Analyzing the Availability of Lexicon in Mathematics Education Using no Traditional Technological Resources

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Abstract **- The contribution of this paper is for researchers to observe different uses of technology resources when analyzing data and meet different kinds of variables. To learn mathematics is somehow difficult to most students in different educational levels. There exists a cultural presumption that it happens and therefore the motivation to learn mathematics is low. In national and international tests Chile performs poorly. Researchers suggest different variables to explain this situation. Additionally, there exist work propositions in development. One of these is to use technological support to improve the students' results regarding mathematics especially in the school system. This paper describes a research from 2012 until today focused in the available lexicon of mathematics on secondary school and university students in the 8ª Region of the country as an important variable that affects significantly mathematics learning. Data about the available lexicon was obtained after the application of the Test of Lexical Availability. Furthermore, to analyze the obtained data, *Lexmath* is created. *Lexmath* is an adaptive hypermedia that employs Excel, graphs theory and *Gephi* software to establish the available lexicon in which mathematics learning is developed and the need to improve it using this software.**

***Keywords*: learning, mathematic, lexmath, ghepi, graphs**

1. Introduction

In Chile, one of the most difficult school subjects to work in the national curriculum is mathematics. Historically this situation has remained unchangeable and little has been progressed to revert the widespread perception that points out the difficult that learning mathematics is [1].

Mathematics teachers and the institutions that train them are required by society as a whole to generate better learning, emphasizing the requirement in the initial teacher training process and the development of appropriate teaching skills to improve them [2]. Classically the skills considered in the initial teacher training are focused on the disciplinary and pedagogical. Nevertheless, considering the body of knowledge related to this field of teaching work and the changes observed in society in which we currently live, it is possible that this tradition should be modified to go into the study of emerging variables that at the same time contribute to the success of classroom teaching. These emerging variables, among others, are related to the communication processes developed during lessons in which the available lexicon of teachers and students is preferred.

From studies on lexicon [3] that indicate that people do not always have an adequate available lexicon to the circumstances of their lives, it is not difficult to admit that it is inherited and carried to school. School is the place that often assumes the responsibility to develop an acceptable lexicon for academic development. It is also possible to admit that the available lexicon of a student who enters higher education does not guarantee future success because it must be consistent with that required by teachers. These statements led to collect data from a test of lexical availability [4]. This instrument is characterized because from certain centers of interest related to the subjects life (home, meals, transportation, games, etc. each one broken down into its constituent elements) it requests to write many words related to each center of interest and its elements in two minutes.

At the same time, it was considered to develop the *LexMath* software that managed to minimize the operative resources required for the analysis of the data collected by the test. In addition, it also served to determine spelling mistakes and misspelled words, storing everything in a database in capital letters with the psychosocial characteristics of each respondent. Subsequently, the system gives access to tools that automatically determine the main statistics and present semantic networks using the tools of graph to visualize the most relevant semantic structures presented (lexical profiles or mental structures). It gives the advantage to allow visualizing the network of relationships that words keep that constitute the available lexicon in a group of people. Additionally,

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Gephi software is added to provide a wide range of metrics graph.

The Fondecyt Project 1120911 [5] was aimed at establishing the mathematical available lexicon in teachers and secondary students in Concepción (capital of the eight region of Chile). Another Fondecyt Project 1140457 [6] was aimed at establishing the available lexicon in students from the mathematics teaching program and its relation to the available lexicon of their teachers during the initial teacher training.

This article is organized as follows: first this introduction that gives the reader a general understanding of the subject matter; second, the available lexicon problem in people is described, especially in math students either in secondary level or university level and the need to establish it quantitatively to make decisions; third, the technological resources implemented for data analysis such as the adaptive platform *LexMath* and the *Gephi* software for the use of graphs and for their analysis; finally the results obtained in these researches are described.

2. Learning levels in mathematics, secondary and university students and teachers and the relation with their available lexicon

Among the variables that interfere with the learning processes in mathematics it is important to consider the language. Classroom visits persistently indicate that whatever the level of performance in the class noted, there are always expressions that are not necessarily semantically correct and sometimes either symbolically [7].

