Διεθνές Συνέδριο για την Ανοικτή & εξ Αποστάσεως Εκπαίδευση

Τόμ. 10, Αρ. 2A (2019)

Graphic-text integration in distance education science textbooks / Αλληλεπίδραση εικόνας-κειμένου σε εγχειρίδια φυσικών επιστημών εξ αποστάσεως εκπαίδευσης

Georgios Ampatzidis, Anastasia Armeni

doi: [10.12681/icodl.2309](https://doi.org/10.12681/icodl.2309)

Graphic-text integration in distance education science textbooks

Αλληλεπίδραση εικόνας-κειμένου σε εγχειρίδια φυσικών επιστημών εξ αποστάσεως εκπαίδευσης

Ampatzidis Georgios
Hellenic Open University, Adjunct Lecturer
ampatzidis.georgios@ac.eap.gr

Armeni Anastasia
University of Patras, Researcher
armeni@upatras.gr

Abstract

Considering the fact that (a) textbooks determine largely what is taught and learned in science classrooms, (b) science textbooks tend to rely heavily on illustrations, (c) the role of textbook in distance education may be even more important than in conventional classroom-centered education, and (d) there is little information available about the graphical demands of science textbooks used in distance education, this paper reports on exploring the graphics included in science textbooks used in a distance learning undergraduate course. More specifically, we investigated the graphics included in three textbooks (chemistry, biology and physics) used in the 'Studies in Natural Sciences' course offered by the Hellenic Open University. Drawing on the Graphical Analysis Protocol (GAP), we coded the 268 graphics identified in mutually exclusive categories concerning text-graphic integration – i.e. (a) level of contiguity between graphics and text, (b) extent of in-text reference to graphics, and (c) captions' function regarding text-graphics connection. The analysis of results suggests that (i) the majority of graphics are contiguous with the relevant text in the biology and physics textbooks but this is not the case for the chemistry textbook, (ii) the majority of graphics are referenced in the text of all three textbooks, and (iii) the majority of graphics in all textbooks have captions that are mostly used to (a) describe the graphics included in the chemistry textbook, (b) identify what is shown in the graphics included in the physics and biology textbooks.

Keywords: *Science textbooks, graphics, distance education, text-graphics integration, undergraduate students*

Περίληψη

Λαμβάνοντας υπόψη το γεγονός ότι (α) τα σχολικά εγχειρίδια καθορίζουν σε μεγάλο βαθμό το περιεχόμενο της διδασκαλίας των φυσικών επιστημών, (β) τα σχολικά εγχειρίδια φυσικών επιστημών τείνουν να βασίζονται σε μεγάλο βαθμό στην εικονογράφησή τους, (γ) ο ρόλος των σχολικών εγχειριδίων στην εξ αποστάσεως εκπαίδευση μπορεί να είναι πιο σημαντικός από ότι στη συμβατική εκπαίδευση, και (δ) υπάρχουν λίγες διαθέσιμες πληροφορίες σχετικά με τις απαιτήσεις της εικονογράφησης των εγχειριδίων φυσικών επιστημών που χρησιμοποιούνται στην εξ αποστάσεως εκπαίδευση, η παρούσα εργασία αναφέρεται στη διερεύνηση της εικονογράφησης των εγχειριδίων φυσικών επιστημών που χρησιμοποιούνται σε μαθήματα εξ αποστάσεως εκπαίδευσης. Πιο συγκεκριμένα, διερευνήσαμε τις εικόνες τριών εγχειριδίων (χημείας, βιολογίας και φυσικής) που χρησιμοποιούνται στο μάθημα «Σπουδές στις Φυσικές Επιστήμες» που προσφέρει το Ελληνικό Ανοιχτό Πανεπιστήμιο. Με βάση το πρωτόκολλο Graphical Analysis Protocol (GAP), κωδικοποιήσαμε τις 268 εικόνες που ανιχνεύθηκαν σε αμοιβαία αποκλειόμενες κατηγορίες που αφορούσαν την αλληλεπίδραση εικόνων και κειμένου – δηλαδή (α) το επίπεδο συνοχής μεταξύ εικόνων και κειμένου, (β) την ύπαρξη αναφορών στο κείμενο για τις αντίστοιχες εικόνες, και (γ) τη λειτουργία των λεζάντων σχετικά με τη σύνδεση εικόνων και κειμένου. Η ανάλυση των αποτελεσμάτων δείχνει πως (1) η πλειοψηφία των εικόνων έχει καλή συνοχή με το κείμενο στα εγχειρίδια βιολογίας και φυσικής, αλλά αυτό δεν ισχύει για το εγχειρίδιο χημείας, (2) για την πλειοψηφία των εικόνων και στα τρία εγχειρίδια υπάρχουν αναφορές στο κείμενο, και (3) η πλειοψηφία των εικόνων και στα τρία εγχειρίδια έχουν λεζάντες που χρησιμοποιούνται κυρίως για (α) να περιγράψουν αυτό που εικονίζεται (εγχειρίδιο χημείας), (β) να προσδιορίσουν αυτό που εικονίζεται (εγχειρίδια φυσικής και βιολογίας).

