Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

***Special Issue*, 2013**

"Concept mapping. An international Outlook"

Fermín González García (Coordinator)

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SEJ-059 LabOSfor

Laboratorio de Investigación en Formación y Profesionalización
Universidad de Granada.

EDITORIAL

SEJ-059 LabOSfor. Laboratorio de Investigación en Formación y Profesionalización.
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ISSN 1989-9572

Journal for Educators, Teachers and Trainers

This new magazine, published yearly, is created with a clear perspective: improving the MUNDUSFOR and DEPROFOR consortia, giving it an international renown and granting it a perspective of research, beyond the educational perspective of today. Our intention is also to develop an electronic magazine for the field of the educational professionals.

The objectives of *Journal for Educators, Teachers and Trainers* (M&DJETT) are therefore centered in different aspects of academic and research diffusion related to the teaching professionals. In one hand, M&DJETT pretends to become an educational research database. In the other hand, a second objective of the publication is to facilitate for young researchers the diffusion of their work, masters and doctorates students above all, and to serve as an advertisement vehicle for works which have not reached the article format yet. Besides, another function for M&DJETT will be the diffusion of publications through reviews.

CONTENTS

Journal for Educators, Teachers and Trainers
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Special Issue "Concept mapping. An international Outlook". Presenting

Presentación del número extraordinario "Mapas conceptuales. Una perspectiva internacional"

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Rector Magnífico de la Universidad de Granada, España

Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

González Lodeiro, F. (2013). Special Issue "Concept mapping. An international Outlook". Presenting. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 6-7.

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Special Issue "Concept mapping. An international Outlook". Presenting

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La Universidad de Granada desarrolla actualmente un gran número de proyectos docentes, de investigación y de innovación, que tienen amplia proyección internacional y que la están situando en una posición de liderazgo en áreas muy diversas del conocimiento. Estos procesos han llevado a establecer y multiplicar las redes internacionales de docencia, innovación e investigación, siendo muchas lideradas por la propia institución, o bien planteadas con la presencia notable de la UGR.

Un elemento clave de la internacionalización es la difusión del conocimiento generado en la Universidad y, dentro de este ámbito, la creación y consolidación de revistas científicas. Un excelente ejemplo de ello es esta joven revista, *Journal for Educators, Teachers & Trainers JETT*, creada en 2010 por un consorcio de cinco universidades europeas, que lidera la Universidad de Granada, y que imparte el Máster Erasmus Mundus MUNDUSFOR destinado a la Formación de Profesionales de la Formación.

La difusión de JETT aspira a convertirse en un referente internacional en el campo de la formación en todos sus ámbitos, publicando artículos en cuatro idiomas (español, inglés, francés y portugués). Para ello, promueve la difusión del conocimiento que se produce en la propia Universidad de Granada, a la vez que recoge las aportaciones más relevantes que a nivel internacional se desarrollan en el campo de la formación.

Presentamos, con estas breves líneas, el número monográfico titulado *Concept mapping. An international Outlook*, impulsado por el secretario de la revista y profesor del Departamento de Didáctica y Organización Escolar de nuestra Universidad, el Dr. José Gijón Puerta, quien desde el grupo de investigación SEJ059, ha coordinado en los últimos años varios proyectos de investigación e innovación vinculados al uso de los denominados *mapas conceptuales*, utilizados en variados campos académicos, y en el mundo empresarial, para la gestión y representación del conocimiento experto, la mejora de los procesos de enseñanza y aprendizaje, la detección de errores conceptuales, y para la generación de nuevo conocimiento. Este número monográfico recoge el estado del arte a nivel internacional, con la coordinación del Dr. Fermín González García, Catedrático de Didáctica de las Ciencias Experimentales de la Universidad Pública de Navarra, pionero en el tema, y un experto reconocido internacionalmente.

Se ha seleccionado para el monográfico un elenco de firmas invitadas, que encabeza el Dr. Joseph D. Novak, profesor emérito en la Universidad de Cornell y creador de los mapas conceptuales en la década de los años setenta del siglo pasado. Junto a él, se incluyen catorce artículos de expertos internacionales de Europa (Finlandia, Reino Unido, Estonia, Italia, Portugal y Malta) y América (Estados Unidos, Argentina, México y Brasil), que abordan los aspectos teóricos, los usos actuales de los mapas conceptuales, y los retos presentes y futuros de este ámbito. Entre ellos, podemos destacar las aportaciones de Alberto J. Cañas, Director asociado del Instituto para la Cognición Humana y de las Máquinas de Florida IHMC, el centro investigador en el que se ha desarrollado el software CmapTools, cuya creación dio un impulso muy importante al uso de los mapas conceptuales a nivel mundial.

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http://www.ugr.es/~jett/index.php

González García, F. (2013). Concept mapping. An international Outlook. Editorial. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 8 – 13.

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EDITORIAL

Concept mapping. An international outlook

Mapas conceptuales. Una perspectiva internacional

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Abstract
The creation of concept mapping and their subsequent evolution go together with the impressive work of Professor J. D. Novak. His works, from the doctoral thesis of 1958 to its current implementation of the more advanced methods to improve the learning process, and therefore the teaching, have pointed to a clear pedagogical approach. This special issue of the Journal represents a magnificent example of his influence, evidenced by the participation of relevant speakers relating their experiences in the fields of teaching, research, and management.

Resumen
La creación de los mapas conceptuales y su posterior evolución van de la mano del impresionante trabajo del profesor J. D. Novak. Sus trabajos, desde la tesis doctoral de 1958 hasta la actual aplicación de los métodos técnicos más avanzados para mejorar el proceso de aprender, y por consiguiente el de enseñar, han señalado una vía pedagógica de inmensa virtualidad. Este número especial del *Journal* representa una magnífica muestra de su influencia, evidenciada por la participación de relevantes ponentes que nos relatarán sus brillantes experiencias en los campos de la docencia, la investigación y la gestión.

keywords
Concept mapping

Palabras clave
Mapas conceptuales

1. Sobre mapas conceptuales

De acuerdo con el eminente profesor Morón (González, Moron, y Novak, 2001), podemos decir que el mapa conceptual de Novak es la ordenación de los distintos aspectos del significado de un concepto, del contexto necesario para entenderlo, y de las ramificaciones del concepto, que abren nuevos caminos a la investigación. Es corriente oír que a veces los problemas de la educación se dejan en manos de pedagogos teóricos no familiarizados con los temas específicos que se enseñan en los diferentes campos del saber. Los mapas conceptuales son la mejor forma de aprender, porque nos obligan a preguntarnos rigurosamente qué queremos decir con cada una de nuestras palabras, a establecer una jerarquía entre los conceptos: de los más universales a los particulares, o a ver analogías y diversidad entre conceptos de la misma extensión.

La técnica de los mapas tiene el prestigio de ser muy vieja y muy nueva: nace en los esquemas de Aristóteles y en el ideal sistemático de la filosofía, cuyo ejemplo más visible serían las obras de Hegel, estructuradas con un rigor matemático. Los mapas conceptuales han permitido profundizar en ese ideal de orden y aplicarlo al proceso de aprender en la escuela. Ellos tienen el mérito de haber desplegado en la enseñanza la virtualidad práctica de los antiguos “árboles de la ciencia”. El punto de partida es la distinción entre aprendizaje memorístico y aprendizaje significativo. Sin establecer dicotomías rígidas, puesto que todo saber es un tipo de recuerdo, los mapas conceptuales permiten que el estudiante practique el aprender significativo: desde el entusiasmo (“inteligencia emocional”) personal, enhebrando los contenidos nuevamente adquiridos con los que posee de antemano, y encontrando por sí mismo lo que debe aprender en su educación.

La creación de los mapas conceptuales y su posterior evolución van de la mano del impresionante trabajo del profesor Novak (1984; 2013). La clave de su proyección universal ha sido la ejemplar dedicación sistemática a su profesión/vocación. Sus trabajos, desde la tesis doctoral de 1958 hasta su actual aplicación de los métodos técnicos más avanzados para mejorar el proceso de aprender, y por consiguiente el de enseñar, han señalado una vía pedagógica de inmensa virtualidad.

Este número especial del Journal representa una magnífica muestra de su influencia, evidenciada por la participación de relevantes ponentes que nos relatarán sus brillantes experiencias en los campos de la docencia, la investigación, y la gestión.

El profesor Novak nos ha admirado a muchos por su saber, pero nos ha ganado por su generosidad en compartir sus ideas. Su creación intelectual se ha enriquecido, aún más, en la medida en que se regalaba a los demás.

El concepto básico de la universalmente conocida teoría de Novak ha sido el de "aprendizaje significativo" frente al memorístico. La fórmula práctica que le ha dado fama internacional ha sido la teoría y técnica de los mapas conceptuales. El mapa conceptual representa el aprendizaje como creación personal, aprendizaje de cosas y al mismo tiempo reflexión sobre el aprendizaje, y de esa manera, el medio para no olvidar lo que se aprende.

Hoy en España estamos embarcados en una reflexión de ámbito nacional para la mejora de la educación. Se trata de hallar respuestas a cuestiones tales como: ¿Por qué hay tantos estudiantes que aprenden tan poco? ¿Por qué da la impresión de que las instituciones educativas fracasan en su cometido de ayudar a los estudiantes a aprender? ¿Por qué están los estudiantes tan poco motivados para aprender y por qué tantos profesores no aciertan a enseñar?

La sociedad del conocimiento y de la información en cuyo seno nos desenvolvemos, demanda expertos en la creación y gestión del conocimiento y esto pasa por un nuevo perfil de profesor y alumno.

El Sistema Europeo de la Educación Superior supone un reto para todos los niveles educativos, ha supuesto una revisión copernicana de los conceptos de aprender y enseñar, con énfasis en el trabajo del alumno. Los mapas conceptuales, junto al poderoso marco teórico en que se fundamentan, constituyen excelentes recursos instruccionales para ayudarnos en esa necesaria adaptación, que incluye también un proceso de profesionalización docente (Fernández-Cruz y Gijón, 2011) y de capacitación para la gestión del conocimiento experto que los profesores poseen (Rodríguez-Higueras, 2012).

En Diciembre de 1990 el prestigioso *Journal of Research in ScienceTeaching (the oficial Journal of the National Association for Research in Science Teaching)* editó un *Special Issue* (Vol. 27, Issue 10) titulado *Perspectives on Concept Mapping.* Cuando uno compara ese número y el ahora editado se da cuenta de la exacta y meritoria visión de sus autores (como auténticos adelantados en el tiempo) acerca del potencial de los mapas conceptuales. Sobre todo si tenemos en cuenta que en EEUU el profesor Novak fue considerado como un revolucionario al estudiar los aspectos cognitivos del aprendizaje y la enseñanza de las ciencias. Mientras otros en la disciplina eran seducidos por las teorías conductistas en boga Novak, casi solo y contra corriente, insistía en estudiar el "trabajo de la mente".

Hay que subrayar que el profesor Novak tuvo el coraje de permanecer fiel a sus ideas frente a un rechazo continuado de las agencias de financiación a sus proyectos y de la antipatía de sus colegas. Hoy sus ideas son casi universalmente aceptadas como "paradigmáticas" y sus métodos (potenciados espectacularmente por el *CmapTools software*, creado por el profesor Cañas y colaboradores (2001) y su equipo en el prestigioso IHMC) son referentes en cada esquina del globo.

Y es que Novak es un eterno optimista, una personalidad humilde y generosa al compartir sus ideas, y un inconformista intelectual. A pesar del enorme éxito de su teoría, que con casi cuarenta años, conserva su valor y virtualidad, ha continuado buscando mejorarla a través de una mayor y mejor integración de la dimensión intelectual con el plano de la afectividad y de la dimensión social de la educación.

Como señalamos anteriormente la muy cualificada selección de autores del número que presentamos muestra el estado del arte de la teoría y praxis de los mapas conceptuales en los campos docente, investigador y de gestión. Constituyen la confirmación científica del enorme vigor de la teoría educativa del profesor Novak y de los mapas conceptuales como instrumentos de meta aprendizaje y de meta conocimiento, de aprendizaje significativo y de construcción del conocimiento.

Finalmente este número quiere representar un humilde y sincero homenaje al profesor Novak por su ingente labor, humildad, extraordinario talento e inagotable generosidad, reconocidas, entre otras instituciones, por la Universidad Pública de Navarra con la concesión del Grado de Doctor Honoris Causa en el año 2002.