Russell [8] was one of the philosophers who suggested that language had an important role in how we understand the world. He noted that the most important thing in relation to language is how we use it stating that clarity of expression was a virtue, an idea that is particularly followed by those working in the philosophy of language. On the other hand, in the core of Wittgenstein's argument (1923) was the belief that language and thought contain a similar logical structure that serves to differentiate what can be significant and clearly expressed (or thought), and what are senseless or meaningless statements. There exists a close relation between language and thought to the point that the language limits coincide with the boundaries of thought; everything that can be thought can be said, everything that can be said can be thought.

The basic learning of mathematics is constituted by concepts or mathematical objects. From them it is that a specific symbolic language that to be understood requires natural and everyday language, which arises from the propositions and is subject to rules and logic [9]. The conducted researches (Op. Cit. [7]) indicate that the language used by secondary school teachers in their lessons is somehow away from what might be noted as a collaborator of learning in the discipline. Most of them use in class a colloquial language without taking precautions about the strictness of their speech. In this sense the teacher should take care of that their students can make sense and meaning to knowledge considering that teaching act is defined as the action whose nature is essentially communicative [10].

The formation of citizens able to learn through language begins from the early years of teaching. It is the teacher who must provide strategies not only to understand a text but also to establish oral and written communication with coherence, property and creativity to achieve in our lives explanatory and argumentative speeches in order to think critically, reason logically and properly develop ourselves in the world today.

People form a mental dictionary called lexicon. It is composed of words (vocabulary) in a particular center of interest (home, transport, algebra, geometry, etc.), which increases, decreases and changes dynamically, being permeated by the context surrounding the individual and the time to live. According to Hall (1992) [11] words that form the mental lexicon are used and stored from speaking, writing respecting the rules of the respective language and its meaning in the context in which they are used.

For the study of the organization of this mental dictionary, various theories have been proposed. Among the most important theories, there are the theory of semantic, prototyping and semantic networks features (Bermeosolo, 2012) [12] and (Manjón, 2008) [13]. Currently it is possible to use mathematical models, such as graphs, to study them, developing software tools to assist in this task. *LexMath* (*www.lexmath.com*) allows establishing quantitatively the mental lexicon of an individual, determining automatically the rates and graphical representations of semantic structures such as the average number of words, different words, cohesion index and the index of lexical availability index (LAI) of each word, which when ordered from highest to lowest gives the mental lexicon to the community and remedial actions adaptively social profile and latent user lexicon.

3. Technological resources and their contribution to the understanding of the processes of data analysis about lexical availability

Lexmath was applied to the analysis of the available lexicon in mathematics detected in 1557 first graders of secondary education according to the national curriculum in Chile (numbers, algebra, geometry, and probability and statistics) and 228 mathematics teaching students in the center of interest Algebraic Structures selected as one of the subjects of the programs with the highest failure rate. 117 belong to the University "A" and 111 to University "B".

Presented below it is the *Lexmath* structure (Fig.1) in which elements such as five labels that constitute work areas can be noticed. Then a general report of the application scope of the lexical availability test and finally statistics that indicate the behavior of all the data collected (Fig. 2).

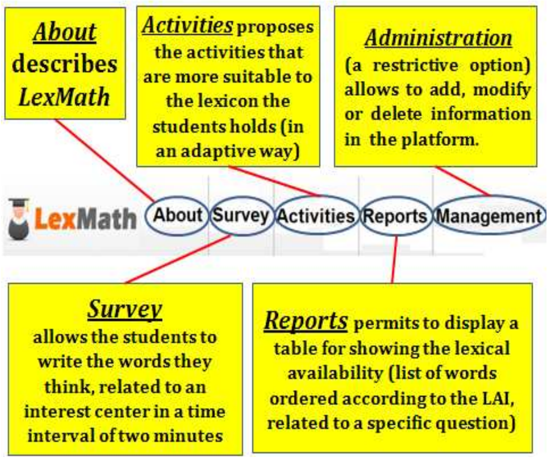

Figure 1. *Lexmath's* structure

Where, first, the software (about) is described and from the data collection (survey) it is possible to propose activities that improve the lexicon present in the sample subjects, (activities) activities that are intentionally developed to adapt the lexicon to the needs of students. The reports about the behavior of the available lexicon are essential and available to work with students. Finally, there exists an administrative support whose responsibility is to control all technological events so that the data source is not affected by some external event.