Λέξεις-κλειδιά: *Εγχειρίδια φυσικών επιστημών, εικονογράφηση, εξ αποστάσεως εκπαίδευση, αλληλεπίδραση εικόνας-κειμένου, προπτυχιακοί φοιτητές*

1. Introduction

Graphical representation has been commonly used to communicate scientific and technical information since the 15th century. Engineers lived in 1400s used notebooks that relied profoundly on graphics; text, when existed, was merely used to explain the images. Some historians suggest that the development of printing, which made illustrated scientific and technical books available to a broader audience, may have contributed considerably to the important technological advances that took place between the16th and 18th century (Hegarty, Carpenter, & Just, 1991).

Images of science seem to occupy today a central role across scientific inquiry itself, mass media reports of science news, and science textbooks (Slough, McTigue, Kim, & Jennings, 2010). Focusing on textbooks, we note that the majority of school texts created to be used for science teaching rely heavily on illustrations (Liu & Khine, 2016). Visual representations are considered as natural extensions of text (Mayer, 2001), critical in the communication of scientific ideas (Ametller & Pintó, 2002); it is commonly believed that text accompanied by well-designed graphics may be more effective in supporting students to build understanding about demanding science concepts (Khine, 2013).

Textbooks are considered by science teachers as resources which support them in organizing their lessons in a way that meets national curricular standards (Abd-El-Khalick, Waters, & Le, 2008). However, it is well known that in most classrooms textbooks *become* the curriculum and determine largely what is taught and learned about science (Liu & Khine, 2016). For instance, Weiss, Banilower, McMahon, & Smith (2001) note that textbooks are the main source used by over 90% of secondary science teachers in USA for planning/delivering instruction and assigning homework. Moreover, Liu & Khine (2016), referring to the Trends in International Mathematics and Science Study of 2007, mention that about 40% of teaching time worldwide corresponds to textbook-based instruction.

As already discussed, textbooks seem to play a significant role in conventional classroom-centered education; however, their role in distance learning environments, blessed with numerous online learning resources, might need to be reviewed (Lau et al., 2018). Textbook-centered distance education has received criticism for creating a single-dimensioned, isolated learning experience while computer-based distance education is promoted as an alternative for being able to support collaboration among remote students in more interactive ways (Johnson, Kemp, Kemp, & Blakey, 2002). Nevertheless, several distance learning courses around the world are designed based on textbooks – whether they should be printed or electronic being an issue of debate (Shepperd, Grace, & Koch, 2008; Yair, 2014) – since they seem to provide specific advantages in teaching and learning: (a) textbooks offer students a sense of structure by providing them a straightforward framework, and (b) they give students the opportunity to study in their own rhythm making them feel independent in their learning (Lau et al., 2018). In fact, the role of textbooks may be even more important in distance education than in conventional classroom-centered education; considering that 'an intelligent and personalized assistance that a teacher or a peer student can provide in a normal classroom situation is not easy to get' (Brusilovsky, 1999, p. 15), distance learning asks for a better preparation of learning materials (e.g., textbooks), along with alternative means with interaction with educators and peer students (Johnson et al., 2002).
Considering the above, we decided to explore the graphics included in science textbooks used in a distance learning undergraduate course. Our focus here is set in evaluating the text-graphic integration; more specifically, the research questions (RQs) we address are:

- (RQ1) What are the levels of contiguity between graphics and text within science textbooks used in a distance learning undergraduate course?
- (RQ2) To what extent are graphics referenced in the text within science textbooks used in a distance learning undergraduate course?
- (RQ3) In what manner are captions used to connect graphics with text within science textbooks used in a distance learning undergraduate course?

2. Methods

Three textbooks used in the distance learning undergraduate course 'Studies in Natural Sciences' offered by the Hellenic Open University (HOU) were investigated. HOU is a Greek state university that offers courses via distance learning at both undergraduate and postgraduate level. 'Studies in Natural Sciences' is an introductory science course which aims at supporting students in building understanding in principles, notions and theories of physics, chemistry and biology. The three textbooks we sampled for our research were:
(a) Atomic Structure, Periodic System, Properties of Atoms (Klouras & Perlepes, 2000), (b) Molecular Biology (Georgatsos, 2001), and (c) Introductory Physics: Classical Mechanics (volume 1) (Tzamarias, 2008).
More specifically:

- Textbook (a) (referred hereinafter as 'chemistry textbook') included three chapters of the unit 'General and Inorganic Chemistry': (i) Atoms, Molecules and Ions, (ii) Arrangement of Electrons in Atoms, (iii) Periodic Properties of the Elements – number of pages: 261.
- Textbook (b) (referred hereinafter as 'biology textbook') included ten chapters of the unit 'Cell Structure and Function': (i) Genetic Material, (ii) Genetic Material and Proteins, (iii) Replication of Genetic Material, (iv) Transcription of Genetic Material, (v) Translation of Genetic Information, (vi) Regulation of Gene

Expression, (vii) Molecular Basis of Mutation, (viii) DNA Repair, (ix) Replication and Expression of Viral Genetic Material – number of pages: 267.

- Textbook (c) (referred hereinafter as 'physics textbook') included two chapters of the unit 'Introduction in Natural Sciences': (i) Introductory Movement Concepts, (ii) Movement in Two and Three Dimensions – number of pages: 258.

In order to answer our research questions we first counted the graphics include in all three textbooks. We identified 47 graphics in the chemistry textbook, 84 graphics in the biology textbook, and 137 graphics in the physics textbook. We then coded all 268 graphics identified in mutually exclusive categories formed drawing on the Graphical Analysis Protocol (GAP) proposed by Slough & McTigue (2013). Both authors coded independently 53 (i.e. about 20%) randomly chosen graphics and the rater agreement was 100% for 'contiguity' and 'indexical reference' and about 94% for 'captions' (see Table 1 for details on categories). The rest of the analysis was carried out by the first author.

Contiguity	**Category**	**Description**
	Unconnected	Graphic is unconnected to text
	Distal	Graphic and relevant text are in different pages (the reader needs to turn page)
	Facing	Graphic and relevant text are in facing pages
	Direct	Graphic and relevant text are adjacent
	Proximal	Graphic and relevant text are in the same page but not adjacent
Indexical Reference	Referenced	Text does not reference the graphic
	Not referenced	Text references the graphic (e.g., 'See Figure 3.1')
Captions	No caption	There is no caption
	Identification	Caption identifies the target of the graphic but does not provide details
	Description	Caption provides a description of the graphic with details
	Engagement	Caption actively engages viewer (e.g., poses a question / asks them to read a specific part of the text)

Table 1. The coding scheme.

