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Development of a taxonomy for key terms in Mathematics Education and its use in a digital repository

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DEVELOPMENT OF A TAXONOMY FOR KEY TERMS IN MATHEMATICS EDUCATION AND ITS USE IN A DIGITAL REPOSITORY

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Although mathematics education is a young discipline, it has developed rapidly over the last 40 years. During this time, the community of mathematics education researchers, teachers' trainers, and mathematics teachers has produced a large quantity of literature published in books, journals, and conference proceedings and on Internet, among other sources. Yet there is currently no taxonomy of key terms for the systematic classification of the documents in this discipline. In this article, we present the procedure by which we constructed a taxonomy for Funes, a digital repository of documents in mathematics education. We establish the conceptual framework on which the taxonomy is based, demonstrate how we tackled problems of ambiguity and synonymy in the controlled vocabularies, and describe a procedure by which the user can perform precise, relevant searches using the taxonomy.

Keywords: documentation, mathematics education, repository, taxonomy, key terms.

Mathematics education is a young discipline that has developed over the last 40 years. During this period, the community of mathematics education researchers, trainers of teachers, and mathematics teachers has been gradually establishing the phenomena analyzed in the research, the conceptual and methodological frameworks through which to study these phenomena, and the problems and strategies for solving them that are analyzed in the practice of educating teachers and students. The researchers, teachers' trainers, and teachers have formed national and international communities and have produced a huge amount of literature that addresses the different interests of their members. Due to this research, mathematics education has consolidated itself today as a research discipline and practice with its own identity. Although there have been some attempts at a documents' classification using thesauruses that have been developed related to this discipline, there is no detailed, structured solution to the problem. We address this problem in order to create a digital repository for documents in the field. In this article, we describe our approach and present the taxonomy we produced. With this aim, in this paper we (a) establish some basic characteristics that a taxonomy of key terms should have; (b) describe Funes, a digital repository of mathematics education documents; (c) present the process that led us to construct a taxonomy of key terms for Funes; and (d) demonstrate the main attributes of the taxonomy we have constructed.

Construction of Controlled Vocabularies

Few research journals and conference proceedings control the vocabulary of their key terms. They usually ask authors for a list of key terms for their own papers, and editors assign these key terms to the documents, without following any organization of the terms they use. The lack of control of vocabulary creates problems when searching for and identifying a specific content. On the one hand, it creates ambiguity, since some terms have more than one meaning. For example, “Mercury” can refer to the planet, the metal, the god in Roman mythology, the name of a journal, or a model of car. On the other, this procedure creates synonymy, the fact that the same concept can be represented by different terms, as in the case, for example, of the terms “spouse” and “husband.” When the contents have been labeled using an uncontrolled vocabulary, two undesirable situations arise: (a) the search produces irrelevant results for the user—as would be the case in a search for “Mercury” when the user is only interested in the metal—and (b) the results do not include all of the relevant content—as would be the case in a search for “husband” when the content is labeled “spouse.”

A controlled vocabulary is a system that permits the search and selection of content through some kind of linguistic description. Its main purpose is to achieve a consistent description of the contents and facilitate their recovery. In this paper, we ground our work on a standard for the construction, formatting, and management of controlled vocabularies (NISO, 2005). According to this standard, the design and development of a controlled vocabulary follow four principles (p. 13):

- to eliminate ambiguity,
- to control for synonyms,
- to establish relationships between terms when appropriate, and
- to verify and validate the terms.

By following these principles, we attempt to fulfill two goals: precision, that is, finding all possible material; and relevance, avoiding results that do not correspond to the user’s interests.

