ISBN: 978-628-95207-8-1. ISSN: 2414-6390. Digital Object Identifier: 10.18687/LACCEI2024.1.1.674

Macrostructural Processing of Text to Enhance Reading Comprehension of Chemistry-Related Texts

Ariza-Rúa, Danilo L, MSc [1]; Rubiano-Labrador, Carolina, Ph. D[2]; Marbello-Peña, Humberto, MSc [3]; González-Campo, María José, MSc [4]; Hurtado Marquez, Julio Seferino, MSc [5]
[1-5]Universidad Tecnológica de Bolívar, Colombia. dariza@utb.edu.co, drubiano@utb.edu.co, hmarbello@utb.edu.co, mgonzalez@utb.edu.co, jhurtado@utb.edu.co.

***Abstract* - In this work, we propose a macrostructural processing of texts to help freshmen chemical engineering students at the Universidad Tecnologica de Bolivar (Cartagena, Colombia) create concept maps to improve reading comprehension of chemistry-related texts. The study used a quasi-experimental approach, including pre- and post-tests, with two intact groups: one experimental group applied semantic structure characterization of chemistry texts and the other acted as a control group. Concept maps were created by both groups during the pre- and post-test. The results showed that a significant difference was only observed in the post-test.**

***Keywords*-- macrostructural processing, reading comprehension, concept maps, chemistry-related texts.**

I. Introduction

Learning chemistry presents undergraduate students with major challenges. The field of chemistry can be complex and abstract and requires students to develop a variety of skills and strategies to master and successfully complete their studies [1-3]. An important skill that is critical to their success is reading comprehension [4]. Good reading comprehension enables students to understand and interpret specific chemical information in textbooks, research articles, laboratory procedures, and other instructional materials. By effectively understanding these texts, students can extract essential information, understand scientific ideas, follow experimental instructions, analyze data, and critically evaluate scientific arguments [5]. The ability to understand chemistry-related texts not only improves their general understanding of the subject, but also allows them to acquire new knowledge and apply it to problem solving and scientific investigation.

In recent years, several studies have highlighted the difficulties that undergraduate students face when attempting to read and understand the information in chemistry-related texts [6–10]. These difficulties may be attributed to students having complex vocabulary, abstract concepts, and scientifically incorrect basic chemical concepts [11–14]. The presence of this technical language can make chemistry-related texts difficult to read and understand, especially for students without a good knowledge of chemistry or related sciences. To overcome these difficulties, it is crucial to implement didactic strategies that promote effective processing, interpretation, and organization of chemical information. A concept map is a strategy that serves this purpose [15-17].

A concept map is a graphical representation of the relationships between concepts connected by linking words. Organize and present knowledge or information on a specific subject or topic. A concept describes an event or object using a name or label. A name or label is a word or symbol that creates an image in a person's mind with certain nuances and features common to all people. This means that the concept is not the same for everyone, even if the same words are used. Linking words or phrases are conjunctions, adverbs, verbs, or other non-conceptual words that are used to connect concepts with sentences that appear to be logically coherent units of meaning [18].

A concept map represents the organization of concepts at different levels of hierarchy or concept inclusion. That is, the most inclusive or general concepts are at the top of the map, and less comprehensive or more specific concepts are at the bottom. In addition, concepts from different hierarchy levels can be related through cross-linking. Cross-links are important when evaluating concept maps because they show an understanding of the different sub-domains of the map and can provide insight into the creator's creative abilities.

Concept mapping is about establishing relationships between concepts to form meaningful propositions. One method to create a concept map is to complete the following steps [19]:

- Select a knowledge domain.
- Construct a focus question in the defined knowledge domain.
- Identify the key concepts.
- Organize concepts according to their hierarchy, starting from the most general concept to the most specific concept.
- Create a preliminary concept map.
- Look for cross-links.
- Review and rebuild the concept map.