3. Results

The majority of graphics are contiguous with the relevant text in the biology and physics textbooks, with proximal and direct accounting for 64/84 and 111/137 respectively. On the contrary, it seems that the majority of graphics are non-contiguous with the relevant text in the chemistry textbook, with facing and distal accounting for

27/47 graphics. In all three textbooks there are no graphics which appear unconnected to the text (Figure 1).

The majority of graphics are referenced in the text. In parenthesis – e.g., ‘(Figure 4.5)’ – or not – e.g., ‘As shown in Figure 5.6, …’ – in most cases the authors of the science textbooks signal the reader when to view to the relevant graphic. Only 3/47, 17/84 and 24/137 of the graphics in the chemistry, biology and physics textbooks respectively are not referenced (Figure 2).

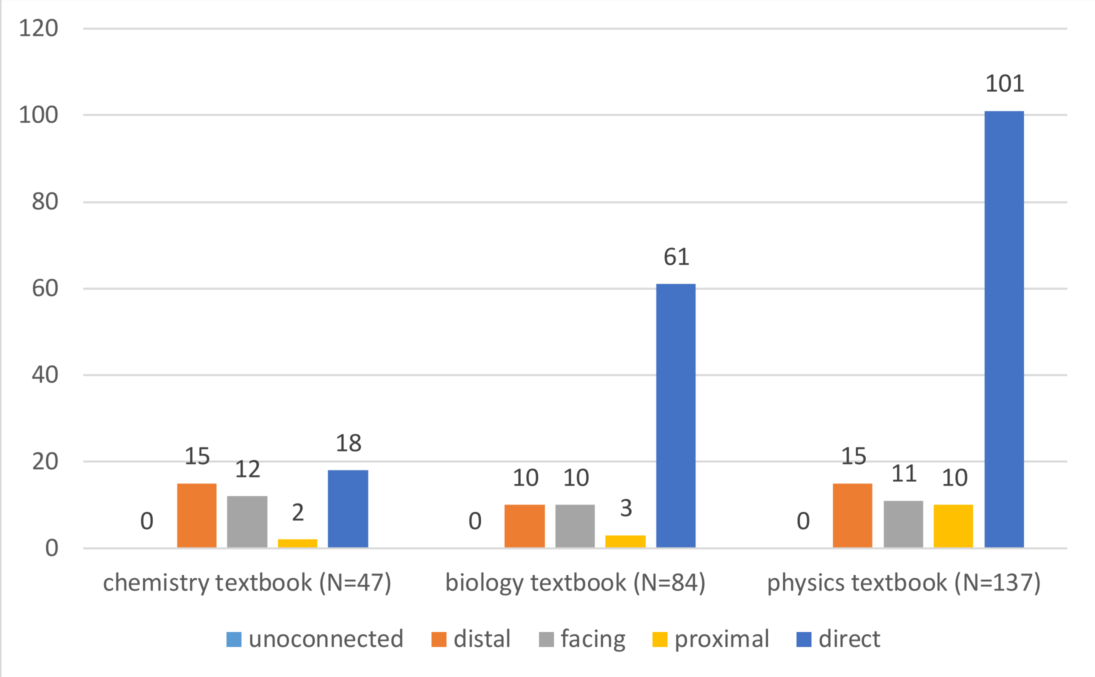

Figure 1. Frequencies of categories of graphics in regard to contiguity.