Digital Repositories of Documents

A digital repository of documents is a networked system formed of hardware, software, data, and procedures that (a) contains digital objects, (b) contains metadata, (c) ensures the persistent identification of the object through use of a single identifier, (d) performs the functions of management, storage, and preservation of the objects, (e) provides easy, controlled, and standardized access to the objects, (f) provides appropriate systems for the security of the objects and metadata, and (g) is sustainable over time (López, 2007, p. 6). A digital repository serves as a tool for managing the digital content of an institution or community to provide support for its members’ research, innovation, and learning. Open digital repositories complement the process of “formal” scientific publication and are vehicles of the *Open Access* movement to provide free online access to documentation without most of the restrictions involved in copyright. Currently, the number of digital repositories is growing fast.[1]

Funes is a digital repository of documents in mathematics education (Gómez, Cañadas, Soler and Restrepo, 2009). Its goal is to contribute to improving the teaching and learning of mathematics by making documents available to the community of mathematics educators that do not have copyright restrictions and that support this community’s work. The target audience of Funes is the community of mathematics educators. This community includes mathematics education researchers, trainers of teachers, and mathematics teachers at all educational levels. The content of Funes is available to the general public at http://funes.uniandes.edu.co. There are no restrictions for access to the portal, and users have access to all of the documents in the repository. The documents are related to some aspect of the teaching and learn-

1 See, for example, http://www.opendoar.org/.

ing of mathematics. They include files in PDF and multimedia format (images, videos, presentations, etc.). Any author who registers may contribute documents to Funes free of charge. The documents that authors submit for publication are reviewed by an academic committee that verifies their legibility, completeness, and coherence. The editor may also verify, correct, and improve the data for identification of the document (metadata). The repository permits the elimination, revision, or replacement of contents that have been included in the system. The academic committee also reviews again the corresponding record when this happens.

Often, the user searches for information on a topic or problem without knowing what documents treat this topic or respond to the problem. In this case, the user must perform a search using key terms. The user expects a search procedure that enables the rapid, precise identification of the documents most relevant to his/her interests. In the following, we describe the procedure that we followed to establish the taxonomy of key terms for Funes and demonstrate the search procedures based on them.

Some taxonomies of key terms in Mathematics Education

Taking into account the principles of controlled vocabularies mentioned above, we propose establishing a taxonomy of key terms for Funes. To do this, our first approach is to identify three kinds of key term, which we call focus, educational level, and topic. Focus refers to the purpose and utility of the document—research, essay, innovation, and activity, whereas educational level identifies the kind of information on the subjects to which the document refers. For this key term, we use an international scale of educational levels: early childhood education, primary education, lower and upper secondary education, adult education, graduate study, vocational training, all levels of undergraduate university education and degree programs.

The main problem focuses on the key terms that we call topics. These refer to the taxonomy that should enable users with a specific interest to perform precise and relevant searches. In our first approach to this problem, we tried to use an existing taxonomy. The taxonomies developed by UNESCO (2010) and ERIC (2010), which are generally recognized in the field of education, turned out to be very limited, because they provide only a small number of key terms in mathematics education. In the case of UNESCO, we find only three terms: (a) the teaching of mathematics, (b) the teaching of statistics, and (c) numeracy. The ERIC thesaurus is more complete and structured, but it is also limited, since the terms repeat when one descends two levels: one finds key terms that also belong to the higher levels with different meanings, yet the thesaurus does not appear to differentiate between those meanings. This shows that the number of key terms specific to mathematics education is limited.

We then decided to analyze MathEduc (FIZ Kalruhe, 2010), the best-known specialized database in mathematics education. This database includes the bibliographic references from approximately 500 research journals, books, and conference proceedings in the discipline. It is a required reference in mathematics education, and it was our primary candidate for creating a taxonomy of topics in Funes. However, when we analyzed this thesaurus, we ran into difficulties. The MathEduc thesaurus appeared to be quite rich in key terms, including about 300. However, this thesaurus includes key terms for educational computer science that do not correspond specifically to those in mathematics education. Further, although MathEduc includes key terms for mathematics contents, it does not differentiate between topics in school mathematics and those in higher mathematics. When we limit analysis to the terms specific to mathematics education, we find about 80 key terms, organized into five categories: (a) educational policy, (b) psychology of mathematics education, (c) teaching of mathematics, (d) foundations of mathematics, and (e) topics in advanced mathematics and school mathematics. For example, in the category on the teaching of mathematics, we find terms related to general studies, philosophical and theoretical studies, teaching objectives, teaching methods, problem solving, evaluation, learning difficulties, and didactic units. This classification is quite debatable from the conceptual point of view. MathEduc solves problems of ambiguity and synonymy by defining most of the key terms in great detail. For example, problem solving is identified by the following phrase: "investigation and solving of problems (e.g., teaching problem solving and heuristic strategies, classification of exercises, problem solving in the curriculum)." This kind of key term was not an option for Funes, as we sought a taxonomy of key terms that followed internationally established standards (NISO, 2005, pp. 23-41). We therefore decided to construct our own taxonomy of key terms. We did, however, impose the condition that all key terms from MathEduc have an equivalent term in Funes.

