

THE CONTRIBUTION OF “POPULAR” BOOKS TO THE INFORMAL LEARNING OF CHEMISTRY

Ana S. Afonso¹ and John K. Gilbert²

¹University of Minho, Portugal

²King's College London, U.K.

Abstract: This study aims at identifying and categorizing books based on chemical ideas for a general audience, at analyzing the text understanding and interest in the themes covered in the book by a non-specialist audience, and at identifying characteristics of the text that can enhance reading with comprehension for that group of individuals. In order to attend to these aims, the catalogues of 59 major publishers, publishing books in Portuguese and English, were searched and 145 books currently available in the market were identified. These books were then grouped according to their themes. In addition, 17 students, with no extensive background in science, were invited to select a book from one of the categories, to summarize it, and to evaluate it using a general framework provided to them. Results show that most of the books are about “biographies of chemists” or about “particular chemicals”, and that readers became interested in some themes covered by the book. An overall understanding of the text was not achieved; in particular, aspects concerned with nature of science were not understood. The readability of the books was constrained by features of the text.

Keywords: books for general audience, comprehension of text, informal science education, learning of chemistry.

INTRODUCTION

“Popular” chemistry books: a partway to chemistry literacy

Chemistry is embedded in all aspects of life; from food preparation, cosmetics, cleaners, and waste disposal to textile preparation. Although the idea of “chemical-free” life is a myth, several misconceptions about what chemicals are and do are spread among citizens (e.g. chemicals are unsafe, cause pollution, and can be avoided by special diets and soaps, synthetic chemicals are causing many diseases) and influence their decisions about health, lifestyle and social policies (Hartings & Fahy, 2011). Consequently, there is a need to improve the levels of chemistry literacy among citizens so that they can move from lower levels of chemical literacy, in which chemistry can inform proper decisions in daily life (i.e. practical literacy), to higher levels of literacy in which individuals can participate in social debates involving chemical sciences (i.e. civic literacy) or appreciate chemistry as a major intellectual activity (i.e. cultural literacy) (Shwartz, Ben-Zvi, & Hofstein, 2006).

Informal chemistry education plays an important role in engaging citizens with chemistry, in particular adults who are no longer in the educational system. Informal chemistry education can be characterized by being voluntary, learner-led, non-assessed, and covering a diversity of contents. It can also be promoted in different settings, ranging from science museums, television, Internet to print. These modes of communication have been successful in engaging and educating citizens in science broadly. However, in some of these informal settings, such as television or science museums, few chemistry ideas are covered. Print has been one of the main modes of communication used by USA adults to engage with science (Masciangioli, 2011). In particular, in the last thirty years there

has been a publishing boom of science books for a non-specialist audience (Turney, 2001). Yet, the role of these books in promoting scientific literacy, in particular chemistry literacy, is unclear due to a lack of systematic studies focusing on this mode of communication.

Chemistry books for non-specialists can be called “popular” chemistry books. They can be defined as books based on chemistry ideas, printed in a large scale for a general audience who are interested in improving their understanding of a particular theme and in being entertained at the same time. General guidelines have been proposed for writing “popular” chemistry books so that they can have an impact on improving chemistry literacy (Emsley cited in Masciangioli, 2011): choose a topic being that is something new, something that answers previous problems, something that overturns beliefs, something that impacts people’s lives; avoid of technical terms but if they are necessary they need to be explained; avoid chemical formulas; neither overestimate the public’s familiarity with the topic nor underestimate their intelligence; include human interesting information; and make chemistry visible by giving it a critical role in stories.

Reading with comprehension

A text can be processed at two different modes: either as a set of propositions (i.e. a description of a text itself, retaining its structure) or as a mental model. Reading with comprehension requires constructing a mental model of what the text is about. A mental model of a text is an adequate mental representation of the elements of the text (e.g. events, states, objects, and protagonists) and their relations (e.g. causal, temporal, and logical) that are explicitly mentioned or that can be inferred from the text. A model of a text is personal, is guided by the reader’s goals, is continuously updated and constructed during reading, and corresponds to an interpretation of a particular text in a particular moment (Kintsch & Rawson, 2005; van Dijk, 1995). Thus, a mental model of a text is a representation of the situations described by a text, rather than a description of the text itself.