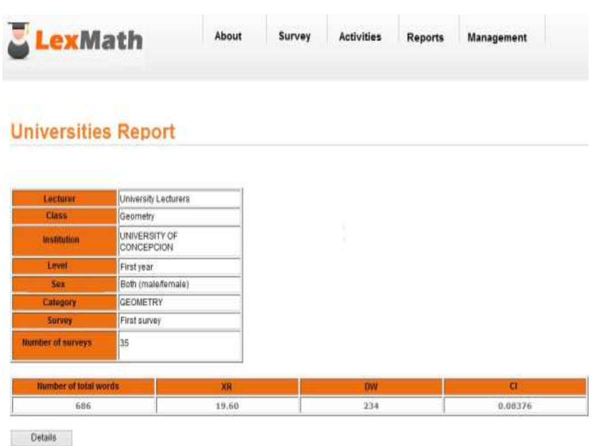

Figure 2: General report of the application of the LAT

In both samples, the application of lexical availability test allowed the collection of data and the use of *Lexmath* generated a list of words according to their frequency in the different centers of interest.

The information was submitted to a digitization process to facilitate the calculation of indexes, frequencies and others. Nevertheless, previously it was necessary to perform a manual process using Microsoft OFFICE – EXCEL.

The amount of words collected had to be reviewed, correcting spelling and validating them for editing. For this purpose it was chosen to type every word with capital letter in singular and omitting stress.

With the modifications made and after processing all the words, the indexes considered in the research were obtained. These indexes are the major contributors to the determination of the lexical richness of subjects. It includes the Lexical Availability Index (LAI) that allows us to express the degree of availability of a term in the speaker's mind, that is, the ease or difficulty with which a word will surface to the speaker's consciousness when needed from the formula:

$$D(P) = \frac{f_1 + \lambda f_2 + \lambda^2 f_3 + \ldots + \lambda^{n-1} f_n}{N} \quad \text{where } \lambda = 0{,}90 \quad (1)$$

Where (1) is the Formula to determine the Lexical Availability index (LAI)

Listed below are presented data lists with their respective word average and cohesion index in both samples (Table 1 and Table 2).

Center of interest	Word Average	Cohesion Index
Geometry	16,3	0,0156
Numbers	13,1	0,0098
Algebra	11,0	0,0071
Statistics and Probability	7,2	0,0065

Table 1. Word Average and Cohesion Index – Secondary students

	Center of interest: Algebraic Structures	Word Average	Cohesion Index
University A	5th term	24,46	0,1193
University B	4th term	10,52	0,0965

Table 2. Word Average and Cohesion Index – Math Teaching Students

The organization that is made of the words collected in the center of interest *Numbers* in the sample of secondary students is shown in Table 3.

Words	LAI	Fi	Fi%
Addition	0,4167935	872	4,28543

Multiplication	0,3957054	1011	4,96855
Subtraction	0,3745111	871	4,28052
Division	0,3415854	897	4,40830
Mathematics	0,2909477	615	3,02241
Fraction	0,2026260	577	2,83566
Equation	0,1394387	413	2,02968
Tenth	0,1071787	308	1,51366
Algebra	0,1058753	290	1,42520
Power	0,0920320	262	1,28760
Number	0,0914247	199	0,97798
Root	0,0873547	290	1,42520
Quantity	0,0806700	222	1,09102
Natural	0,0751334	193	0,94850
Calculator	0,0670536	187	0,91901
Rational	0,0660475	168	0,82563
Whole	0,0642100	163	0,80106
Problem	0,0641965	179	0,87969
Real	0,0620536	169	0,83055
Calculation	0,0572460	152	0,74700
Geometry	0,0570368	186	0,91409
Sum	0,0566660	120	0,58974
Count	0,0558978	154	0,75683
Negative	0,0557459	184	0,90427

Table 3. Organization of words collected in center of interest *numbers* – Secondary students

It is continued until the first fifty (50) words arranged in ascending order according to their Lexical Availability Index (LAI) value which ranges from 0 and 1.This information helps establish what the most used words by students are (the higher the LAI the more frequent the word is).