2. Estructura del monográfico

El monográfico pretende una mirada internacional sobre los mapas conceptuales en las últimas décadas, presentando además las investigaciones y reflexiones más importante de los últimos años. Las aportaciones al monográfico proceden tanto del continente americano (con artículos de EEUU, México, Argentina y Brasil) como desde Europa (artículos de Reino Unido, Malta, Italia, Estonia, Finlandia y Portugal).

Así, conforman el monográfico quince artículos, además de este editorial y de una presentación del Dr. Francisco González Lodeiro, Rector Magnífico de la Universidad de Granada, al que agradecemos especialmente haber escrito para la revista JETT una introducción al número monográfico.

Dado que en este número se abordan my diversas dimensiones del tópico "mapa conceptual", no se ha planteado establecer distintas secciones en el volumen. Hemos optado por una organización alfabética de las aportaciones al monográfico, salvo en el caso del profesor Joseph D. Novak, cuyo artículo abre el número. Sin embargo, sí podemos agrupar las distintas aportaciones al contenido estructurante –los mapas conceptuales- en torno a varios tópicos que describimos a continuación.

En primer lugar, debemos destacar sin duda la aportación del profesor *Novak*, que abre el monográfico. Como creador de los mapas conceptuales a finales de la década de los años setenta del siglo pasado, sus opiniones y reflexiones sobre la forma en que los mapas conceptuales pueden potenciar los procesos de enseñanza y aprendizaje son sin duda tremendamente valiosas.

Junto al artículo del profesor Novak, podemos establecer un conjunto de aportaciones referidas a los mapas conceptuales como *Método para potenciar los procesos de enseñanza y aprendizaje significativo*: *M.K. Åhlberg*, de la University of Helsinki, *L. P. Molina Azcárate*, de la Escuela y Liceo Vocacional Sarmiento. Gymnasium, Universidad Nacional de Tucumán y *J. A. Valadares*, de la New

University of Lisbon comprenden este apartado. El estudio de *Åhlberg* aborda un procesdo de desarrollo desde los mapas de Novak y la comparación con los mismos. *Valadares* realiza una reflexión general sobre el desarrollo de los mapas conceptuales y su relación con la Ciencia. *Molina Azcárate* aborda los errores conceptuales para lograr aprendizaje significativo, en un estudio con alumnos de educación secundaria en Argentina.

En segundo lugar, podemos establecer un apartado para la *Integración de las TIC*, en el que *A. J. Cañas, L. Bunch y J. D. Novak*, del Institute for Human and Machine Cognition de Florida –IHMC-, junto a *P. Reiska*, presentan la herramienta informática CmapAnalisys, como una utilidad para analizar mapas conceptuales. También en este apartado podemos incluir el trabjo de *A. B. Prieto* y *R. Chrobak*, de la Universidad Nacional del Comahue, Neuquén, en el que se describe un estudio de caso en el noroeste de la Patagonia argentina, sobre la relación entre la disponibilidad de agua y la actividad solar, integrado la TIC y herramientas metacognitivas en el ámbito de la educación ambiental. *I. M. Kinchin*, de la University of Surrey, aborda problema en la construcción de mapas cuando se pretende un aprendizaje dinámico entre estructuras de conocimiento, por ejemplo, a través de la construcción de mapas secuenciales en el tiempo, o indicando las relaciones entre las estructuras del mapa que representan contextos de aprendizaje complementarias, incluyendo la enseñanza se lleve a cabo como una actividad en línea, pudiéndose modificar los modelos existentes de desarrollo de e-learning (tales como el modelo TPACK) para acomodar una vista de perspectivas múltiples.

En tercer lugar, incluimos un apartado para el *Uso de mapas en distintas disciplinas de las Ciencias Experimentales* y afines*,* en las que esta herramienta tiene una amplia tradición, iniciada por el propio Novak. *G. Cutrera S. Spitcich y R. Chobak*, profesores de distintas universidades argentinas, se analiza cómo un futuro profesor en química vehiculiza nociones sobre la naturaleza de la ciencia a través de su discurso, sintetizándose el análisis a través del empleo de mapas conceptuales. *C.A. Soares Mendonça*, de la Unidade Acadêmica de Garanhuns, realiza unas reflexiones teóricas sobre el uso de mapas y caracteriza y ejemplifica diversas aplicaciones que han demostrado su eficacia desde el punto de vista del aprendizaje significativo. *N. L. Gallenstein*, del Department of Education University of South Carolina Beaufort, ofrece una explicación de los mapas conceptuales para estudiantes de edades comprendidas entre los 3 y los 13 años, presentando varios ejemplos, incluyendo un proyecto de evaluación en el área de matemáticas. También se describen los numerosos beneficios del uso de mapas conceptuales tanto para estudiantes como para profesores.

En cuarto lugar, podemos encontrar artículos que presentan *Estudios centrados en el uso de mapas conceptuales en el ámbito de la educación superior*. *B. Guardian Soto J. Veloz, I. Rodriguez y L. Veloz,* el Instituto Politécnico Nacional, México, presenta la experiencia en la carrera de Ingeniería en Computación que se imparte en el Instituto Politécnico Nacional (IPN) México en los últimos 8 años con alumnos y profesores. *J. Vanhear,* del Directorate for Quality and Standards in Education, Training and Professional Development Unit de Malta, por su parte, estudia el uso de mapas y “v” heurística en educación superior, a través del estudio de la producción de estudiantes universitarios.

En quinto lugar, por último, se presentan aportaciones relacionadas con *Revisiones y estudios longitudinales sobre el uso de mapas conceptuales* y los problemas que estos plantean. *R. Hoffman y J. Beach*, del Institute for Human & Machine Cognition (IHMC) de Florida, hacen una revisión de “las lecciones aprendidas” en la creación de modelos de conocimiento compuestos de mapas conceptuales, en una amplia gama de dominios, incluidos los de pronóstico del tiempo, la oncología clínica y el análisis del terreno. *P. Reiska y K. Soika*, de la Tallinn University, resalta los problemas que pueden aparecer cuando los mapas conceptuales son usados como instrumento de investigación en un estudio a gran escala e intenta definir también cómo seleccionar un instrumento válido para realizar este tipo de estudios, ya que en muchos casos los investigadores desean analizar el conocimiento de los estudiantes, pero sólo controlan si fueron capaces de crear mapas conceptuales.

3. El presente y el futuro de los mapas conceptuales

Al valorar globalmente este número monográfico de la revista JETT, podemos realizar algunas afirmaciones sobre el estado de las propuestas que J. D. Novak realizó en torno al aprendizaje significativo y al uso herramientas de representación del conocimiento basadas en mapas conceptuales.

En primer lugar, podemos ver claramente el vigor y la actualidad de estas propuestas. Y esto es así no sólo por la variedad y la calidad de los artículos incluidos en el monográfico, sino porque encontramos en ellos discusiones sobre problemas y retos planteados, sobre líneas de trabajo futuras y sobre novedades y mejoras en la creación, utilidad y análisis de los mapas conceptuales. El presente de las teorías que Novak desarrolló hace unas décadas y de las herramientas que diseño para mejorar la enseñanza y el aprendizaje significativo está pues asegurado (González, 2008).

En segundo lugar, se ha afianzado el uso de los mapas conceptuales en las instituciones educativas de la mayor parte de América y Europa. Así podemos encontrar en este monográfico aportaciones de América Latina, América Central y América del Norte y también de distintos países europeos. Y el proceso de expansión del uso de mapas conceptuales continua actualmente, siendo cada vez más amplia la participación en los congresos bienales que se celebran alternativamente en Europa y América.

En tercer lugar, por último, podemos adivinar un futuro interesante para el desarrollo de las herramienta de representación y gestión del conocimiento, como son los mapas conceptuales, incluyendo la mejora del software específico para su elaboración, así como para permitir el análisis de la información contenida en ellos. Será un placer para nosotros volver a revisar el estado del arte dentro de veinte años y comprobar la influencia que en la mejora de los procesos de enseñanza y aprendizaje hayan podido tener estas los mapas conceptuales para la representación del conocimiento.

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Journal for Educators, Teachers and Trainers
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ISSN 1989 - 9572

Empowering Learners and Educators

Empoderamiento de aprendices y educadores

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 04 de diciembre de 2012

Fecha de revisión: 20 de diciembre de 2012

Fecha de aceptación: 28 de diciembre de 2012

Novak, J.D. (2013). Empowering Learners and Educators. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 14 – 24.

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http://www.ugr.es/~jett/index.php

Empowering Learners and Educators

Empoderamiento de aprendices y educadores

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Abstract
The most important factor leading to empowerment of individuals is the ability and commitment to achieve high levels of meaningful learning. Meaningful learning requires integration of new concepts and propositions into the learner's cognitive structure to achieve high levels of organized knowledge that can be represented as knowledge models. Concept mapping and new educational strategies can facilitate the process.

Resumen
El factor más importante que lleva al fortalecimiento de las personas es la capacidad y compromiso para alcanzar altos niveles de aprendizaje significativo. El aprendizaje significativo requiere la integración de nuevos conceptos y proposiciones en la estructura cognitiva para alcanzar elevados niveles de conocimiento organizado que puede ser presentado en forma de modelos de conocimiento. Los mapas conceptuales y nuevas estrategias educativas pueden facilitar este proceso.

Keywords
Empowerment, meaningful learning, scaffolding, concepts and propositions, concept maps, creativity, knowledge models, New Model

Palabras clave
Fortalecimiento, aprendizaje significativo, andamiaje, conceptos y proposiciones, mapas conceptuales, creatividad, modelos de conocimiento, Nuevo Modelo.

1. Introduction

One only needs to put “empowerment” into Google or other search engines to see an enormous range of ideas put forward for “empowerment”. One might come away from such a search convinced that there is nothing new to be said about empowerment. That conclusion, I argue, is not correct and this paper seeks to add a new dimension to the query: “What is empowerment and how do we help people achieve this?”

I recall that as an elementary school student I wondered why some of my classmates had trouble understanding why 2X2 = 4, and 2+2 equals 4, but 3+2 =5 and 3X2 = 6. It took me many years to understand that what makes sense to a person very much depends on the quality of learning experiences that person has had, as well as innate aptitudes. It took even longer to understand a theory of learning and a theory of education that could explain why some students learn so little and recall so little, while other students leap forward to deep understanding. And why are some people so creative when faced with a new task and others simply flounder? So what have I learned? Over the past 60 years I have come to understand and appreciate the powerful impact that meaningful learning has on the thinking, feeling and acting of humans leading to empowerment in virtually any context. I shall seek to summarize this in this paper.

2. The Psychology of Meaningful Learning

None of the psychology I was presented as a student at the University of Minnesota was of value in understanding the dilemmas I note above. At Minnesota in the 1950’s, behavioral psychology was taught exclusively. This psychology held to the dogma that we must seek to understand human learning by observing human *behavior*, not on speculation on what may be going on in the brain. And the causes of behaviors, it was assumed, can also be studied with rats and cats and other organisms because the “laws of behavior” once discovered could be applied to any organism. The champion of this view was B.F. Skinner, and the “bible” for behaviorists was his 1938 book, *The Behavior of Organisms*, written while he was a professor at Minnesota. I recall telling my educational psychology professor, Gordon Mork, that behaviorism was useless for understand how people learn science, but he argued that this was the only learning psychology he knew. In fact, I did not learn about Jean Piaget’s monumental works until I sat in on seminars with Professor Smock at Purdue University in the early 1960. While I found some of Piaget’s ideas about children’s development of cognitive operational skills interesting, they did not explain how I learned science or how I observed my children learning science, albeit the latter was mostly at home.

The breakthrough for me and my students came with Ausubel’s 1963 book, *The Psychology of Meaningful Verbal Learning*. Here was a learning psychology that made sense to us and we sought immediately to try to understand and apply his ideas. We were further helped with his 1968 book, *Psychology of Learning: A cognitive view.* Subsequently I had the opportunity to coauthor a revision of his book (Ausubel, Novak, and Hanesian, 1978). Ausubel very carefully described the differences between meaningful learning and rote learning. In meaningful learning, the learner makes a conscious effort to integrate new concepts and propositions with related ideas already held by that learner. In contrast, when rote learning, the learner makes no effort to integrate new ideas with existing ideas and arbitrarily incorporates the new information into his/her cognitive structure. Later Marton and Saljö (1976 a,b) Described *deep* learning and *surface* learning in a manner somewhat similar to Ausubel’s meaningful and rote learning, respectively, but without the detail of Ausubel’s theory. *Concepts* are a central idea in our work so we are careful to define concept: a perceived regularity or patter in events or objects, or records of events or objects, designated by a label (usually a word). Concepts alone have little meaning until they are combined with *linking words* to form *propositions*. Propositions acquire meaning through meaningful learning. Creative people find new patterns in events or objects and thus create new concepts and new relationships or propositions. These are the building clocks of all knowledge.