Construction of the Funes Taxonomy

Our goal was to base the Funes taxonomy on the a solid conceptual framework specific to mathematics education and (b) efficient for registering and searching documents (Pinto, 2008), while also addressing problems of ambiguity and synonymy. We decided to differentiate the key terms that refer to mathematics education clearly from those that refer to mathematics contents. We separated the mathematics education terms into key terms for school mathematics and key terms for higher mathematics. In constructing these two taxonomies, we based our work on the taxonomy used by TIMMS (Mullis, Martin, Ruddock, O'Sullivan, Arora and Eberber, 2005) and TEDS-M (Tatto, Schwille, Schmidt, Ingvarson and Beavis, 2006).

For the key terms in mathematics education, we decided to adopt a curricular approach (Rico, 1997). By mathematics curriculum, we mean the educational plan that each society establishes for the discipline. The curriculum seeks to address four central questions (p. 381) concerning (a) the knowledge to be taught, (b) learning, (c) teaching methods, and (d) evaluation of the learning achieved. Reflection and analysis of the curriculum may be based on these four basic questions—why, for what purpose, how, and how much—giving rise to four dimensions—conceptual, cognitive, formative, and social—and five levels—goals, disciplines, education system, planning for teachers, and local planning. This focus gave rise to the nine basic categories of key terms in mathematics education that Funes uses: (a) education system, (b) education center, (c) classroom, (d) student, (e) teacher, (f) learning, (g) teaching, (h) evaluation, and (i) curriculum. We included one category for the relationship between mathematics education and other disciplines and another category for the key terms related to research and innovation in mathematics education. We also included a general category for key terms specific to mathematics education that do not fit clearly into the structure of the curriculum.

We followed a cyclical process for construction of the taxonomy. First, we reviewed the way some research journals, conference proceedings, and national and international databases assign key terms to their documents, with two main goals: (a) to ensure that the key terms they consider had their equivalent in the Funes taxonomy, and (b) to ensure that the documents from these sources could be classified appropriately using our taxonomy. Second, we asked several international experts to review the taxonomy and try to classify their own documents using it. This cyclical process led us to change the structure and content several times.

The taxonomy of key terms used in Funes is found in Gómez and Cañadas (2010). Figure 1 shows the structure of the codes for levels 3 and 4 for *numbers* as first code for school mathematics *school mathematics*.