The same applies to the analysis of the available lexicon in *Algebraic Structures* in students of the Mathematics Teaching Program in university A, sorted by Lexical Availability Index from the highest to the lowest as shown below:

Word	f_i	f_r	LAI
Grupo	30	0,88235	0,760
Anillo	32	0,94118	0,737
Cuerpo	15	0,44118	0,312
Conjunto	14	0,41176	0,252
Operación	15	0,44118	0,207
Relación	9	0,26471	0,175
Isomorfismo	10	0,29412	0,158
Abeliano	9	0,26471	0,148
Campo	9	0,26471	0,145
Teorema	10	0,29412	0,137
Homomorfismo	8	0,23529	0,134

Table 4. Lexical Availability Index in center of interest *Algebraic Structures* – Math teaching students

In which the words *grupo* (group) and *anillo* (ring) are very powerful in these types of classes.

The following image (Fig. 3) shows a *LexMath* screen where reports of AL and LAI are observed and graphs that present semantic structures. To what was mentioned before, it must be added the feature of *Lexmath* software to generate semantic structures through graphs (Fig. 4).

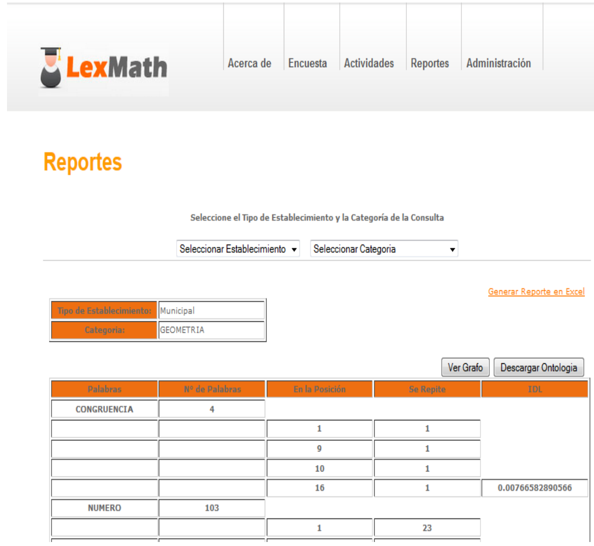

Figure 3: *Lexmath's* report of LAI

Figure 4: Graph generated from semantic structures

From a practical point of view, graphs permit to study the interrelations between units that interact with each other. To understand the structure of a graph it is important to know some basic type of terminology: a) Vertex: Node; b) Link or Edge: connection between two vertexes (nodes); c) Adjacency: it is said that two vertices are adjacent if there is a direct link between them; d) Vicinity: set of vertices adjacent to another; e) Search: sequence of edges traversed to go from a source node to a destination one; f) Loop: road linking a node to itself (it begins and ends in the same node); g) Order: number of nodes in the graph; h) Degree of node: number of edges in it. From this language it is possible to understand the characteristics of the types of graphs.

To compare a graph with another, it is necessary to take into account graphs metrics. From *Lexmath* it is possible download an file with format *Gephi* (*http://www.gephi.org*) software which provides a wide range of metrics which are considered: the "degree", which corresponds to the number of edges that have an impact on a given vertex; the "density", which refers to the proportion of the number of relations present in the sample in relation to the total; the "clustering coefficient" which measures the density of connections between the direct neighbors of a node and the "modularity" constituting the set of highly interconnected nodes.

The following image (Fig. 5) shows the contribution of *Gephi* to the study of the available lexicon in the center of interest *Algebra* in students of secondary education.