While a teacher can do things to encourage meaningful learning, it is the learner who must choose to perform the knowledge integration. Moreover, the depth and quality of the learning will depend on how well organized the learner’s relevant knowledge is and on how skillful she/he is in integrating not only the new knowledge with prior relevant knowledge but also on the concomitant feelings and actions that may be pertinent. To become a highly meaningful learner in any domain often requires years of practice at integrating new knowledge with prior relevant knowledge and also integrating the acting and feelings during the learning. Achieving high levels of meaningful learning in any domain can be a lifelong pursuit. When done superbly well, it can also be a truly creative process. This is illustrated in Figure 1.

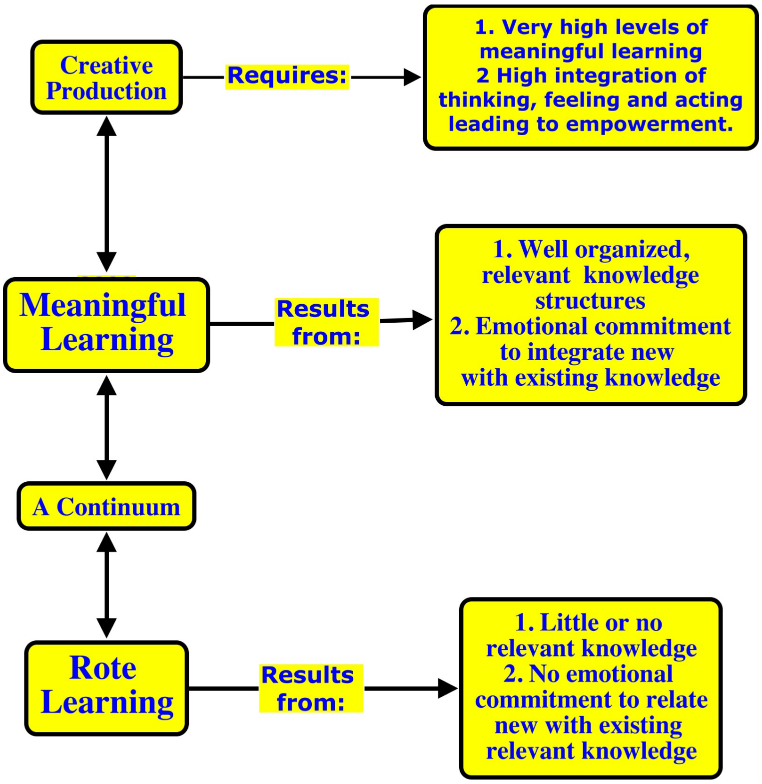

Figure 1. Learning approaches can vary from simple rote memorization to very high levels of meaningful learning, and only the latter leads to empowerment of the learner and creativity.

The concept of *meaningful learning* is profound. There are three requirements for meaningful learning. First, the material to be learned must be inherently meaningful. Nonsense syllables cannot be learned meaningfully. Virtually all school subject matter is potentially meaningful. Second, the degree of meaningfulness of material to be learned will depend partly on how much relevant knowledge the learner already has and on how well it is organized in her/his cognitive structure. Third, the *learner must choose* to incorporate new concepts and propositions into her/his relevant existing cognitive structure. The latter affective dimension can vary widely depending on how much effort the learner is willing to make to integrate the new information with relevant existing ideas. Where some form of performance is required in a learning task, it becomes imperative that the learner seek actively to integrate thinking, feeling, and acting, and also to consider constantly how the actions, feelings and ideas come together to form the most powerful meanings. This is what we see in experts in any field from sports to poetry, science, math or dance.

Another distinction that Ausubel made clear is that quality of learning is distinct from style of instruction. He characterized instruction as varying on a continuum from direct *expository or reception* teaching to autonomous *discovery or inquiry* learning. The orthogonal relationship between learning approach and instructional approach is shown in Figure 2.

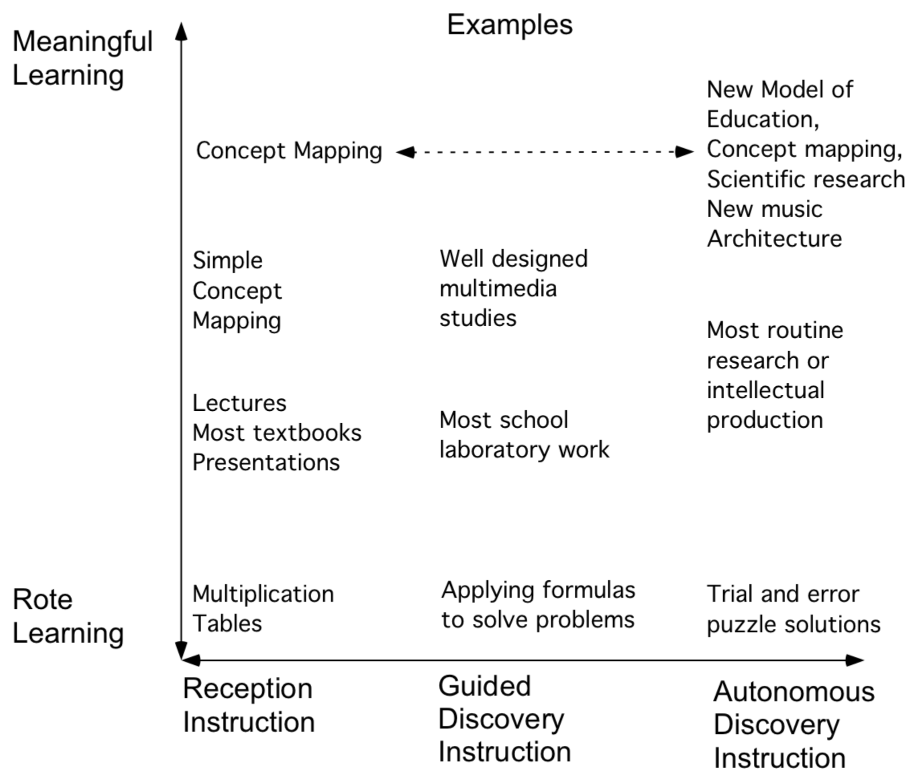

Figure 2. Learning approach can vary from very rote to highly meaningful, and instructional approach can very from direct reception learning to highly autonomous discovery or inquiry learning. (From Novak, 2010, figure 5.7).

What makes quality education so challenging to achieve is that there are many interacting factors that need to be considered simultaneously. Furthermore, we usually are dealing with a relatively broad spectrum of individual learners. Figure 3 shows the five *elements* involved in any educational event that interact in the construction of meanings. In my theory of education, all five of these elements interact to achieve high levels of meaningful learning. Simply stated, my theory of education states: *Meaningful learning underlies the constructive integration of thinking feeling and acting leading to* ***empowerment*** *for commitment and responsibility.* A full discussion of the five elements and their interactions and my theory can be found in Novak, 2010. The more we learn about he nature of human brain functions, the more we see support for the educational ideas presented here (e.g., Gazzaniga, 2008).

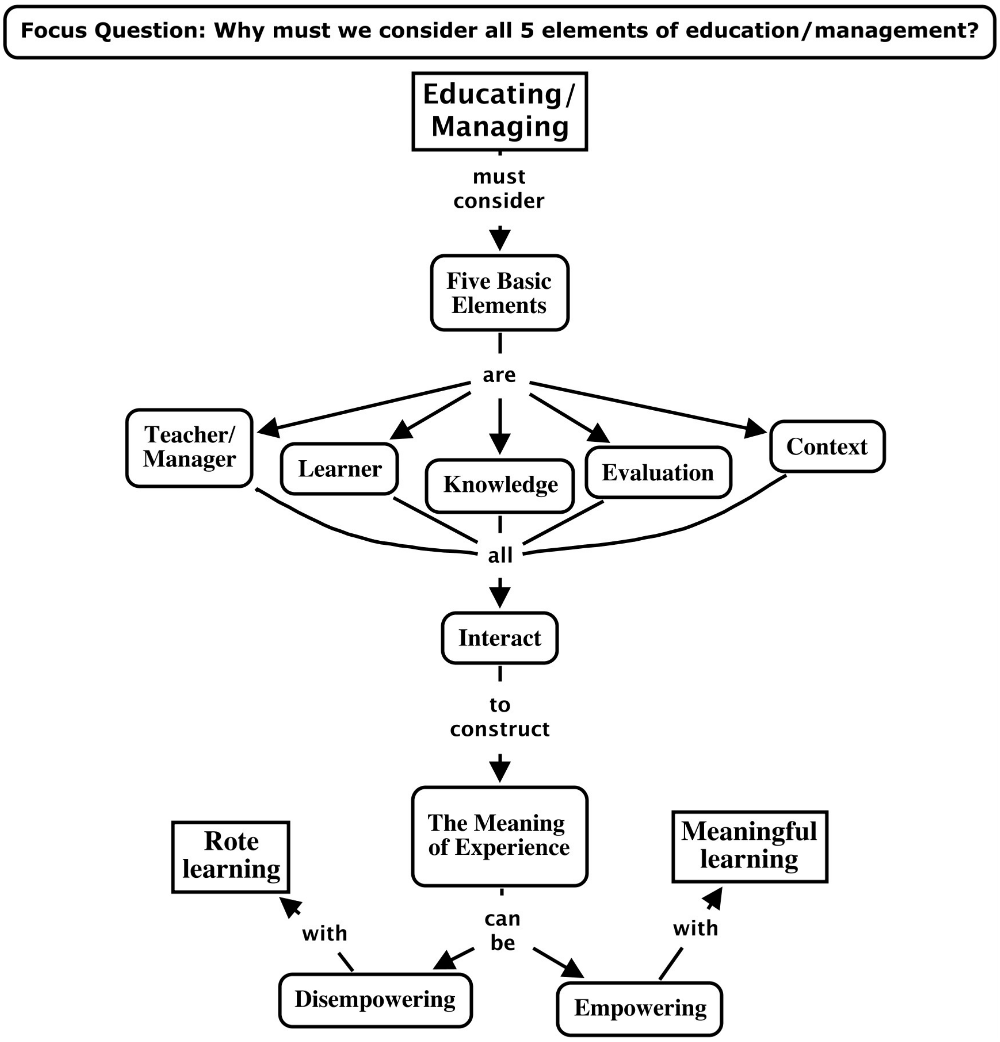

Figure 3. Education and management involve five elements, each of which interact in the construction of new meanings. When well done, education leads to empowerment of the learner or worker (From Novak 2010, figure 2.2).

3. The Importance of Metacognitive Learning

Over the last few decades there has been a great increase in understanding of the importance of helping learners learn about learning and the use of strategies to facilitate this process. Collectively these ideas are know as *metacognitive learning*. Among these ideas is that we can assist learners by providing *scaffolding* for facilitating learning (Wood, et al, 1976; Hogan and Pressley, 1997; Novak, 1990; 2010). In meaningful learning, new concepts and propositions need to be integrated with existing relevant ideas in the learner's cognitive structure. A common form of scaffolding is to present a learner with sample problems and possible solutions, thus aiding the learner to see ways to solve this class of problems. Another scaffolding tool is a sample concept map that shows some of the key concepts in a given domain of knowledge and key relationships between these concepts. Other important concepts might also be suggested, and the learner's task is to determine how these can be meaningfully incorporated into the sample concept map. We call these small sample maps "expert skeleton" concept maps, since they were prepared by a person who has expertise in this domain of knowledge and serve as the "skeleton" for addition of other concepts and propositions. Some additional suggested concepts, that might be offered in a "parking lot", help the learner build on the skeleton map. It is also important for the learner or teacher to identify a *focus question*; that is, a key question that the concept map will help to answer. To be effective, it is essential that the learner identify and incorporate additional relevant concepts on their own and figure out valid ways to incorporate these additional concepts to form meaningful *propositions*. While concepts are the building blocks of knowledge, propositions are really the *units of meaning*. Concepts alone convey very little meaning. Thus the learner moves beyond this given scaffold structure of knowledge in this domain and creatively builds her/his own elaborations. The additional concepts might be identified through a variety of learning strategies that will be discussed below. Figure 4 shows an example of an expert skeleton concept map with some additional relevant concepts in the "parking lot".