Constructing a mental model implies the simultaneous activation of top-down (e.g. retrieval of prior knowledge) and bottom-up (e.g. recognition of “data” from the text) processes. This is an easy task for skilled and knowledgeable readers but a problem solving activity for non-skilled or less knowledgeable readers. For the former readers, top-down processes ensure that text information, consistent with their prior models and expectations, is integrated in their mental structure; while the bottom-up processes call the readers’ attention to novel information. It is expected that skilled and knowledgeable readers can not only select, synthesize and organize the main ideas in a coherent summary (i.e. provide an overall understanding of a text) but also build a mental model that goes beyond a literal interpretation of the text by making predictions, mental imagery, and creating links with prior experiences. For less knowledgeable readers, the activation of prior knowledge is poor and inferences from the text are difficult to perform. This results in a superficial integration of the new information into their existing mental structures. In an extreme situation, top-down processes may dominate reading, resulting in inferences based on prior guesses, oversimplifications and processing of irrelevant information. Consequently, misreading will occur and an inadequate mental model will be created (Adams, 1980; Kintsch & Rawson, 2005).

In this constructive process of meaning, different factors influence the readers’ processing of a text, namely (Irwin, 1983):

- the reader's individual characteristics: Who is reading? Attends to the reader's prior knowledge about the topic, emotional attitudes towards the topic and the reading task, and reading skills;
- the reading material itself and its individual characteristics: What is being read? Refers to micro-structural features (e.g. world familiarity, sentence length, inter-sentential coherence); macro-structural features (e.g. summaries of the main points clear organizational pattern of the text, form of the text – expository, narrative,...); and elaborative features (e.g. analogies, pre and post-reading questions, examples);
- the situational characteristics: Why, when and where are they reading? Concerns the purpose of the reading task and the social, emotional and physical environments.

A major challenge consists in finding an appropriate match between the reader and the reading material. The reading material is a channel of communication between the writer and the reader and writers need to take decisions on the form and content of the text by making considerations on a given audience. In the light of the literature, this study aims at:

- Identifying and categorizing the “popular” chemistry books that are currently available in the market
- Analyzing the text understanding and interest in the themes covered in the book by a non-specialist audience
- Identifying characteristics of the text that can enhance reading with comprehension for that group of individuals.

METHODOLOGY

In order to identify and categorize “popular” chemistry books currently available in the market, the abstracts of “popular” chemistry books, published in English or Portuguese, were searched in the catalogues of major publishers. 145 books, identified in 59 publishers, were then grouped according to their main themes. In addition, 17 undergraduate Portuguese students of education with no extensive background in science were invited to select a book from one of the categories of books created, to read it from cover to cover, to provide a summary of the texts and to evaluate the books. The readers' choices were confined to books published in Portuguese. Yet some of them were translations of books originally written in English or French. Since situational characteristics affects reading outcomes, a list of general aspects that students should have in consideration when evaluating the books were provided to them. These aspects, based on the literature on text comprehension, include: the interest and the appeal of the book; the chemical ideas included in the book; the relevance of the information provided; specific features of the text; the overall written style; and the way chemical knowledge is produced. In addition, 11 students, who produced unusual or incisive evaluations, were interviewed. The data from the books' evaluation were analyzed by using the literature on “reading with comprehension” as a framework.

RESULTS

Popular chemistry books

As can be seen from Table 1, most of the books were published in English, most of the authors were male, and most of the books are included in the categories “biographies of chemists” and “particular chemicals”. Although less frequent, some books fit into the categories “chemical cookbook/hands-on chemistry”, “foundation ideas in chemistry”, “fiction with an emphasis on chemistry”, “use of chemistry in other disciplinary fields”, “history of developments in chemistry”, and “chemistry in everyday life”.