However, the proposed method presents difficulties in creating the concept maps, mainly due to the structure and construction of the propositions and the lack of a good focus question. As a result, most concept maps created deal with objects rather than events, resulting in descriptive and classifying concept maps instead of explanatory maps with more dynamic propositions. Macrostructural processing of text can be used to improve the structure and style of proposition writing when creating concept maps from reading text [20].

When understanding a text, the subject carries out semantic processing of the text in his memory, which is based on the construction of a hierarchical representation system. Processing begins at the lowest level of representation of the text, which corresponds to the contribution of lexical and syntactic knowledge to the topic and includes the identification and processing of the literal meaning of words and sentences in the text. A higher level is the propositional text base, which refers to the semantic content of the text and consists of a set of propositions and the relationships between them that express the meaning clearly expressed in the text. The semantic structure of the discourse is characterized at two levels: microstructure and macrostructure.

The microstructure consists of the semantically related terms of a text and is established as a hierarchical set of propositions of the text or our internal representation of the text in which a local coherence is established and in which the ideas contained in the surface structure are recognized [21]. Microstructure is used to extract the essence of the text. In the text below, the following propositions stand out (P1-P45):

"What does Chemistry study?

Chemistry is the science that studies matter and analyzes its properties, structure, composition, transformations, and the energy released or absorbed in these transformations. The material properties are characteristic or similar characteristics of substances. They can be divided into two categories: chemical and physical. Physical properties include properties of substances that we can determine with various measuring devices or with our senses. For example, length, density, boiling point, electrical conductivity, physical state of a substance (solid, liquid or gaseous), color, brightness, etc. Chemical properties are the ability of some substances to transform into other, new substances. For example, heat of combustion – energy released when a compound burns completely (combustion).

An atom is the structural unit of matter and consists of a nucleus and electrons. The nucleus contains positively charged particles called protons and neutral, uncharged, particles called neutrons. There are electrons, particles with a negative charge, around the nucleus. An atom can lose or gain electrons. When it loses electrons, the atom becomes positively charged and forms a cation. When it gains electrons, it becomes negatively charged and forms an anion. The cation and the anion are called ions.

All chemical substances are divided into two categories: pure substances and mixtures. A pure substance is a stable set of particles (atoms, ions, or molecules) with a certain, fixed and constant composition and some specific physical and chemical properties. Both elements and compounds are examples of pure substances. Elements cannot be broken down into simpler chemical components. For example, there are metals and non-metals. Chemical substances that consist of different elements are called chemical compounds. Water is a compound and consists of hydrogen and oxygen.

A change in matter can be physical or chemical in nature. A physical change is a change in the state of matter that does not result in the formation of new matter. For example, boiling, melting, condensation, freezing and sublimation. A chemical change is a transformation in which a new substance is created. An example of a chemical change is the formation of carbon dioxide and water when methane gas is burned.

A chemical reaction is a transformation of matter in which a substance with a certain composition and properties changes into another substance with a different composition and properties. At the same time, the composition of the nucleus does not change. During chemical reactions, some chemical bonds are broken, and new chemical bonds are formed.

The transformation of matter always involves the release or absorption of energy. An exothermic change is a process of energy release. The process of energy absorption is an endothermic change. A chemical reaction is exothermic if the energy of the chemical bond formed in the products is less than the energy of the chemical bond broken in the reactants. An endothermic change occurs when the energy of the chemical bond formed in the product is greater than the energy of the chemical bond broken in the reactant."