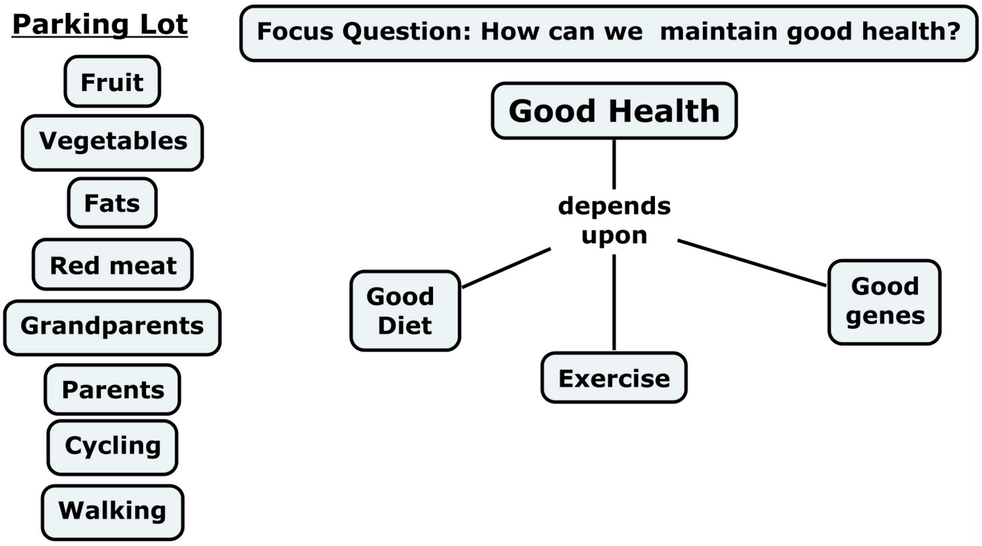

Figure 4. An expert Skeleton concept map with a "parking lot" suggesting concepts that might be added.

CmapTools software, that can be downloaded at no cost at: http://cmap.ihmc.us, allows for easy creation of concept maps (Cañas, et al, 1993; Cañas, et al. 2001). It also allows the addition of any kind of digital resource by simply "dragging" the icon for the resource and "dropping" it on a target concept. The resource then becomes part of the file for the concept map and can be later accessed by simply clicking on the icon for the resource, and selecting the desired resource when more than one of the same type is attached. Figure 5 shows an example of how the map in figure 4 might be expanded with additional concepts and additional resources of several types added. We refer to the elaborated concept map with attached resources as a *knowledge model*. There is virtually no limit to how creative a learner can be in creating a highly integrated, rich knowledge model for any topic of interest. These files can be stored and built upon later and/or combined with other knowledge models. CmapTools also allows for easy collaboration in building knowledge models, either working simultaneously or asynchronously at various times and locations. Collaborative learning can enhance learning for all participants and still permit considerable individual creativity. If the "History" tool is activated in CmapTools, a record will be made for each addition to the concept map.

Building knowledge models either individually or in small groups pays an extra dividend in that it engages learners in practices that help them understand the nature of knowledge and the process of knowledge creation. It also leads to better understanding and skill in learning how to learn *meaningfully*. In short, the practices involved help people *learn how to learn* (Novak and Gowin, 1984). In corporations or in science laboratories and many other settings, new knowledge creation is typically a team effort (Drucker, 1993; Nonaka & Tachiuchi, 1995). Examples of the value of concept mapping in organizations varying from governmental groups, to non-profits, to corporations can be found in Moon, Hoffman, Novak, and Cañas, 2011.

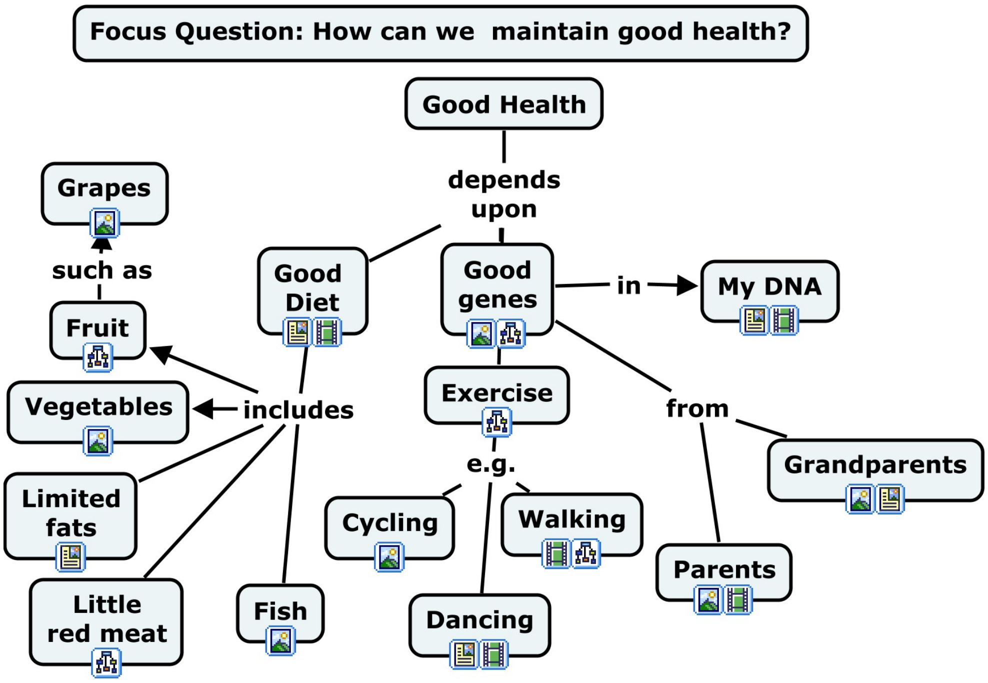

Figure 5. A concept map built by adding some concepts to the map in Figure 4, and also adding resources, including texts, subordinate concept maps with greater details, photos, and video clips. Resources can be mined from the Internet or be materials created in laboratory, field, library, or other sources (see Figure 6).

4. A New Model for Education

The explosive development in the past twenty years of computers, CmapTools software, the Internet, and our understanding of how people learn make it possible now to engage in a **New Model for Education** (Novak, 2004; Novak and Cañas, 2004; Novak, 2010). In school or other settings, a wide array of learning activities commonly used in the past can now be deployed more effectively. Figure 6 illustrates how beginning with an expert skeleton concept map for an area of study, and employing some of the many strategies commonly used, can feed into elaboration of a knowledge model. The resulting knowledge models become a record of meaningful learn by groups or individuals an can aid and foster future meaningful learning. It is a common problem in many organizations that there are limited or poor records of the learning and the problem solving that has occurred, with the result that mistakes made in the past are repeated again. For individual learners, none have the comprehensive records of their learning that knowledge models provide. Thus the facilitating effect of building on past learning is usually poorly done. We also recommend that an individual or group identify a good *focus question* that will be answered by the knowledge model as it is developed. It is common for the focus question to be modified or changed as the model is built, since new insights arise in the process.

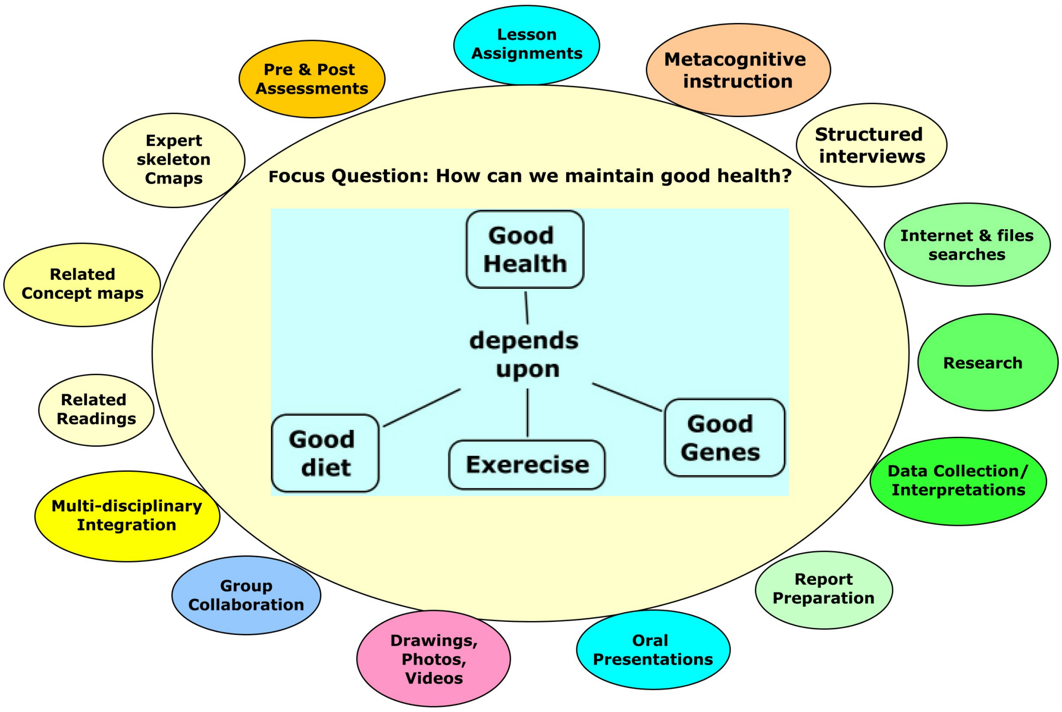

Figure 6. Schematic illustration for a New Model for Education. Starting with a good focus question and an expert skeleton concept map, individuals or groups can engage in a wide array of learning activities (small ovals) in guided meaningful learning resulting in a comprehensive knowledge model even much more elaborate that Figure 5.

As of this writing, I am aware of only a small number of schools and other organizations using our New Model. One of the best examples is Otto Silesky's school in San Jose, Costa Rica. Otto is Principal of a small publically supported school that was set up to serve students who were not doing well in regular public schools. The school was having reasonably good success for a number of years, but in 2003, Otto and his teachers decided to move to implement essentially our New Model. Switching from relatively traditional instructional methods to practices that involved heavy use of computers, the Internet, and meaningful learning strategies was not easy for the teachers or the students, and scores on the National year-end exams declined somewhat from previous years. Nevertheless, both teachers and students felt that good things were happening with the new program and they continued with these efforts. Figure 7 shows that not only did National exam test scores improve, but 100% of the students were meeting the standards set. This is a rare level of success for any school, and especially for a school were most students had not been very successful in traditional schools. Moreover, a much higher percentage of graduates were applying for and admitted to college programs, and they were doing well in college. Otto's school was an exemplary case of how empowering learners through optimal learning programs can positively impact the lives of learners.

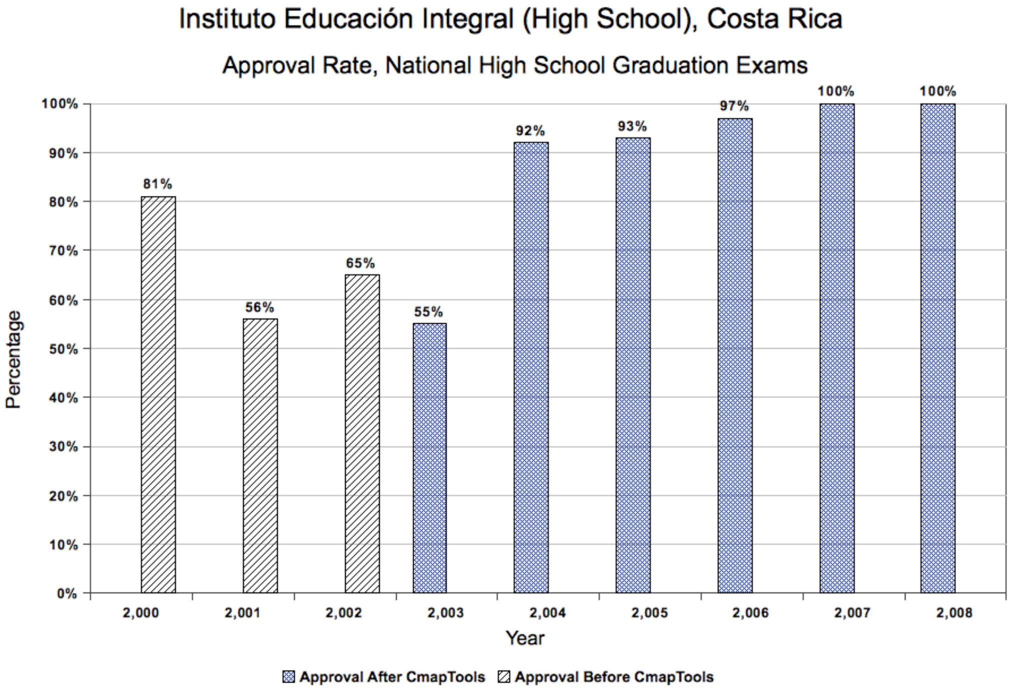

Figure 7. Approval rates on year-end National exams for students in Otto Silesky's school that moved in 2002 toward a New Model for Education.