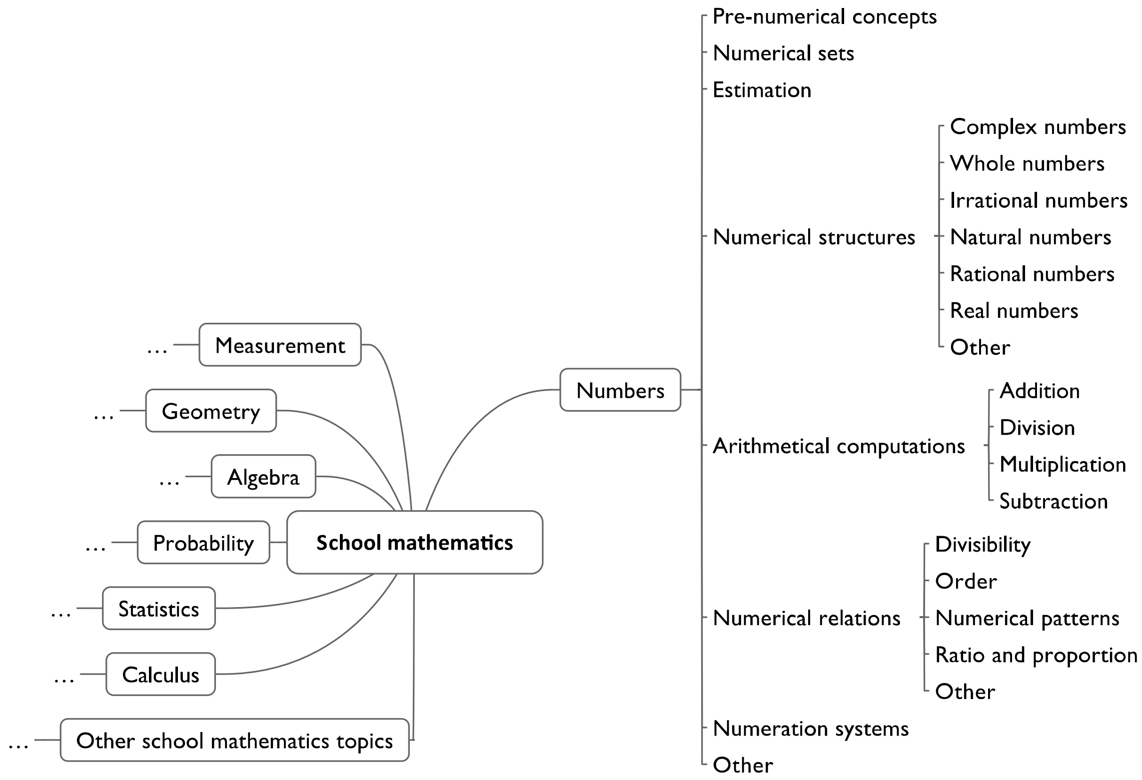

Figure 1. Learning category in Funes

Precision, Relevance, and Efficiency of Funes Taxonomy

Funes solves problems of ambiguity using its own structure. For example, the term "evaluation" appears in several key terms, but these key terms are found within sections that give them the meaning specific to these contexts. In various key terms, we use "other," which is also identified with the category of key terms to which it belongs. We tackle synonymy indirectly. Each concept has a single key term assigned in Funes, but the editorial committee keeps a database of synonyms as a way to ensure the completeness of the taxonomy. A user who searches the term "learning community" will not find it in Funes, but he or she will find "community of practice". We hope to use this database as a tool for the user in the future, but at present it is only an internal work tool.

Funes resolves problems of relevance and efficiency in the following way. The user has access to the structure of key terms with which we have labeled at least one document. Figure 2 presents a portion of this structure. The user can click on any of the links to obtain a list of documents labeled with the corresponding key term.

Funes

- 01. Education system
    - Entrance to different educative levels
    - Curricular documents
    - Management and quality
    - Legal issues
    - Educational policies
- 02. Education centre
    - Management and organization
        - Mathematics department
        - School educational project
    - Resources
        - Didactical resources and their availability
        - _Other (resources)
- 03. Classroom
    - Classroom management
        - The discourse
        - Student's behavior management
        - Socio-cultural norms
    - Didactical materials
        - Textbooks
        - Manipulative materials
        - Audio-visual media
        - Computer resources
            - Calculators
            - Computers
            - Internet
            - Software
            - _Other (computer resources)
        - _Other (didactical materials)
    - Interpersonal relationships
        - Between students
        - Teacher-students
        - _Other (interpersonal relationships)

Figure 2. (Partial) structure of key terms in Funes

By clicking on one of the links, for example on beliefs (in Learning – Affective aspects), the user obtains the list of documents labeled with this key term. Figure 3 presents part of this list.

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Figueras, Olimpia (2011). *Atrapados en la explosión del uso de las tecnologías de la información y comunicación.* PNA, 5(2), pp. 67-82 .

Figueras, Olimpia; Guillén, Gregoria (2004). *Estudio exploratorio sobre la enseñanza de la geometría en primaria: elaboración de una encuesta.* En Castro, Encarnación; de la Torre, Enrique (Eds.), Investigación en educación matemática : Octavo Simposio de la Sociedad Española de Investigación en Educación Matemática (S.E.I.E.M.) (pp. 219-228). A Coruña: Servicio de Publicaciones.