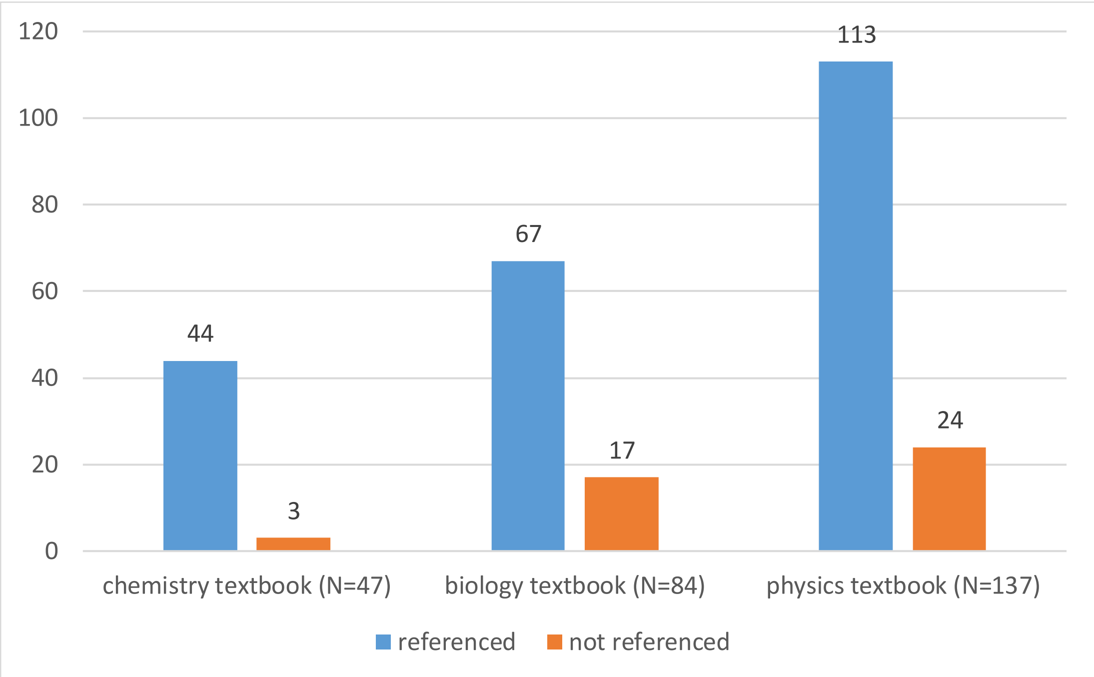

Figure 2. Frequencies of categories of graphics in regard to indexical reference.

The majority of graphics in all textbooks have captions. Only one graphic in the chemistry textbook has no caption, while there are 12/84 and 62/137 graphics that appear uncaptioned in the biology and physics textbooks respectively. When they exist, captions are typically used to identify (e.g. ‘Tertiary configuration of a tRNA molecule’) or describe (e.g., ‘Scattering of alpha particles aiming at a gold foil: the alpha particles of a beam fall on the gold foil and almost all go through it as if it did not exist. Some particles are slightly deflected and a small percentage (1 in 20000) scatter through angles larger than 90^o’) the graphic most of the times. We have to notice that in the chemistry book descriptive captions dominate the graphics while in the biology and physics textbooks identification is more frequent than description in regard to captions’ function. A smaller number of captions intend to engage the reader (e.g., ‘In what direction will the ball move?’).