At this writing, there are relatively few schools, corporations and other organizations employing essentially our New Model for education. Money has not been the problem (Hanushek, 1981); we are spending more that enough on education in most settings to implement the New Model. What we are lacking is the leadership needed to implement the tools and ideas encompassed in the New Model. However, as it continues to become more obvious that we need to do more to empower learners to take charge or their own meaning making, in school or work settings, it is inevitable that we shall see more changes toward this goal. The needs are huge, and the rewards for this kind of action can be enormous.

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Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

ISSN 1989 - 9572

Concept mapping as an empowering method to promote learning, thinking, teaching and research

Los mapas conceptuales como un potente método para promover el aprendizaje, la enseñanza y la investigación

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 30 de diciembre de 2013

Fecha de revisión: 15 de enero de 2013

Fecha de aceptación: 22 de enero de 2013

Ahlberg, M. (2013). Concept mapping as an empowering method to promote learning, thinking, teaching and research. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 25 – 35.

Journal for Educators, Teachers and Trainers
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Concept mapping as an empowering method to promote learning, thinking, teaching and research

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Abstract
Results and underpinning of over twenty years of research and development program of concept mapping is presented. Different graphical knowledge presentation tools, especially concept mapping and mind mapping, are compared. There are two main dimensions that differentiate graphical knowledge presentation methods: The first dimension is conceptual explicitness: from mere concepts to flexibly named links and clear propositions in concept maps. The second dimension in the classification system I am suggesting is whether there are pictures or not. Åhlberg's and his research group's applications and developments of Novakian concept maps are compared to traditional Novakian concept maps. The main innovations include always using arrowheads to show direction of reading the concept map. Centrality of each concept is estimated from number of links to other concepts. In our empirical research over two decades, number of relevant concepts, and number of relevant propositions in students' concept maps, have been found to be the best indicators and predictors of meaningful learning. This is used in assessment of learning. Improved concept mapping is presented as a tool to analyze texts. The main innovation is numbering the links to show order of reading the concept map and to make it possible to transform concept map back to the original prose text as closely as possible. In Åhlberg and his research group's research, concept mapping has been tested in all main phases of research, teaching and learning.

Resumen
Presentamos los resultados que sustentan más de veinte años de investigación y desarrollo de programas centrados en los mapas conceptuales. Se comparan diferentes herramientas gráficas de presentación del conocimiento, especialmente mapas conceptuales y mapas mentales. Hay dos dimensiones fundamentales para diferenciar los métodos de representación gráfica del conocimiento. La primera dimensión es la claridad de los conceptos: desde meros conceptos hasta los denominados enlaces flexibles y posposiciones claras en los mapas conceptuales. La segunda dimensión en el sistema de clasificación que sugiero es si existen o no imágenes. Las innovaciones y desarrollo de los mapas conceptuales de Novak realizados por Åhlberg y su grupo de investigación, son comparados con los tradicionales mapas de Novak. Las principales innovaciones incluyen el uso de puntas de flecha para indicar el sentido de la lectura. La importancia o papel central de cada concepto se estima a través del número de enlaces con otros conceptos. En nuestra investigación empírica a lo largo de dos décadas, el número de conceptos relevantes y el número de proposiciones relevantes en los mapas de los estudiantes, se consideraron como los mejores predictores del aprendizaje significativo. Esto se utiliza para la evaluación del aprendizaje. Otra innovación importante es la numeración de los enlaces, para mostrar el orden de lectura del mapa conceptual y para hacer posible su transformación en un texto tan parecido al original como sea posible. En Åhlberg y en los estudios de su grupo, los mapas conceptuales han sido probados en todas las fases principales de la investigación, la enseñanza y el aprendizaje

keywords
Improved concept mapping, graphical knowledge presentation methods, mind mapping, research methods, text analysis, meaningful learning, theoretical underpinnings.

Palabras clave
Mapas conceptuales mejorados, métodos de representación gráfica del conocimiento, mapas mentales, métodos de investigación, aprendizaje significativo, fundamentos teóricos.

1. Introduction

I first read about concept mapping in the beginning of 1980s, over 30 years ago. The strongest memory is when I found just published Novak & Gowin (1984) in the Academic Bookstore in 1984. At that time, I was a lecturer in the Department of Teacher Education at University of Helsinki. My work involved teaching research methods for becoming classroom teachers. They did not like so much about learning about research methods, because “we are becoming teachers, not becoming researchers”. I often repeated to them that teachers ought to monitor and make research on their own pupils’ learning in order to promote it, to give valid and reliable feedback, evaluations and grades (Åhlberg 1992). Novak & Gowin (1984) made me think that concept maps and Vee heuristics are versatile tools, which can be used to promote meaningful learning, teaching and research on learning and teaching.

I experimented with concept mapping over four years and developed my own versions of Novakian concept mapping for different purposes. Results of my concept mapping design experiments were first published in Finnish (Åhlberg 1989a). At the same year I had a chance to publish two short papers also in English (Åhlberg 1989b and 1989c). Already in these three papers I presented my version of Novakian concept mapping, that I have called improved concept mapping, and new theoretical underpinnings based on modern science and philosophy of science (for details and references: Åhlberg 1993). The 1993 paper was published when I was a visiting scholar at Cornell University for three months. Professor Joe Novak was my mentor there. After that I have taught concept mapping as a research method for thousands of people all around the world where I have travelled. I have developed a method for how in five minutes to learn to make excellent concept maps. In five minutes the whole classroom or auditorium can learn the main principles of concept mapping. Concept mapping is a skill. It takes plenty of practice to become an expert concept mapper.

Since 1984, I have become convinced that concept mapping can be used successfully in education and in research on and for education practically always and everywhere. Everything that can be talked and/or written can be concept mapped. The benefit of concept mapping is showing externally, explicitly, hidden and implicit conceptual and propositional structures. This promotes shared understanding, learning, thinking and acting. One of the most important events in my personal history, is publishing with Dr. Johannes Wheeldon a textbook of research methods (Wheeldon & Åhlberg 2012), in which research on concept maps and Mind Maps are analyzed and presented in detail.

2. Comparing different graphical knowledge presentation tools, especially concept mapping and mind mapping

Nowadays different types of graphic representation tools have become very common. Many terms are used, e.g. concept maps, mind maps, spider maps, spider diagrams, clustering etc. Often the same term is used for many different methods or techniques. It confuses, if you are not an expert in this field. In this paper theoretical background for concept maps, mind maps and other similar graphic representation tools will be presented.

From viewpoint of human evolution, it is clear that first humans learnt how to speak, then how to write and finally how to create graphical representations based on writing. First those presentations were made by pens. Nowadays there are also digital options. On the 21st century these graphical representations may include sound, speaking, video clips etc. At least CmapTools software makes it possible for every computer user, free of charge.

As Paivio (1986) clearly shows in human mind there are at least (1) concepts and propositions and (2) images, sense memories of sight, hearing, touch, smell and taste. Only concepts and propositions are easy to share. Private sense memories are in our minds, but extremely difficult or even impossible is to share them.

Two of most used graphical knowledge presentation methods are probably Novakian concept mapping and Buzanian mind mapping. I have met many people who are not able to make a difference between Novakian concept maps and Buzan type mind maps. That is why I have used the same concepts and created from them both a concept map and a mind map (e.g. Åhlberg & Ahoranta 2002 and Åhlberg 2008). The following two figures are from Åhlberg (2008). The concepts are clearly circled in the concept maps in the Figure 2. Creating a Mind Map using these concepts, is a very revealing experiment. It makes clear that concept mapping is an accurate method to present thinking and mind mapping is just a mapping of associations using a tree analogy, not revealing how the concepts are linked accurately to form propositions/statements/claims of the world.

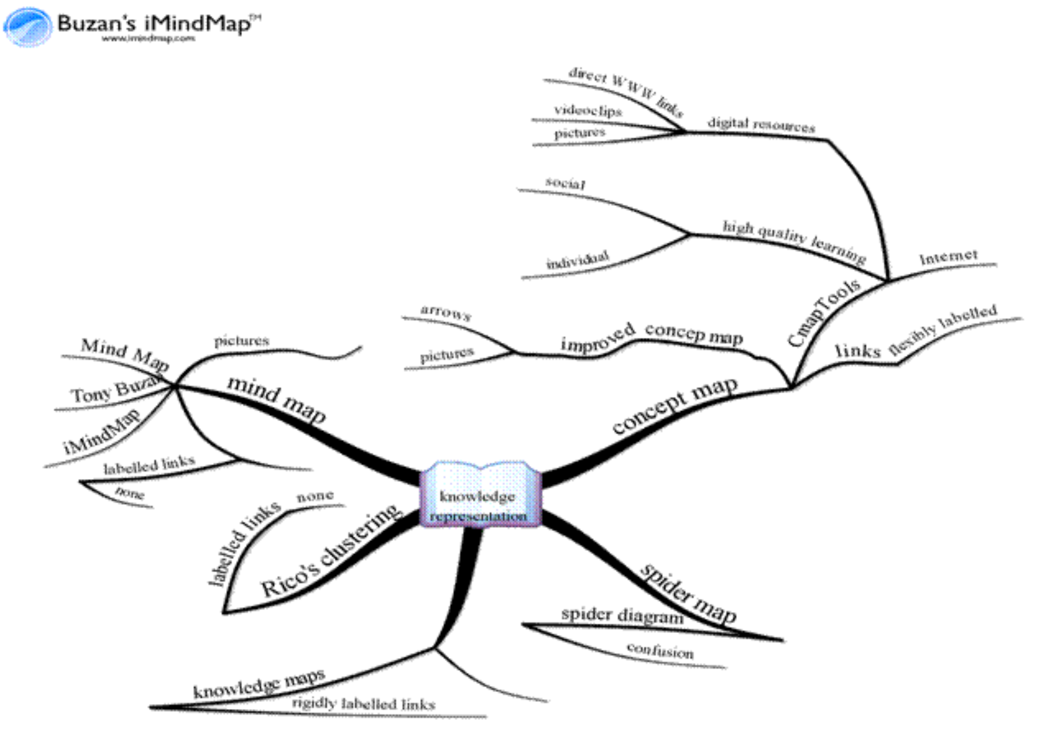

Figure 1. A mind map created using the same concepts as in the following concept map (Fig. 2). It is impossible to transform this to ordinary meaningful prose text.