P1. [Chemistry] (is) [science]
P2. [Chemistry] (studies) [matter]
P3. [Chemistry] (analyzes) [properties, structure, composition, transformations, and energy] of [matter].
P4. [Properties] are characteristics of [matter]
P5. [The properties of matter] (differentiate) [materials]
P6. [The properties of matter] (categorized into) [chemical and physical]
P7. [Physical properties] (determined) [instruments or our senses]
P8. [Physical properties] (include) [length, density, boiling point, electrical conductivity, state of aggregation, color, and brightness]
P9. [State of aggregation] (are) [solid, liquid, or gas]
P10. [Chemical properties] (transform) [substances] to into [new substances]
P11. [Chemical property] (is) [heat of combustion]
P12. [Matter] (is made up) [atoms]
P13. [Atoms] (consist of) [nuclei and electrons]
P14. [Nucleus) (contains) [protons and neutrons]
P15. [Protons] (are) [positively charged particles]
P16. [Neutrons] (are) [neutral and uncharged particles]
P17. [Electron] (is) [negatively charged particle]
P18. [Atom] (loses or gain) [electrons]
P19. [Atom] (loses) [electrons] (becomes) [cation]
P20. [Cation] (is) [positively charged atom]
P21. [Atom] (gain) [electrons] (becomes) [anions]
P22. [Cations and anions] (are) [ions]
P23. [Chemical substances] (are) [pure substances and mixture]
P24. [Pure substance] (is) [set of particles (atoms, ions, or molecules)]
P25. [Pure substance] (has) [a definite, fixed, and constant composition]

P26. [Pure substance] (has) [specific physical and chemical properties]
P27. [Elements and compound] (are) [pure substances]
P28. [Elements] (do not decompose into) [simpler chemical components]
P29. [Metals and non-metals] (are) [elements]
P30. [Chemical compound] (consists) of [different elements]
P31. [Water] (is) [chemical compound]
P32. [Water] (is made up) of [hydrogen and oxygen]
P33. [Matter change] (can be) [physical or chemical]
P34. [Physical change] (is) [change state of matter]
P35. [Physical change] (does not form) [new matter]
P36. [Physical changes] (include) [boiling, melting, condensation, freezing, and sublimation]
P37. [Chemical change] (produces) [new substance]
P38. [Chemical change] (is) [burning of methane]
P39. [Burning of methane] (produces) [carbon dioxide and water]
P40. [Chemical changes] (are) [chemical reactions].
P41. [Chemical reactions] (is) [transformation of matter]
P42. [Chemical reaction] (produces) [substances] with a different [composition and properties]
P43. [Chemical reaction] (does not change) [nucleus]
P44. [Matter transformations] (involves) [release or absorption of energy]
P45. [Exothermic change] (releases) [energy]
P46. [Endothermic change] (absorbs) [energy]

This structured list of propositions represents the main ideas presented in the text. Each proposition consists of a subject, concept or object, an action, and an object (concept or property) where applicable. For example, in preposition P1, [Chemistry (concept)] is [study, (action)] of [matter (object)].

Macrostructure is a set of propositions that structure the semantic description of the global content of a text. Macrostructure is constructed through the application of macrorules to the sequences of the text's micro propositions and the prior knowledge schema of the reader. There are basically three macro rules: deletion, generalization, and construction [21, 22].

Deletion removes all propositions in the sequence that do not express a semantic condition on the interpretation of the remaining proposition. Generalization involves replacing a set of propositions with a more general proposition, particularly a proposition that captures the meaning of all other propositions. Construction consists of generating a proposition that replace some propositions. This proposition can be inferred from information derived from the microstructure and the reader's prior knowledge. The following is an example of a macrostructure generated from the set of propositions P1-P46:

P1. [Chemistry] (is) [science]
M1. [Chemistry] (studies) [matter] (analyzing) its [properties, structure, composition, transformations, and energy]
M2. [Properties](are) [chemical and physical]
M3. [Physical properties (are determined) by [instruments and our senses] for example [length, density, boiling point, electrical conductivity, state of aggregation, color, and brightness]
P10. [Chemical properties] (transform) [substances] to into [new substances]
P11. [Chemical property] (is) [heat of combustion]
M4. [Matter] (is made up) [atoms] consisting of [nucleus and negatively charged electrons]
M5. [Nucleus] (contains) [positively charged protons and uncharged neutrons]
M6. [Atom] (becomes] [positive cation losing electrons] and [negative anion gaining electrons]
M7. [Pure substance] (is) [a set of particles with a definite, fixed, and constant composition] and [specific physical and chemical properties]
P23. [Chemical substances] (are) [pure substances and mixture]
P27. [Elements and compound] (are) [pure substances]
M8. [Elements] like [metals and non-metals] (do not decomposed into) [simpler chemical components]
P30. [Chemical compound] (consists) of [different elements]
M8. [Water] (made up of) [oxygen and hydrogen] (is) [a chemical compound]
P33. [Matter change] (can be) [physical or chemical]
M9. [Physical changes] (do not produce) [a new substance]
P36. [Physical changes] (include) [boiling, melting, condensation, freezing, and sublimation]
M10. [A chemical change or chemical reaction] (is) [a transformation that produces a new substance]
M11. [An example of chemical change] (is) [the production of carbon dioxide and water when methane gas burns]
P43. [Chemical reaction] (does not change) [nucleus]
P44. [Matter transformations] (involves) [release or absorption of energy]
P45. [Exothermic change] (releases) [energy]
P46. [Endothermic change] (absorbs) [energy]

The propositions labeled with a capital letter M represent the new propositions resulting from the application of the macro rules. For example, the preposition M4 was formed from proposition P12, P13, and P17 using the generalization rule. Figure 1 shows the general scheme for creating the macrostructure.

Building a macrostructure in this way does not ensure comprehension, as students often develop a list of propositions that lack any discernible hierarchy. Hierarchy can be achieved when macrostructure is represented in a concept map because it is associated with abstraction and implies the ability to identify key ideas and the relationships between them while ignoring less relevant details.

The selection of key concepts for the construction of the concept map is carried out by immersing ourselves in the propositions of the elaborated macrostructure, which contains the global meaning of the text. The map shown in Figure 2 results from selecting the key concepts of the macrostructure presented above.

Our aim in this study was to evaluate the influence of macrostructural processing of a text on improving reading comprehension of chemistry-related texts assessed through the construction of concept maps. Well-made maps reflect good reading comprehension.

.

Microstructure

P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P1, P12, P13, P14, P15, P16, P17, P18, P19, P20, P21, P23, P24, P25, P26, P27,… P46

↓

application of macrorules:
deletion, generalization, and construction

↓

P1, M1, M3, P10, P11, M4, M5, M6, M7, P23, P27, M8, P33, M9, P36, M10, M11, P43, P44, P45, P46.

Figure 1. General scheme for creating the macrostructure.