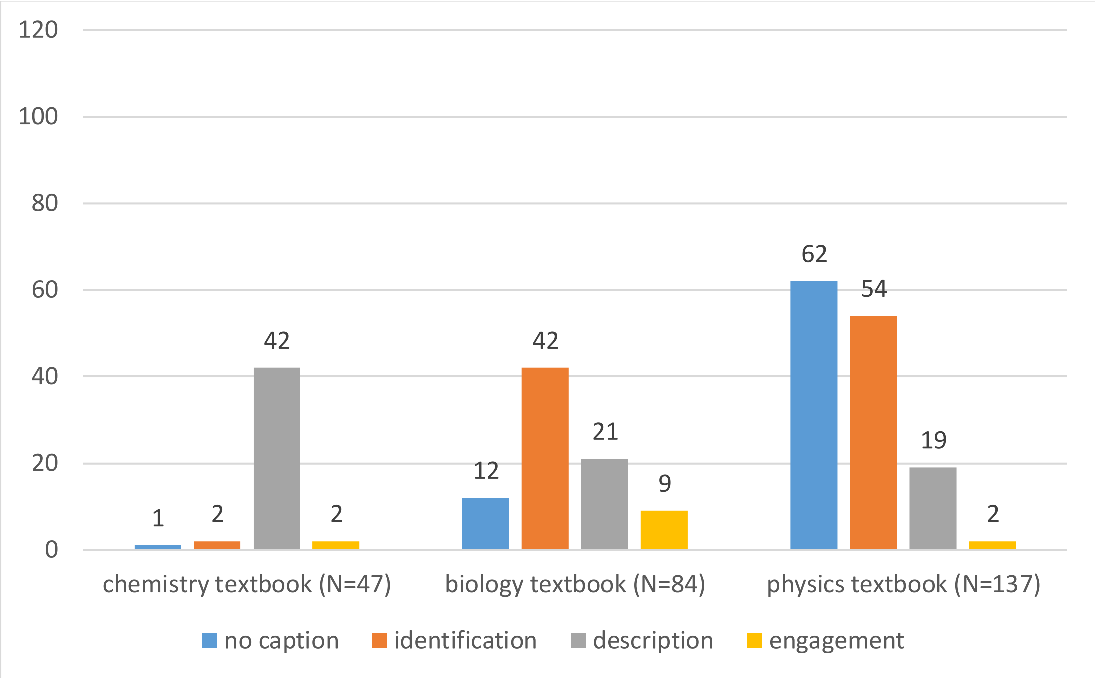

Figure 3. Frequencies of categories of graphics in regard to captions.

4. Discussion

As already discussed, science teaching rely largely on illustrations since graphics are considered very important in the communication of science concepts. Graphical demands of textbooks used in conventional education have been considerably explored – e.g., university education (Bowen, Roth, & McGinn, 1999), primary education (Slough et al., 2010; Liu & Khine, 2016), secondary education (Liu & Treagust, 2013) – but there is little information available about the graphical demands of science textbooks used in distance education. Our attempt to explore some aspects of the text-graphic integration in science textbooks used in a distance learning university course resulted in interesting observations regarding the effectiveness of illustrations.

The majority of graphics in all three books we investigated are referenced in the text. Slough et al. (2010) argue that references of the graphics included in the text is an efficient way to signal the reader when to observe the graphic and can offer a guide on how the reader could integrate the textual and the visual information. However, Peeck (1993) claims that simply drawing students’ attention to illustrations does not support them effectively in processing the visual information and he suggests that students should be asked to do something with them.

One way to ask students to do something with graphics would be the graphics to have engaging captions. In the case of the three textbooks explored, only few captions of the graphics identified aimed to engage the reader. Keeping our focus on captions, we note that extended captions have been found to facilitate the understanding of visual information (Bernard, 1990). The authors of the chemistry textbook seem to adopt the idea that large captions are helpful for students: 42/47 graphics of the textbook they authored include captions that offer lengthy descriptions of what is shown. In the case of the biology and physics textbooks, captions are more often used to identify than to describe what is depicted.

Moving to the position of graphics in relation to the text, Slough et al., (2010) note that the proximity between the text and the graphics contributes to their effectiveness. Mayer (2001) argues that students perform better at tasks when the texts and illustrations are placed close to each other rather than separate from one another. Most of graphics in the biology and physics textbooks are in close proximity, however this is not the case for the chemistry textbook. Trying to explain the fact that the majority of graphics in the chemistry book and their relevant text are placed in different pages, we may notice that the graphics included are too large since they have detailed, descriptive captions. It seems that authors of science textbooks have important decisions to make concerning text-graphic integration and such decisions are not easy; making graphics more effective in one way may influence their effectiveness in other ways.

We acknowledge the limitations of our study: we do not assume our results to be generalizable since our research is limited by the number and type of the science textbooks we investigated. We plan to extend our study by investigating more science textbooks used in the undergraduate course of focus and in different distance learning courses. Finally, although we have discussed how the variables explored contribute to the effectiveness of graphics, we make no claim about whether students learn better or not depending on the text-graphic integration observations we discuss. More research should be done in order to explore connections between individual variables and increased student learning.

References

Abd-El-Khalick, F., Waters, M., & Le, A.-P. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching*, *45*(7), 835–855.