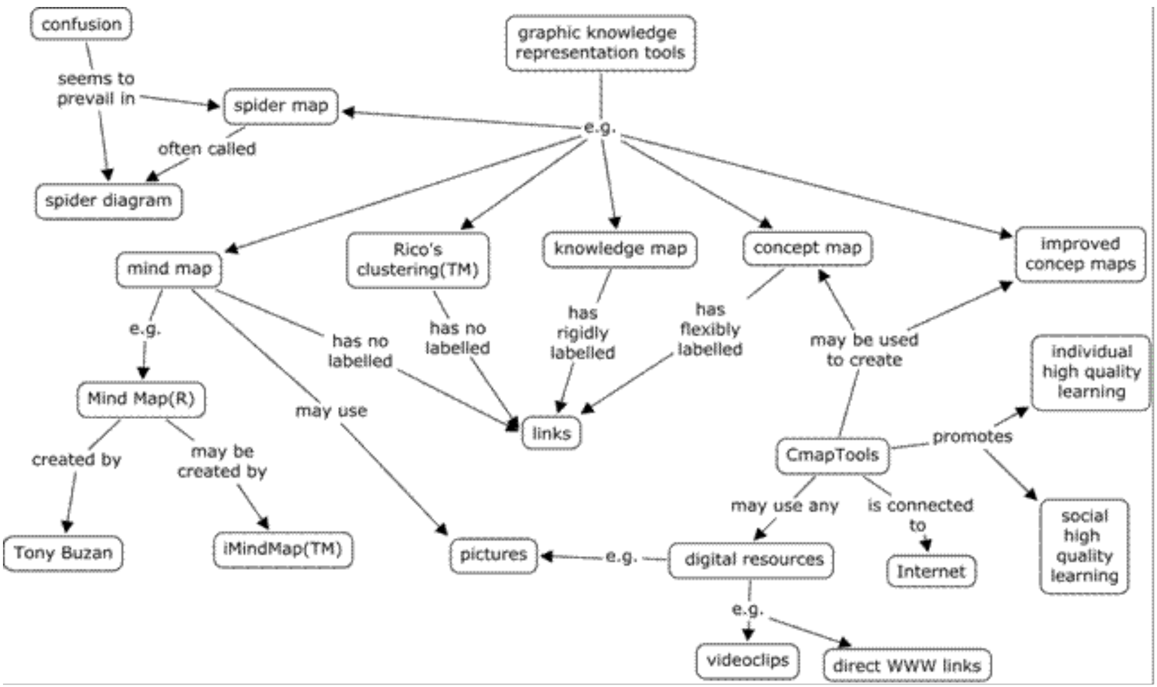

Figure 2. Concept map created from the same concepts as used in the mind map of the Figure1.

I have compared different methods that people nowadays use to present knowledge externally (Åhlberg 1990, 1993 and 2008). In the following comparison table (TABLE 1.) have not included those kinds on methods that use propositions as basic elements and call them “concept maps” (e.g. Palmer 1995). There are no cumulative research for the benefits of circling propositions, and calling them “concept maps”. It creates only intellectual confusion and chaos. The results are presented in the following table (TABLE 1). I found two main dimensions that differentiate graphical knowledge presentation methods: The first dimension is conceptual explicitness: from mere concepts to flexibly named links and clear propositions in concept maps The second dimension in the classification system I am suggesting is whether there are pictures or not.

	NO PICTURES	**PICTURES**
CONCEPTS AND FLEXIBLY NAMED LINKS	Type 7: Novak (1981): concept map; Novak & Gowin (1984) concept map; Ahlberg (1989a, b): concept map; Fisher (1990): semantic networking	Type 8: Åhlberg (1988): concept maps; Fuata'i (1985, 90): concept map; Heinze-Fry (1987, 263) concept map
CONCEPTS AND RIGIDLY NAMED LINKS	Type 5: Fridja (1972, 4);Dansereau & al. (1979): network; Anderson 1985: network of concepts; Wiegman & al. (1992): knowledge mapping	Type 6: Greeno (1976): network of propositions
CONCEPTS AND UNNAMED LINKS	Type 3: Collins & Quillian (1969): illustration of hypothetical memory structure; Rico (1983- 2008) clustering; Heimlich & Pittelman (1986): semantic mapping; Grice & Skinner (1993, 110): visual brainstorming; Tillema (1993) network of concepts	Type 4: Glass, Holoyak & Santa (1979); Glass & Holoyak (1986, 158) *conceptual network*
ONLY CONCEPTS AND NO PROPER LINKS	Type1: Hanf (1971): mapping; Schaefer (1979, 91); Trochim (1985 – 1989) Wandwersee (1987) concept circles	Type 2: Buzan (1974 – 2006): *brain pattern* (1974), mind maps (later on) ; Russell (1979): *mind maps*

Table 1. Comparison of different types of graphic knowledge representation tools in which conceptual level is prominent. Based on Åhlberg (1993) and (2008) in which these are described in more detail.

3. Varieties of concept mapping, in particular traditional Novakian concept mapping compared to Åhlberg's improved concept mapping

I have compared different varieties of concept mapping (Åhlberg 2004) comparing in particular original Novakian concept mapping and versions that I have developed from it.

Most articles published that describe the use of concept mapping refer to Novak and Gowin (1984) In their book, the most common version of concept mapping is as follows: There are circled concepts with links connecting them, and the links are labeled or phrased in order to create meaningful statements. The ideal concept map has hierarchy. Links flowing from the top concept to other concepts are mostly lines. It's only when links are horizontal or are read upwards that arrows are used. This formatting style for concept maps is presented as his pending trademark in Novak (1998). It is remarkable that Wandersee (2000, p. 136) criticized one of the figures in Novak's (1998) book because the “concept map on rhizobotany … fails to follow the Novakian Standard Concept Mapping Format.”

Novak (1998) has applied for a trademark of his style of concept mapping: Concept Maps ™. However, many of Novak's own students and research partners do not follow all the rules. Neither does Novak himself (e.g., Novak, 2002). According to Novak and Gowin (1984, p. 182): “Lines connecting concepts were not labeled in our earlier work.” They referred to manuscripts and publications from the 1970s. Now a research question arises: When did the first labeled links appear in concept maps? This is an important question because everything in the world is somehow connected. It does not tell very much about somebody's thinking and learning if s/he only lists words, arranges them spatially, circles them, and links them by lines. But if links are labeled, then meaningful statements about the world are created and everybody knows what that person thinks or has learned about the world, and considers important enough to express. As far as we know, Novak (1981, p. 14) was the first publication in which the links were named and meaningful propositions were created out of concepts. This is the form of Novakian concept maps that has been spread globally.

"The Novakian Standard Concept Mapping Format" (expression from Wandersee 2000, p. 136) is used on the IHMC CmapTools (Cañas et al. 2004) Web site (IHMC 2004) Web site as well as the Web site of the First International Conference of Concept Mapping (CMC2004 2004). The links are mainly lines, and arrowheads are used only according to "the Novakian Standard Concept Mapping Format."

Safayeni, Derbentseva, and Cañas (2005) presented an idea about cyclic concept maps, which are hierarchical. This is a special case of an improved method of concept mapping in which the concept map can be constructed in any way that is the best justified option. This is because according to modern science, the world is a system and everything in the world is connected. That is why a concept map can be interpreted as a tentative theory of a part of the world. Hierarchies or circles may sometimes be natural and economical, but sometimes a network can be an even better option.

Elements of an improved method of concept mapping Ahlberg (2001) presented a list of commonalities differences between improved concept maps and traditional Novakian concept maps. Applying (Åhberg 2004) an improved list from the viewpoint of research methodology is as follows:

1) All concepts are interpreted as main elements of thinking and learning, and they are always inside frames. In Novak and Gowin (1984, pp.14, 22, 52) and Novak (1998, p. 100) concepts are sometimes inside frames and sometimes not.
2) Novak and Gowin (1984) and Novak (1998) prefer very short verbal labels for concepts. However, concepts sometimes require many words in order to be correctly labeled. There is no accurate limit on how many words may be included in a concept label. In an improved concept map as many words as are needed are used to name the concept accurately.
3) In order to have a meaningful proposition, all links between concepts have arrowheads to show in which direction the connection from one concept to another is to be read. However, if they were following their own rule, in Novak and Gowin (1984) and Novak (1998), only the concepts that are either horizontal or are to be read upwards should have an arrowhead. Thus, this complex rule is not always remembered even by those who use the traditional Novakian concept mapping (e.g., Novak & Gowin, 1984, p. 176; Novak, 1998, pp. 52, 84,121). Novak (2002, p. 553) presented a concept map "showing the nature and structure of concept maps." In this concept map all links have arrowheads, not only horizontal or upward links. Already Novak and Gowin (1984, p. 102) presented a concept map in which all links had arrowheads, and they called it "a good concept map." We agree, it is a good one.
4) The expressions connected to links may be short or long, but they must accurately express the thinking of the person whose thoughts are concept mapped. Novak and Gowin (1984) and Novak (1998) favor very short verb expressions. The essential point is that the link includes a verb expression and the resulting proposition is meaningful and more or less true, plausible, probable, et cetera.
5) You may connect pictures, videos, sounds, et cetera to concept maps (e.g., Ahlberg, 1993; IHMC, 2004). Novak and Gowin (1984) and Novak (1998) never do this.
6) Novak and Gowin (1984) and Novak (1998, 2001) stress the importance of Ausubel's learning theory. Ahlberg (1993 and 2002) came to conclusion that whatever learning theory is used, you may still use concept mapping because it is as general a method as is speaking or writing. Everything that is spoken or written may be transformed to concept maps, and all good concept maps may be easily transformed back to ordinary speaking or writing.
7) Novak and Gowin (1984) and Novak (1998) argued that concept maps should always be hierarchical. This is often sound and economical, but not always. For instance, Novak and Gowin (1984, pp. 16-18) demonstrated how the same concepts can be arranged hierarchically in three different ways. The same effect could be better achieved if the most important concept is sometimes in the center of the concept map but sometimes somewhere else, as long as that choice can be justified to be the best option. Then, we

may imagine the center of the concept map as the top of a pyramid seen from above. It is good to remember that the world is a system, and therefore, sometimes the best presentation for the world and its part systems are conceptual systems, which are not always hierarchical. Novak and Gowin (1984, p. 16 - 18) presented three concept maps illustrating the same concepts. They look hierarchical, but there is no way to show that the topmost concept is either the broadest or most inclusive one, as it should be in a real conceptual pyramid according to Novak and Gowin (1984, p. 33) and Novak (1998, pp. 3, 227). There are also ontological and epistemological reasons why good concept maps may not be always hierarchical. The world is a system, and therefore, the best conceptual representation of it is a conceptual system, a concept map, which may not always be hierarchical. A similar idea has come into the minds of Safayeni, Derbentseva, and Cañas (2003) who presented an argument for cyclic concept maps, which are not hierarchical.

8) In a good concept map each concept is mentioned only once, similar to a good geographical map in which each place is named only once. Novak (1998, e.g., pp. 14, 66-67, 121) does not always follow that simple and elegant rule. Nicoll, Francisco, and Nakhleh (2001, p. 864) showed that there may sometimes be practical reasons not to follow this rule. Sometimes there is a concept that has so many links to other concepts that the only imaginable option is to have this concept twice in the concept map, but this kind of exception needs a good explicit explanation.
9) If each concept is only mentioned once on the concept map, then it is easy to count how many links each concept has to and from other concepts. The number of links with other concepts is a good estimate of centrality of that concept in the thinking of the person whose thoughts are concept mapped. Let's explore a "Gedanken" experiment: If you would remove from the concept map, the concept with the most links to other concepts, this would result in the greatest possible damage to the concept map. That is to say, that concept is, in this sense, the most central concept in the concept map. This idea has also been tested and presented by Ahlberg and Ahoranta (2002), Ahlberg, Turja, and Robinson (2003), and Ahlberg, Aanismaa, and Dillon (2005).
10) Sometimes it is useful to be able to read a concept map only in the order that you intend it to be read. It may not always be from top to bottom. For example, it may be a transformed part of a textbook, and the order in which propositions are read is important. Then you may add to each link a number showing the order according to which the propositions should be read.

4. Concept mapping as a tool to analyze texts

I have developed concept mapping as a research method to analyze texts, such as textbooks and/or interview transcripts (e. g. Åhlberg 1989, 1991, 1993 and 2012). The main point is to number propositions in the order, they are in the original text. The numbers can be added either near to the arrowheads of links or linking phrases as in the example below.

The following excerpt is from the interview the Director General of the National Board of Education is from (Siirilä & Ahlberg 2012). It is an answer to the question focused on how the interviewee understands concept of Education for Sustainable Development (ESD):

"(1) *In ESD thinking, thinking skills, sense of community etc. will be promoted.* (2) *Pupils will learn to create, learning by doing, integrating ideas broadly.* (3) *ESD is focused on creation of a worldview, integration of personality, and creating sufficient capabilities, in order that pupils will become able to flourish in this world.*(4) *ESD is not rote learning, and is not learning those kinds of contents that do not have any practical value, learning those kinds of contents that do not have any practical value.* (5) *This is the way, how sustainable development becomes a value, that influences the whole societal change via behavior of individuals.*" Numbering statements from (1) – (5) is done in order to show, how a concept map can be created that follows the original text as closely as possible.
This text can be transformed into a concept map in the following way (Fig. 3).