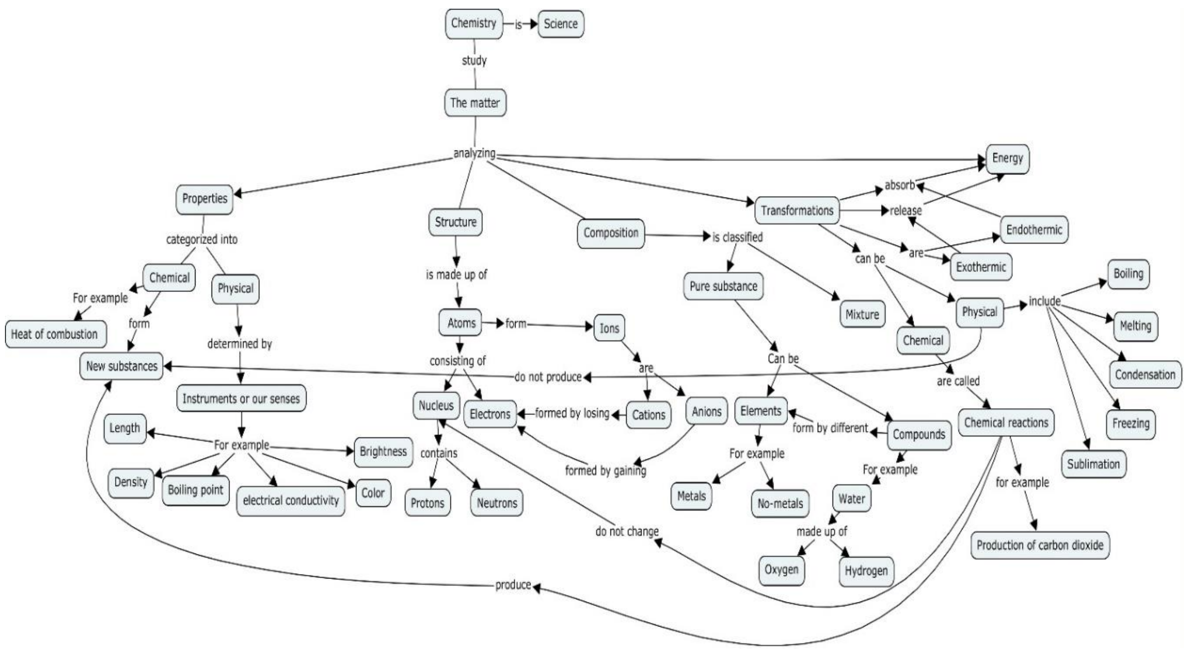

Figure 2. Concept map about "What does Chemistry study

II. MATERIALS AND METHODS

A pre- and post-test quasi-experimental design was used with two intact groups: an experimental group with 16 students and a control group with 15 students. The study lasted 6 weeks and included four steps:

A. *Training Step*

The two groups were trained in the creation of concept maps over 2 weeks in 3 sessions of 4 hours each:

a) Reading a document on concept mapping [18]. The following activities were carried out to explain the components of a concept map:

- Analysis of a map on a chemistry topic.
- Recognition of concepts.
- Representation of mental images of concepts.
- Recognition of linking words.
- Construction of propositions.

b) Selection of the text. A section of a 190-word explanatory chemistry text was selected to create the map.

c) Concept mapping activities. After each student has read the chemistry text:

- Selected 15 key concepts and appropriate linking words.
- Organized the concepts according to their hierarchy.
- Developed propositions using the selected concepts.
- Constructed a preliminary conceptual map of the text.
- Shared their maps with the aim of reviewing the concepts and adding new ones, as needed.
- Constructed a final concept map.

B. *Pre-test Step*

The two groups created a concept map by reading a chemistry text, following the instructions in the training step, and using the IHMC software CmapTools (https://cmap.ihmc.us/cmaptools/) which the students were already familiar with using prior to this work. The concept maps were evaluated using a rubric and the evaluation scheme [23]. Scores are distributed based on elements of the map, such as propositions, hierarchies, cross-relationships, and examples.

C. *Instruction step of macrostructural processing of text*

The following classroom activities were carried out to introduce the experimental group to the macrostructural processing of texts:

a) Text processing at the linguistic level

- Reading aloud the chemistry text " What does Chemistry study " for the literal processing of words and phrases.
- Recognize the meaning of words using a specialized dictionary.

b) Text processing at the semantic level

- Development of microstructure processes from the recognition of basic propositions of the text, and the interrelationships between them.
- Developing a text macrostructure from recognizing global themes and their interrelationships using three macrorules: deletion, generalization, and construction.
-

D. *Post-test step*

At the end of the sixth week, both groups read a text on the topic of chemistry. The control group used the traditional method of reading, while the experimental group used macrostructural processing of text. The two groups created concept maps that were scored similarly to the pretest.

III. Results

The t-test of equality of means was used as a result of a multiple-choice chemistry test to demonstrate group equivalence. As shown in TABLE I, the test revealed no significant differences between the two groups ($t = 0.444$, $p > 0.05$).

TABLE I
MEANS AND STANDARD DEVIATIONS FOR THE CONTROL AND THE EXPERIMENTAL GROUPS

	Groups	N	M	SD	"t"
Multiple-choice Chemistry Exam	Control	15	4.0200	0.51575	0.444*
	Experimental	16	3.9438	0.43965	

* p > 0.05; gl. = 29

A. *Pre-test Step*

The pre-test results show no difference in scores for concept maps constructed by the two groups ($t = -0.837$, $p > 0.05$, gl = 29), as shown in TABLE II.