Table 1: The language of publication, authors' gender and categories of "popular" chemistry books (n=145)

"Popular" chemistry books		f
Language	Portuguese	36
	English	109
Author's gender	Female	22
	Male	123
Category	- Chemical cookbook/hands-on chemistry: describe phenomena and reactions that can be safely explored by readers	4
	- Foundation ideas in chemistry: deal with the core ideas of chemistry	9
	- Fiction with an emphasis on chemistry: present chemistry embedded in a fictional story	9
	- Use of chemistry in other disciplinary fields: discusses the contribution of particular chemistry ideas to research and development of other disciplinary fields	10
	- History of developments in chemistry: conveys how chemistry emerged and developed over the years	17
	- Chemistry in everyday life: emphasize the contribution of chemistry in daily life and social life	18
	- Biographies of chemists: recount the life and time of a chemist and his/her contribution to chemistry	38
	- Particular chemicals: focuses on the chemistry, applications and implications of particular substances and chemical species	40

Comprehension of the text and factors affecting it

In spite of the diversity of titles of the books selected by readers (Table 2), the data show that reading with comprehension was a difficult task for them (Table 3). Most of the readers' summaries of the books are descriptions of the text itself or parts of it, maintaining the structure of the book in their summaries. Few readers (two) built mental models of their texts, and they only reflect an overall understanding of the text. Thus, for the majority of the readers, the reading process seems to have been restricted to decoding of individual idea units and sentences (Irwin, 1993).

Issues on the nature of chemistry (NOC) were not valued and understood by readers. Their views on NOC reflect fragmented and naïve understanding of scientific enterprise and scientific inquiry, as the following example illustrates:

"Experiments in chemistry result from observing the world. They are the grounds for building theories which are sometimes incompatible. Sometimes, scientists steal researches from their peers. This book mentions the pressure that scientists feel to publish. However, in order to publish scientists need to submit their papers to peer review" (Reader 2, *Water*)

Two reasons may explain this finding: readers may hold strong misconceptions about the theme, and aspects on the NOC are scattered along the text and not explicitly mentioned. The former reason may guide readers to select only the information presented in the text that support their beliefs on NOC. The latter reason may restrict the readers' opportunities to critically reflect on their views on NOC and to move towards acceptable conceptions, due to their difficulty in selecting, synthesizing and organizing the main ideas in a coherent summary.

Table 2: Reference of the books selected by readers in each category

Category	Reference of the selected books
Chemical cookbook/hands-on chemistry (2 readers)	Mateus, A. (2001). <i>Chemistry in our head: Spectacular experiences that you can have at home</i> (Química na cabeça: Experiências espetaculares para você fazer em casa). Minas Gerais: UFMG
Foundation ideas in chemistry (2 readers)	Atkins, P. W. (1995). <i>The Periodic Kingdom: A Journey into the Land of the Chemical Elements</i> . New York: Basic books. Laszlo, P. (1995). <i>A palavra das coisas ou a linguagem da química</i> (The word of things or the chemical language). Lisbon: Gradiva
Science fiction with an emphasis on chemistry (1 reader)	Djerassi, C. & Hoffmann, R. (2001). <i>Oxygen: A Play in 2 Acts</i> . Weinheim: Wiley-VCH
Use of chemistry in other disciplinary fields (2 readers)	Bourre, J. (1993). <i>Comida inteligente: A Dietética do Cérebro</i> . (Clever food: The diet of the brain). Lisbon: Gradiva Watson, J. (1980). <i>The Double Helix: A Personal Account of the Discovery of the Structure of DNA</i> . New York: W.W. Norton
History of developments in chemistry (2 readers)	Laszlo, P. (1996). <i>A nova Química</i> (The new chemistry). Lisbon: Instituto Piaget Pimentel, G. (1998). <i>Oportunidades em Química – Hoje e amanhã</i> . (Opportunities in Chemistry: Today and Tomorrow). Lisbon: Sociedade Portuguesa de Química.
Chemistry in everyday life (2 readers)	Schwarcz, J. (2001). <i>The Genie in the Bottle: 67 All-New Commentaries on the Fascinating Chemistry of Everyday Life</i> . Toronto, ON: ECW Press Escoval, M. T. (2010) <i>Acção da Química na Nossa Vida</i> (Chemistry in our life). Lisboa: Presença.
Biographies of chemists (3 readers)	Filgueiras, C. (2007). <i>Lavoisier e o estabelecimento da química moderna</i> (Lavoisier and the contemporary chemistry). São Paulo: Odysseus Levi, P. (1994). <i>The periodic table</i> . New York: Schocken books Oliver S. (2002). <i>Uncle Tungsten: Memories of a Chemical Boyhood</i> . New York: Alfred A. Knopf
Particular chemicals (3 readers)	Aldridge, S. (2001). <i>Magic molecules: how drugs work</i> . Cambridge University Press. Ball, P. (2000). <i>Life's Matrix: A Biography of Water</i> . New York: Farrar Straus & Giroux Colborn, T., Dumanoski, D. and Myers J. P. (2010). <i>Our stolen future: How do we disposal chemical synthetic substances – our fertility, intelligence and survival</i> . New York: Penguin