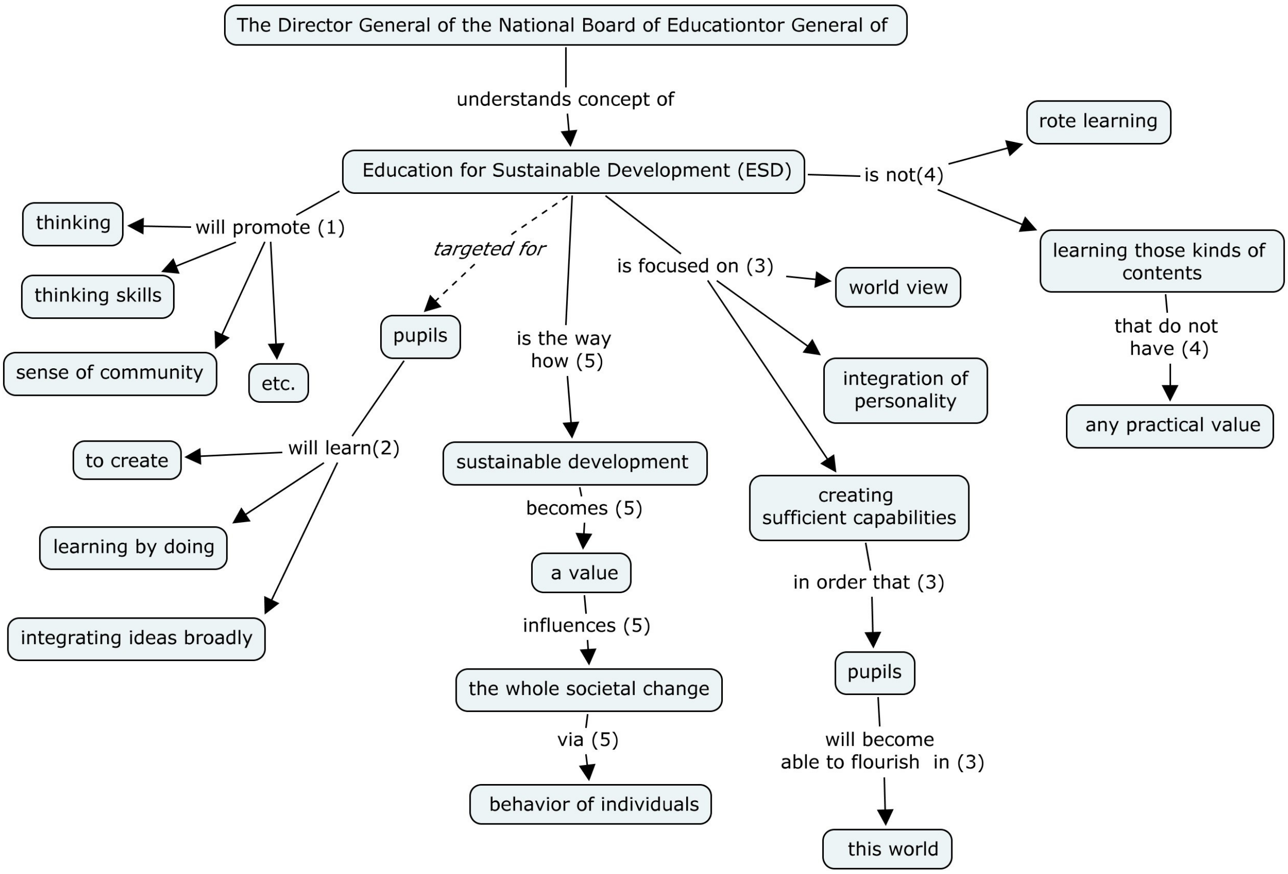

Figure 3. The text has transformed into a concept map, in the way that it can be transformed back into the original text. The most central concept in this concept map is 'Education for Sustanable Development (ESD)'. It has at eleven links with other concepts. More than any other concepts have links with other concepts.

5. Conclusion

In Åhlberg's and his research group's research, concept mapping has been tested in all main phases of research, teaching and learning. Theories, theoretical frameworks and research designs have been explicated with improved concept mapping. Student learning has been monitored and promoted by improved concept mapping. Texts have been analyzed with improved concept mapping. Concept map has been used as a quality tool in Continual Quality Improvement of organizations. Based on research and development results and experiences new applications and development for concept maps have been created. The following are some of the main documents of this development over two decades: Åhlberg (1998, 1989a, 1989b, 1990, 1991, 1992, 1993; 1997; 2008), Åhlberg & Ahoranta (2004), Åhlberg, Turja, & Robinson (2003), Åhlberg, Äänismaa, & Dillon (2005), Wheeldon & Åhlberg (2012).

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Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

ISSN 1989 - 9572

Cmapanalysis: an extensible concept map analysis tool

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 18 de febrero de 2013

Fecha de revisión: 27 de febrero de 2013

Fecha de aceptación: 07 de marzo de 2013

Cañas, J.A.; Bunch, L.; Novak, J.D. y Reiska, P. (2013). Cmapanalysis: an extensible concept map analysis tool. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 36 – 46.

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Abstract
Concept maps are used extensively as an assessment tool, and the literature is abundant with studies on the use of concept maps for assessment and on the assessment of concept maps. The assessment of concept maps can be an arduous process, in particular when assessing a large number of maps. CmapAnalysis is a software tool that facilitates performing various analysis measures on a collection of concept maps. A set of measures that consider size, quality and structure properties of the maps are included. The program is designed to be extensible, allowing users to add their own measures. The program is not intended to replace the individual evaluation of concept maps by teachers and instructors, as it does not capable of “understanding” the content of the maps. It is aimed at researchers who are looking for more general trends and measures across a large number of maps, and who can extend it with their own measures. The output of CmapAnalysis is an Excel spreadsheet that can be further analyzed.

Resumen
Los mapas conceptuales han sido utilizados ampliamente como una herramienta para la evaluación, existiendo una abundante literatura con estudios sobre este uso, pero también sobre la evaluación de los mapas conceptuales. La evaluación de mapas conceptuales puede ser un arduo proceso, sobre todo cuando evaluamos un elevado número de mapas. CmapAnalisys es una aplicación informática que facilita la realización de diversas dimensiones de análisis en un conjunto de mapas conceptuales. Incluye un conjunto de dimensiones, considerando el tamaño, la calidad y distintas propiedades estructurales de los mapas. El programa se ha diseñado para ser ampliable, permitiendo a los usuarios añadir sus propias dimensiones. Es programa no está destinado a sustituir la evaluación individualizada de mapas por los profesores, pues no es capaz de “entender” el contenido de los mapas. Está dirigido a investigadores que buscan tendencias y dimensiones generales en un gran número de mapas, que pueden ampliar con sus propias dimensiones. CmapAnalysis genera los datos en una hoja de cálculo Excel que puede analizarse posteriormente.

Keywords
Assessment concept mapping, learning assessment tools, CmapAnalisys software.

Palabras clave
Evaluación de mapas conceptuales, herramientas de evaluación del aprendizaje, software CmapAnalisys.

1. Introduction

Concept maps have been used for many years as a tool for people of all ages and all domains of knowledge to express their understanding about a topic. More specifically, in education concept maps have been shown to be useful as a tool for teachers to assess students' understanding, whether at the beginning, during, or end of the study of a topic (Novak & Cañas, 2004). However, concept maps themselves have to be "assessed" – that is, the concept maps constructed by students need to be assessed by the instructor to get an appreciation of the student's understanding (and possibly assign a grade). The literature is abundant with studies on the use of concept maps for assessment and on the assessment of concept maps (e.g., Besterfield-Sacre, Gerchak, Lyons, Shuman, & Wolfe, 2004; Daley, 1996; Fischler et al., 2002; McGaghie, McCrimmon, Thompson, Ravitch, & Mitchell, 2000; Reiska, 2005; Rice, Ryan, & Samson, 1998; Schmidt, 2006; Strautmane, 2012; Turns, Atman, & Adams, 2000; Walker & King, 2003; West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000), beginning with that proposed by Novak & Gowin (1984).

Although Ruiz-Primo and Shavelson (1996) have reported problems in using concept mapping as an assessment tool, there are many studies showing that concept mapping is an appropriate tool for testing students achievement (Fischler et al., 2002; McGaghie et al., 2000; Reiska, 2005; West et al., 2000). Some of the studies also show that there is a high correlation between the concept mapping and other knowledge tests (Mikelskis, 1999) but some studies did not prove the correlation between concept map scores and e.g. multiple choice exam performance (McGaghie et al., 2000).

One of the difficulties of applying assessment rubrics or algorithms is the time it takes to apply them to a large number of concept maps. If the class is large, or if the assessment is being done for research purposes on a large number of Cmaps, the time to manually analyze the maps, or transcribe their content for analysis, can be considerable.

Automatic assessment of concept maps has been included as part of several concept mapping tools, e.g. C-Tools (Harrison, Wallace, Ebert-May, & Luckie, 2004), COMPASS (Gouli, Gogoulou, Papanikolaou, & Grigoriadou, 2003) and CRESST (Herl, O'Neil, Chung, Dennis, & Lee, 1997). These systems are concept map editors with an assessment tool incorporated. They don't lend themselves to evaluating a large collection of concept maps for research purposes, or applying different types of assessment criteria to a set of maps.

CmapAnalysis is a software tool that facilitates the analysis of sets of concept maps utilizing various algorithms, rubrics and techniques. The tool provides a set of assessment options by default, and can be extended by the user to apply other assessment techniques that he/she defines. We don't propose or recommend that CmapAnalysis be used as an "automated" concept map assessment tool, and that instructors take its results as grades to be assigned to the maps. On the contrary, we propose that by automatically performing the routine operations of the analysis, instructors, and researchers, can dedicate more time to evaluate the results of the analysis and what they mean and represent. CmapAnalysis does not include a concept map editor; it presumes that the concept maps have already been constructed and stored in the CXL format (Cañas, Hill, et al., 2006).

2. Assessment Algorithms & Techniques

The content of a concept map can be divided into three general categories (Reiska, 2005):

1. Size
2. Quality
3. Structure

Size describes how many concepts, linking words and propositions are in a concept map. Typical measures in this category are Number of Concepts (or Concept Count), Number of Linking Words and Number of Propositions. Measures from this category also describe students' knowledge. Students with more knowledge about certain topic and focus question usually include more concepts and linking words in their concept maps. However, measures from this category alone can also mislead, because large number of proposition does not always mean that the student has good knowledge – the propositions can also be incorrect. All measures in category Size are quantitative and can be calculated automatically.

Quality describes what kind of concepts, linking words and propositions are in a concept map. Typical measures in this category are *Number of Correct Propositions* (or *Correct Proposition*

Count), Average Rating of Propositions, and *Relevance of Concepts*. The evaluation of propositions is mostly carried out with expert rating. That means that propositions will be rated by experts or compared with the propositions from expert concept map or an expert reference matrix. *Quality* measures can be qualitative and quantitative. To calculate the measures in this category additional information is needed. This information is commonly provided via expert ratings in the form of concept maps or ratings matrices.

Structure describes how the concepts are connected to each other. Typical measures in this category are *Centrality of Concepts, Number of Cross Links, Density,* and *Inter-Cluster Proposition Count.* The measures from this category provide information on how well the concepts are connected, such as whether there are any central concepts, are there any separate sub maps, is the map a "chain", a "tree" or a "star" (one central concept). The structural measures provide useful information, however the use of these measures without measures from other categories gives us limited information about the knowledge of students. All measures in category *Structure* are quantitative and can be calculated automatically.

While the measures from first two categories (*Size* and *Quality*) provide information that can be gathered with other testing methods (e.g. essay or multiple choice test), the *Structure* measures are unique for concept maps. Combining the measures for *Structure* with the measures for *Quality* offers unique information. Analyzing concept maps from this point of view has not been well developed yet. One of our aims with *CmapAnalysis* is to develop a flexible tool that allows the researcher (or teacher) to create their own measures, in particular measures that combine *Quality* and *Structure.* Soika, Reiska & Mikser (2010) used *CmapAnalysis* to find out how the knowledge and the structure of mental models are influenced by the animation and the paper instruction by upper secondary level chemistry students.