TABLE II
PRE-TEST COMPARISON FOR CONTROL AND EXPERIMENTAL GROUPS

	Groups	N	M	SD	"t"
Concept Map	Control	15	30.1333	10.72292	-0.837*
	Experimental	16	33.0000	8.262365	

* p > 0.05; gl. = 29

B. *Post-test Step*

As shown in TABLE III, the post-test results in scores for concept maps constructed by the two groups revealed a statistically significant difference (t = 2.374, p 0.05, gl = 29), with the experimental group achieved higher results.

TABLE III
POST-TEST COMPARISON FOR CONTROL AND EXPERIMENTAL GROUPS

	Grupo	N	M	SD	"t"
Test	Control	15	40,6405	9,71433	2,374*
	Experimental	16	46,8937	6,97828	

* p < 0.05; gl. = 29

IV. Discussion

The results show that students in the experimental group who used macrostructural text processing developed better conceptual maps than students in the control group who did not use it. This could be because the concept maps also communicate the macrostructure [24] and highlight the macrostructure of the information more clearly [25]. Furthermore, if a concept map is created without building a macrostructure, students are limited to defining the topic of the text and do not attempt to develop various meaningful propositions.

An analysis of both groups' concept maps revealed that students in the experimental group created more valid hierarchies based on the concepts present in the macrostructure sentences. This means that the degree of conceptual completeness could best be determined by the students in the experimental group. Furthermore, the propositions made did not "deviate" from the focal question of the concept map, unlike the control group's propositions, many of which deviated from the focal question. In summary, the best concept maps were those that corresponded to the propositional macrostructure of the text.

Ratings of the conceptual maps produced by both groups without macrostructure text processing at pretest were similar. This behavior could be explained by the fact that both groups created conceptual maps that had poor coherence or no hierarchical organization, which is characteristic of maps created by subjects who are in the novice phase of using conceptual maps.

V. Conclusions

Creating good concept maps from a text is closely related to good reading comprehension. Macrostructural processing of text can significantly improve the quality of concept maps in producing propositions that reflect the meaning of the text. Implementing this technique in educational environments can be helpful in increasing awareness in the learning process, especially for scientific concepts.

Macrostructure text processing provides students with a tool to improve of concept maps constructions as they make propositions that reflect the meaning of the text. Therefore, we finally recommend using macrostructure text processing when creating concept maps based on written texts.

Acknowledgment

The authors express their gratitude to the faculty of basic sciences and the first-year students in the chemical engineering program at the Technological University of Bolívar-UTB for actively taking part in this research.

References

[1] F. Erika, B. K. J. I. J. o. R. Prahani, and M. i. Education, "Innovative chemistry learning model to improve argumentation skills and self-efficacy," vol. 7, no. 1, pp. 62-68, 2017.

[2] H. K. Wu and P. J. S. e. Shah, "Exploring visuospatial thinking in chemistry learning," vol. 88, no. 3, pp. 465-492, 2004.

[3] T. Hadinugrahaningsih, Y. Rahmawati, and A. Ridwan, "Developing 21st century skills in chemistry classrooms: Opportunities and challenges of STEAM integration," in AIP Conference Proceedings, 2017, vol. 1868, no. 1: AIP Publishing.

[4] D. T. Pyburn, S. Pazicni, V. A. Benassi, E. E. J. C. E. R. Tappin, and Practice, "Assessing the relation between language comprehension and performance in general chemistry," vol. 14, no. 4, pp. 524-541, 2013.

[5] Y. J. Dori, S. Avargil, Z. Kohen, and L. J. I. J. o. S. E. Saar, "Context-based learning and metacognitive prompts for enhancing scientific text comprehension," vol. 40, no. 10, pp. 1198-1220, 2018.

