, an expanded exploration of science accommodated for the comics form could enhance our understanding of how the concerns that Kuhn (1996), Feyerabend (2002) and Latour (1987) raise can be addressed.[14] If we can recall the diagram on page seven of this article we can see how some of these concerns are addressed: (1) we see a textbook description of a double helix that (2) becomes associated with a speaker when placed in a speech balloon; (3) once spoken, the claim is discussed, refined and re-defined and (4) associated with a speaker; (5) this redefinition, then, enters the new, evolved textbook without, as Latour (1987) writes, "any trace of fabrication, construction or ownership" (15). For Latour (1987) the question becomes: 'Why do scientists hide the process of discovery in textbooks?' However, the above description has farther-reaching consequences. Specifically, the disagreement of the two characters and the singular paradigm that informs the redefined textbook claim is presented as objective by the removal the actors, speech balloons, and associations with contextual and social development (and, perhaps, discovery[15]) of knowledge. Opening the black boxes of the contextual and social developments of science through the comics form, as we have already seen, can enhance student comprehension of how science is performed and the suppositions under which scientific knowledge develops.

Latour's (1987) use of a comic strip begins to open up the ways in which we can begin to think about the applicability of the comics form in the science classroom. However, Latour (1987) uses the comic strip to illustrate the problems of science textbooks, not as a solution to the problem that he identifies. And yet, if we use his (Latour's) example of showing the development of the knowledge disseminated in a science textbook, we can begin to open the black boxes.

[14] See Perales-Palacios and Vilchez-Gonzalez (2002).

[15] I use the word "perhaps" here not to insinuate that discovery is absent from scientific development; rather, "perhaps" is being used to indicate that the process of the comic strip that Latour (1987) uses is based on an existing paradigm and seems only to be refined and redefined, and not revealing new information through experimentation.

While there are other examples of science comics that could work as models for a comics form science textbooks[16], Gonick's (2005) work resembles an effective textbook that does not seek to reduce science to the most basic concepts for "dummies" (Gonick, 2008); instead, Gonick's (2005) work exposes science in such a way to open those black boxes as well as develop an understanding of how scientific work is done. Still, Gonick (2008) writes that he directed this specific work (*The Cartoon Guide to Physics*) towards a general, popular audience. By using his (Gonick's) work as an example of how a textbooks in comics form can be used in science classroom, we may begin to see a revolution in the education of future scientists.

[16] See *Physics: Why Matter Matters* by Dan Green and Simon Basher; *The Periodic Table* by Adrian Dingle and Simon Basher; *Quantum Entanglement, Spooky Action At a Distance, Teleportation and You(Including a Brief but Helpful Section on Why,Perhaps,You Should Not Try This At Home)* by Jim Ottaviani and Roger Langridge; *Suspended In Language : Niels Bohr's Life, Discoveries, And The Century He Shaped* by Jim Ottaviani et al.; *The Cartoon Guide to Chemistry* by Larry Gonick; and *The Cartoon Guide to Genetics* by Larry Gonick.

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