Ametller, J., & Pintó, R. (2002). Students’ reading of innovative images of energy at secondary school level. *International Journal of Science Education*, *24*(3), 285–312.

Bernard, R. M. (1990). Using extended captions to improve learning from instructional illustrations. *British Journal of Educational Technology*, *21*(3), 215–225.

Bowen, G. M., Roth, W.-M., & McGinn, M. K. (1999). Interpretations of graphs by university biology students and practicing scientists: Toward a social practice view of scientific representation practices. *Journal of Research in Science Teaching*, *36*(9), 1020–1043.

Brusilovsky, P. (1999). Adaptive and Intelligent Technologies for Web-based Education. *Special Issue on Intelligent Systems and Teleteaching, KünstlicheIntelligenz*, *4*, 19–25.

Georgatsos, I. (2001). *Molecular Biology*. Patra: Hellenic Open University.

Hegarty, M., Carpenter, P. A., & Just, M. A. (1991). Diagrams in the comprehension of scientific texts. In R. Barr, M. L. Kamil, P. Mosenthal, & P. D. Pearson (Eds.), *Handbook of reading research* (Vol. 2). New York, NY: Longman.

Johnson, R., Kemp, E., Kemp, R., & Blakey, P. (2002). From electronic textbook to multidimensional learning environment: Overcoming the loneliness of the distance learner. In *Proceedings of the International Conference on Computers in Education 2002* (Vol. 2, pp. 632–636). Auckland, New Zealand: IEEE.

Khine, M. S. (Ed.). (2013). *Critical Analysis of Science Textbooks*. Dordrecht, Netherlands: Springer.

Klouras, N. D., & Perlepes, S. P. (2000). *Atomic Structure, Periodic System, Properties of Atoms*. Patra: Hellenic Open University.

Lau, K. H., Lam, T., Kam, B. H., Nkhoma, M., Richardson, J., & Thomas, S. (2018). The role of textbook learning resources in e-learning: A taxonomic study. *Computers & Education*, *118*, 10–24. https://doi.org/10.1016/j.compedu.2017.11.005

Liu, Y., & Khine, M. S. (2016). Content Analysis of The Diagrammatic Representations of Primary Science Textbooks. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(8), 1937–1951.

Liu, Y., & Treagust, D. F. (2013). Content Analysis of Diagrams in Secondary School Science Textbooks. In M. S. Khine (Ed.), *Critical Analysis of Science Textbooks: Evaluating Instructional Effectiveness* (pp. 287–300). Dordrecht, Netherlands: Springer.

Mayer, R. E. (2001). *Multimedia learning*. Cambridge, NY: Cambridge University Press.

Peeck, J. (1993). Increasing picture effects in learning from illustrated text. *Learning and Instruction*, *3*(3), 227–238.

Shepperd, J. A., Grace, J. L., & Koch, E. J. (2008). Evaluating the Electronic Textbook: Is it Time to Dispense with the Paper Text? *Teaching of Psychology*, *35*(1), 2–5.

Slough, S. W., & McTigue, E. M. (2013). Development of the Graphical Analysis Protocol (GAP) for Eliciting the Graphical Demands of Science Textbooks. In M. S. Khine (Ed.), *Critical Analysis of Science Textbooks* (pp. 17–30). Dordrecht, Netherlands: Springer.

Slough, S. W., McTigue, E. M., Kim, S., & Jennings, S. K. (2010). Science Textbooks' Use of Graphical Representation: A Descriptive Analysis of Four Sixth Grade Science Texts. *Reading Psychology*, *31*(3), 301–325.

Tzamarias, S. E. (2008). *Introductory Physics: Classical Mechanics* (Vol. 1). Patra: Hellenic Open University.

Weiss, I. R., Banilower, E. R., McMahon, K. C., & Smith, P. S. (2001). *Report of the 2000 national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research.

Yair, Y. Y. (2014). Print vs. Digital books in distance education. *ACM Inroads*, *5*(1), 28–29.