[6] M. Cooper and M. J. J. o. C. E. Klymkowsky, "Chemistry, life, the universe, and everything: A new approach to general chemistry, and a model for curriculum reform," vol. 90, no. 9, pp. 1116-1122, 2013.

[7] R. Vladušić, R. Bucat, M. J. C. E. R. Ožić, and Practice, "Understanding of words and symbols by chemistry university students in Croatia," vol. 17, no. 3, pp. 474-488, 2016.

[8] J. J. S. i. S. E. Quílez, "A categorisation of the terminological sources of student difficulties when learning chemistry," vol. 55, no. 2, pp. 121-167, 2019.

[9] A. E. J. A. R. R. Okanlawon, "Using appropriate strategies to improve students' comprehension of Chemistry texts: A guide for Chemistry teachers," vol. 5, no. 4, 2011.

[10] S. Markic, J. Broggy, and P. Childs, "How to deal with linguistic issues in chemistry classes," in Teaching chemistry–A studybook: Brill, 2013, pp. 127-152.

[11] G. Sirhan, "Learning difficulties in chemistry: An overview," 2007.

[12] B. Utami, S. Saputro, A. Ashadi, M. Masykuri, and S. Widoretno, "Critical thinking skills profile of high school students in learning chemistry," in International Journal of Science and Applied Science: Conference Series, 2017, vol. 1, no. 2, pp. 124-130.

[13] M. M. Woldeamanuel, H. Atagana, and T. J. A. J. o. C. E. Engida, "What makes chemistry difficult?" vol. 4, no. 2, pp. 31-43, 2014.

[14] L. J. E. q. Cardellini, "Chemistry: why the subject is difficult?" vol. 23, pp. 305-310, 2012.

[15] E. Morfidi, A. Mikropoulos, A. J. E. Rogdaki, and I. Technologies, "Using concept mapping to improve poor readers' understanding of expository text," vol. 23, pp. 271-286, 2018.

[16] K. J. J. o. S. E. Oliver and Technology, "An investigation of concept mapping to improve the reading comprehension of science texts," vol. 18, pp. 402-414, 2009.

[17] M. Kalhor and G. J. L. S. J. Shakibaei, "Teaching reading comprehension through concept map," vol. 9, no. 4, pp. 725-731, 2012.

[18] J. D. Novak, A. J. J. F. I. f. H. Cañas, and M. Cognition, "The Theory Underlying Concept Maps and How to Construct and Use Them1," pp. 1-36, 2008.

[19] J. D. Novak, A. J. J. F. I. f. H. Cañas, and M. Cognition, "The theory underlying concept maps and how to construct them," vol. 1, no. 1, pp. 1-31, 2006.

[20] T. A. Van Dijk, Macrostructures: An interdisciplinary study of global structures in discourse, interaction, and cognition. Routledge, 2019.

[21] W. Kintsch and T. A. J. P. r. Van Dijk, "Toward a model of text comprehension and production," vol. 85, no. 5, p. 363, 1978.

[22] W. J. D. p. Kintsch, "Information accretion and reduction in text processing: Inferences," vol. 16, no. 1-2, pp. 193-202, 1993.

[23] M. Besterfield-Sacre, J. Gerchak, M. R. Lyons, L. J. Shuman, and H. J. J. o. E. E. Wolfe, "Scoring concept maps: An integrated rubric for assessing engineering education," vol. 93, no. 2, pp. 105-115, 2004.

[24] J. C. Nesbit and O. O. J. L. t. v. d. C. Adesope, NC: Information Age Publishing, "Concept maps for learning," pp. 303-328, 2013.

[25] A. M. O'Donnell, D. F. Dansereau, and R. H. Hall, "Knowledge Maps as Scaffolds for Cognitive Processing," Educational Psychology Review, vol. 14, no. 1, pp. 71-86, 2002/03/01 2002.