Flores, Patricia; Figueras, Olimpia; Pluvinage, François (2007). *Los docentes, sentidos construidos en la escuela sobre las matemáticas. Un estudio en la ciudad de México.* En Camacho, Matías; Flores, Pablo; Bolea, María Pilar (Eds.), Investigación en educación matemática (pp. 335-342). San Cristóbal de la Laguna, Tenerife: Sociedad Española de Investigación en Educación Matemática, SEIEM.

Forgasz, H. J.; Leder, G. C. (2011). *Mathematics, computers in mathematics, and gender: public perceptions in context.* PNA, 6(1), pp. 29-39 .

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Gil, Francisco; Moreno, Francis; Gámez, Pilar (2003). *Concepciones de los futuros profesores sobre enseñanza y aprendizaje de las matemáticas.* En Castro, Encarnación (Ed.), Investigación en educación matemática : séptimo Simposio de la Sociedad Española de Investigación en Educación Matemática (pp. 213-226). Granada: Universidad de Granada.

Girnat, Boris (2011). *Ontological beliefs and their impact on teaching elementary geometry.* PNA, 5(2), pp. 37-48 .

Figure 3. Partial list of documents that correspond to a key term

By clicking on the link that corresponds to a document, the user obtains the detailed information on this document and can download the corresponding file (Figure 4).

Ontological beliefs and their impact on teaching elementary geometry

Girnat, Boris (2011). *Ontological beliefs and their impact on teaching elementary geometry*. PNA, 5(2), pp. 37-48 .

PDF
Disponible bajo la licencia Creative Commons No Comercial Sin Derivar.
670Kb

URL Oficial: http://www.pna.es

Resumen

This paper proposes a conceptual framework to classify ontological beliefs on elementary geometry. As a first application, this framework is used to interpret nine interviews taken from secondary school teachers. The interpretation leads to the following results: (a) the ontological beliefs vary in a broad range, denying the assumption that a similar education provokes analogue opinions; and (b) ontological beliefs have a remarkable influence on the standards of proofs and on the epistemological status of theorems, and also on the role of drawing, constructions and their descriptions, media, and model building processes.

Tipo de Registro:	Artículo
Términos clave:	13. Matemáticas escolares > Geometría 06. Aprendizaje > Aspectos afectivos > Creencia 11. Educación Matemática y otras disciplinas > Fundamentos de la Educación Matemática > Epistemología
Nivel Educativo:	Educación Secundaria y Bachillerato (13-18 años)

Figure 4. Classification of a document in Funes

Discussion

In the current context, learning is a social process in which we learn interdependently within the multiple communities of practice to which we belong. The mathematics education community forms around a variety of people (teachers, innovators, researchers, administrators, and other groups) who are associated with educational institutions, associations, and other collectives. Information and communications technologies (ICT) present an opportunity for organizing and structuring this multiplicity of professionals into a social system of learning on different scales, in which each can learn from the others and contribute to their learning. Digital repositories are a tool that can use ICT technology to contribute to this goal.

This document presents the procedure that we used to construct the taxonomy of key terms used in Funes. Given the characteristics of the thesauruses and taxonomies that currently exist in mathematics education, we have justified the need to construct a new taxonomy. We have presented the conceptual framework on which we based the construction of the Funes taxonomy, indicated how this taxonomy tackles the problems of ambiguity and synonymy inherent in controlled vocabularies, and demonstrated the procedure that a user may currently use to perform precise, relevant searches.

The Funes taxonomy is not a thesaurus. We have not yet established the links needed within this structure to relate terms. The Funes taxonomy is a living structure that must evolve over time according to the needs of users and the characteristics of the documents published in the repository. For example, in the future, Funes will have a procedure to permit users to assign labels freely to the documents. These labels, as well as suggestions for new key terms, could lead to changes in the taxonomy.

We believe that the procedure presented to construct the taxonomy of key terms in Funes can be used in other didactical disciplines. Since the structure of the curriculum is general in character, it would be necessary to refine the key terms of the discipline within this curriculum structure and establish the contents of the discipline, at both the school and the advanced levels.

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