Table 3: Readers' comprehension of the text (n=17)

Comprehension of the text	f
Bellow descriptive mode	2
Descriptive mode	13
Mental model mode	2

Several features of the text were pointed out as enhancing understanding. They include: 1) elaborative features, namely illustrations of mechanisms or drawings; analogies that employ familiar analogues; and adjunct questions; 2) macrostructure features, such as presence of sub-headings; and 3) microstructure features, particularly explanations of scientific vocabulary (Table 4).

Table 4: Comments on features of the text that were perceived as affecting understanding

Comments	Aspects mentioned and examples of response
Elaborative features (n=23)	<ul style="list-style-type: none"> • Illustrations “The images helped me to understand the descriptions presented in the text, allowing a more concrete idea about the objects that are mentioned.” (Reader 13, <i>Oxygen: A Play in 2 Acts</i>) • Analogies “There are some analogies that support comprehension. For example ‘a living organism is like a chemical factory’ (Reader 14, <i>Opportunities in chemistry: today and tomorrow</i>) • Adjunct questions “Questions are also present in the majority of the chapters, which is useful because they hold the readers’ attention, involving them with the text and leading to self-questioning.” (Reader 15, <i>Our stolen future: are we threatening our fertility, intelligence, and survival?</i>)
Macro-structure features (n=27)	<ul style="list-style-type: none"> • Sub-headings “The book organization around themes and sub-themes contributed for organizing mentally the information understood for each theme.” (Reader 4, <i>Magic molecules: how drugs work</i>)
Micro-structural features (n=10)	<ul style="list-style-type: none"> • Scientific vocabulary explained “The author provides several definitions that enhance understanding, e.g. on p. 51, the author says that: ‘I found a huge demijohn of technical benzene, at 95 percent purity. Manuals prescribed rectifying it and then putting it through a final distillation in the presence of sodium. To rectify means to distil it by fractions’ (Reader 10, <i>The Periodic Table</i>)

Interest in the themes covered by the books

Although sustained interest in the themes covered by the books was low, readers experienced motivation and interest in some sections of the books. Interest typically arises from reading a synopsis of the book that includes information about the importance of a theme and attends to reader’s interests and non-expertise on the theme. Interest in a given part of the book can then be raised, depending on whether or not the text matches the information provided in the synopsis; the themes covered are linked to reader’s concerns/needs/interests; and the author avoids specialist language. An example is:

“The synopsis is appealing because it focuses on the fundamental aspects of the book and mentions that it is appropriate to the general public. It called the readers’ attention to the importance of reading the book without involving them in a scientific and complex reading. [After reading the book] I was interested to learn about some themes, i.e. recreational drugs or cancer. The theme “recreational drugs” was of interest to me because it is a contemporary theme that we face in our everyday life, mainly in clubs. Similarly, I was interested in the theme “cancer” because one of my family members suffered from that disease. On the other hand, in spite of the cutting edge research on the theme “gene-based medicine”, I was not interested in the topic. It is very complex and is not clearly related to my everyday life.” (Reader 4, *Magic molecules: how drugs work*)

CONCLUSIONS

The results of the study suggest that those who only read Portuguese will have restricted opportunities to develop their chemical literacy through “popular” science books, since

these are scarce. There is a need to stimulate female chemists to write “popular” science books. Finally, more book titles on “fiction with an emphasis on chemistry”, “chemistry in other disciplinary fields”, and “chemistry in everyday life” are needed. Books on “fiction with an emphasis on chemistry” contain narrative, which is a key element in science communication (Stockmayer & Gilbert, 2002); books on “chemistry in other disciplinary fields” and “chemistry in everyday life” can be successful in raising cultural and practical literacy.

For less knowledgeable readers, reading “popular” chemistry books with comprehension may be enhanced when they include: a) elaborate features (e.g. analogies with familiar analogues, drawings, illustrations of mechanisms, pictures, and pre- and post-reading questions); b) macroscopic features (e.g. sub-headings); c) microscopic features (e.g. explanations of scientific terminology). In addition, understanding NOC requires an explicit approach to the issue as already pointed out by (Khishfe & Lederman, 2007). Comprehension and interest are related (Irwin, 1983). Arising and sustaining the latter can be facilitated by including frequent and explicit links between the theme being addressed and the interests/needs/concerns of the readers, and by keeping a tied continuity between the synopses and the different parts of the book.

REFERENCES

- Khishfe, R., & Lederman, N.G. (2007). Relationship between instructional context and views of nature of science. *International Journal of Science Education*, 29(8), 939–961.
- Stockmayer, S., & Gilbert, J.K. (2002). Informal chemical education. In J.K. Gilbert, O. De Jong, R. Justi, D.F. Treagust, & J.H. Van Driel (Eds.), *Chemical education towards research-based practice* (pp. 143-164). Dordrecht, The Netherlands: Kluwer.
- Hartings, M.R., & Fahy, D. (2011). Communicating chemistry for public engagement. *Nature Chemistry*, 3, 674-677.
- Shwartz, Y., Ben-Zvi, R., & Hofstein, A. (2006). The use of scientific literacy taxonomy for assessing the development of chemical literacy among high-school students. *Chemistry Education: Research and Practice*, 7(4), 203-225.
- Masciangioli, T.M. (2011). *Chemistry in primetime and online: communicating chemistry in informal environments*. Washington, D.C.: National Academies Press
- Turney, J. (2001). More than story telling-reflecting on popular science. In S.M. Stockmayer, M.M. Gore, & C. Bryant (Eds.). *Science Communication in theory and practice*. London: Kluwer Academic Publishers.
- Irwin, J.W. (1983). *Teaching reading comprehension processes*. New Jersey: Prentice-Hall
- Kintsch, W., & Rawson, K.A. (2005). Comprehension. In M.J. Snowling, & C. Hulme, (Eds.), *The science of reading: a Handbook* (pp. 209-247). Malden, MA: Blackwell publishing
- van Dijk, T.A. (1995). On macrostructures, mental models, and other inventions: A brief personal history of the Kintsch-van Dijk Theory. In C.A. Weaner III, S. Mannes & C.R. Fletcher (Eds.). *Discourse comprehension: Essays in honor of Walter Kintsch*. New Jersey: Lawrence Erlbaum.
- Adams, M.J. (1980). Failures to comprehend and levels of processing in reading. In R.J. Spiro, B.C. Bruce, & W.F. Brewer (Eds.), *Theoretical issues in reading comprehension: perspectives from cognitive psychology, linguistics, artificial intelligence, and education* (pp. 11-32). New Jersey: Lawrence Erlbaum