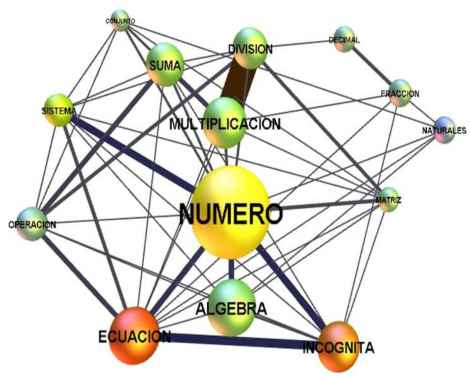

Figure 5: *Gephi's semantic structure – Center of interest Algebra in secondary students*

Why *Algebra* words are not observed? It is possible to say that these words belong to the center of interest *Numbers*.

It does not happen the same with teaching students from the university A, in the center of interest *Algebraic Structures*, as seen in Fig. 6.

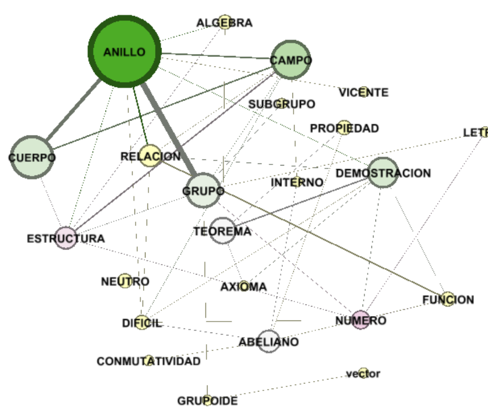

Figure 6: *Gephi's semantic structure – Center of interest Algebraic Structures in math teaching students in University A*

The same is true for teaching students of university B as seen in Fig. 7.

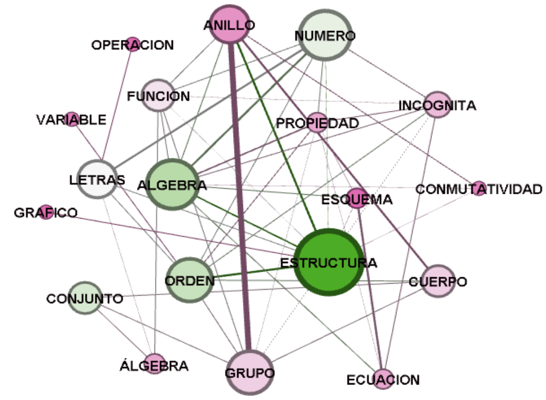

Figure 7: *Gephi's semantic structure – Center of interest Algebraic Structures in math teaching students in University B*

In both cases we are faced with a situation of lexical availability consistent with expectations for the center of interest studied.

4. Discussion

In relation to the secondary education students' sample:

- It cannot be observed an available lexicon in mathematics that permits learning-teaching interaction that generates understanding and appropriation of the expected mathematical knowledge
- According to the analysis by level of schooling, a gradual but not significant growth is observed.
- Gender analysis indicates no significant differences in lexical availability in any center of interest.

In relation to the mathematics teaching program sample:

- The analysis of lexical availability of student also notes a strengthening as the number of years in the program increases regardless of how many times the subject is repeated.
- It is observed at the same time, a disparity of words that constitute the lexicon of students among which the most common are group, ring and body.

In relation to the technological tools

- The data analysis from the searching of appropriate technological tools, although not traditional, it is feasible and strengthens its characteristics.
- The way of introducing non-traditional technological tools is available. It only lacks interest to innovate to better understand the relation between the variables that come together in a research.

- The configuration of *Lexmath* is truly an innovation in data analysis in which conceptual networks are involved.
- The use of graphs to better visualize, understand and interpret the behavior of semantic networks generated in such events.

5. Conclusion

Next researches would be focusing in the teachers because it is possible they cannot use a lexicon as the mathematics requires: clear symbolic and conceptual ideas. On the other hand it is possible that sociocultural level on the students interferes with their mathematical learning

Using no traditional technological resources to analyze data improves their meaning and their comprehension but this use must be very well selected because it is likely to make mistakes regarding the nature of the variable and data.

Technological resources permit to analyze collected data faster than other resources. This is an advantage when it is necessary to display some strategy to improve some educational situation.

Acknowledments

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