3. CmapAnalysis

CmapAnalysis is a cross-platform application that enables users to define and execute analyses over *sets of concept maps*. The result of the analysis is a Microsoft Excel spreadsheet containing one row for each concept map in the analyzed set with columns for each of the desired measures. *Measures* range from simple counts of concepts and propositions to more complex calculations such as identifying the top three most central concepts in each map.

CmapAnalysis was designed with several objectives in mind:

a. CmapAnalysis should support *Size, Quality and Structure* measures in the analysis of concept maps, as described above.
b. CmapAnalysis should take as input Cmaps in the open CXL file format in addition to the .cmap format, allowing the analysis of concept maps developed by concept mapping programs that utilize CXL.
c. CmapAnalysis can handle large sets of concept maps, calculating the measures in (a) to all the maps.
d. In addition to the analysis measures incorporated into the program described below, CmapAnalysis should be extensible, meaning that users (with technical inclination) should be able to add other measures to the program.
e. The results provided by the program should be in a format that lends to further analysis (e.g. Excel spreadsheet).

4. Using CmapAnalysis

Selecting the set of maps to analyze involves browsing for a folder in the computer's file system. The tool recursively searches the selected folder for Cmaps in either the CmapTools (Cañas et al., 2004) binary format (.cmap) or the concept map open XML format (.cxl). The CXL format is preferred since the analysis tool leverages standard XML technologies to perform its task (see Section X).

Configuring the content of the analysis involves selecting the set of desired measures from a menu where each measurement defines a column in the resulting table, as shown in Figure 1. The tool has several groups of predefined measures including basic Cmap information, topological characteristics and topological taxonomy score (Cañas, Novak, et al., 2006), and centrality measures concerning the level of connectedness among concepts in the map. These groups of measures can be applied with very little if any configuration. The groups of measures for concept clusters and for scoring propositions require the user to provide additional input such as a list of concepts or propositions. The results of running CmapAnalysis on a set of expert Cmaps as specified in Figure 1 are shown in Figure 2.

4.1. Measures included in CmapAnalysis

Basic Cmap Info Measures: include all of the metadata properties of the concept map, many of which are editable through the CmapTools map Properties window. The measures include:

- *Author Email*: the email address of the creator of the concept map that can be blank.
- *Author Name*: the name of the creator of the concept map that can be blank.
- *Author Organization*: the name of the author's organization that can be blank.
- *CmapTools Version*: the version of the CmapTools client last used to save the map.
- *Date Created*: the date the map was created in the format YYYY-MM-DDTHH:MM:SS-GMT, for example 2006-01-05T16:02:46-06:00.
- *Date Last Modified*: the date of the last save made to the concept map in the same format as Date Created.
- *Language*: a two character ISO-639 code (http://www.loc.gov/standards/iso639-2) representing the language of the map content, for example 'en' for English and 'es' for Spanish.
- *Size*: the size of the concept map in bytes as of the last time the map was saved.
- *Title*: The name of the concept map that is the same as the file name without the .cmap or .cxl extension.

Topological Taxonomy Measures include the topological taxonomy score (Cañas, Novak, et al., 2006) between 0 and 5 where higher scores typically indicate higher quality concept maps. This group of measures also includes the following individual aspects of the concept map that are considered in calculating the taxonomy score:

- *Avg Words* per Concept: the total count of words, as separated by whitespace, in all concepts divided by the number of concept in the map. Concise concepts are important to the taxonomy score.
- *Branch Point Count*: the total number of concepts and linking phrases that have at least one incoming connection and more than one outgoing connection.
- *Concept Count*: the number of concept in the map.
- *Linking Phrase Count*: the number of linking phrases in the map.
- *Orphan Count*: the number of concepts in the map that have no connections.
- *Proposition Count*: the number of propositions (i.e. concept-linking phrase-concept) in the map.
- *Root Child Count*: the number of concepts in the map that have an incoming connection from a root concept. A root concept is defined as one that has outgoing connections but no incoming connections.
- *Sub Map Count*: the number of root concepts found in the map.
- *Taxonomy Score*: the topological taxonomy score computed for the map.

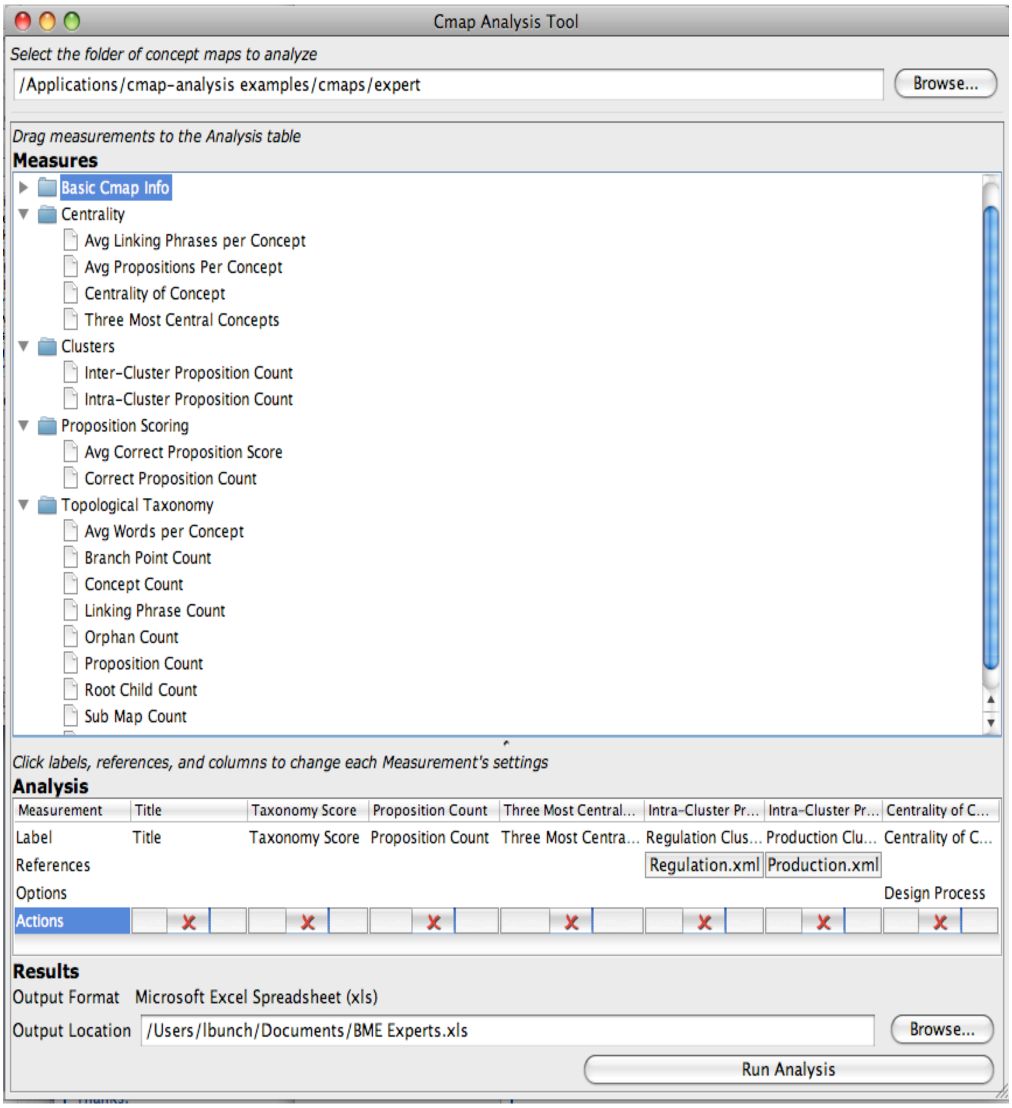


Figure 1. A Screenshot of the CmapAnalysis tool's dialogue box to define the analysis measurements.

Centrality Measures concern the connectedness of the concepts in the map, and include:

- *Avg Linking Phrases per Concept: the ratio of linking phrases to concepts.*
- *Avg Propositions per Concept: the ratio of propositions to concepts.*
- *Centrality of Concept: the number of connections into and out of a given concept. The user provides a concept label in the Option field for this measure. The tool searches for the first occurrence of a concept with a matching label, ignoring whitespace and the case of the letters in the concept, and computes the Centrality of this concept.*
- *Three Most Central Concepts: a comma-separated list of the text labels from the three concepts with the highest centrality measure in the map.*

Proposition Scoring Measures involve comparing the propositions in the map to a list of propositions provided by the user as an XML file that is selected using the References field of the measurement definition. We are aware that editing XML files is not a user-friendly interface and hope to correct this in future versions of CmapAnalysis. The following example illustrates the XML format for the list of propositions:

```
<proposition-score-list xmlns:cm="http://cmap.ihmc.us/xml/cmap/">
<cm:proposition score=".75">
    <cm:concept label="BME Design Process"/>
    <cm:linking-phrase label="involves"/>
    <cm:concept label="brainstorming"/>
```

```
    </cm:proposition>
    <cm:proposition score=".5">
      <cm:concept label="FDA approval"/>
      <cm:linking-phrase label="leads to"/>
      <cm:concept label="product on the market"/>
    </cm:proposition>
  </proposition-score-list>
```

- *Correct Proposition Count*: the number of propositions in the concept map that match one of the propositions in a given list. Whitespace and letter case are ignored for the comparison. Proposition scores are not considered by this measurement.
- *Avg Correct Proposition Score*: sums the score value for all propositions in the map that match one in the given scored proposition list, then divides this score sum by the number of propositions in the map that were matched.

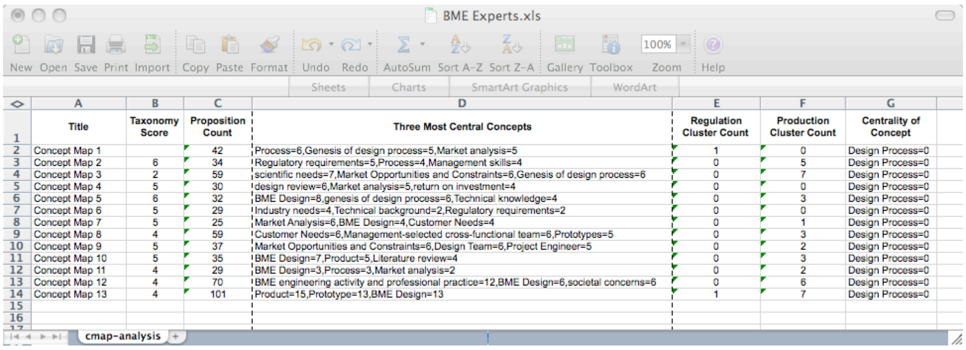
Cluster Measures provide a way to analyze relationships among groups of concepts with a map, for example the number of propositions in the map that relate key physics concepts with key chemistry concepts. These measures are configured with a single XML file that defines a list of one or more clusters where each cluster is a named list of concepts. We expect that a future version of CmapAnalysis will provide a more user-friendly interface for defining the clusters.

```
<cluster-list xmlns:cm="http://cmap.ihmc.us/xml/cmap/">
  <cluster id="Design">
    <cm:concept label="Design Process"/>
            <cm:concept label="design"/>
            <cm:concept label="innovation"/>
      </cluster>
  <cluster id="Production">
    <cm:concept label="Marketing"/>
            <cm:concept label="product"/>
    <cm:concept label="manufacturing"/>
  </cluster>
</cluster-list>
```

- *Intra-Cluster Proposition Count*: the number of propositions in the map that occur *within* a given cluster. Intra-cluster propositions have both concepts defined in a single given concept cluster. For this measure, the provided XML cluster definition file should include only one cluster.
- *Inter-Cluster Proposition Count*: the number of propositions in the map that occur *between* concepts in the given clusters. Inter-cluster propositions have a concept in one of the given clusters and a concept in another cluster. For this measure, the XML cluster definition file should include at least two concept clusters.

5. CmapAnalysis Implementation

The analysis tool takes advantage of the CXL format of the concept maps to apply powerful standard XML processing and query tools to implement the analysis. The analysis execution step is defined as a transformation from the collection of maps as XML documents to a single resulting XML document in the Microsoft Excel format. We use a combination of the Extensible Stylesheet Language Transformation (XSLT) and XML Query Language (XQuery) to walk through the set of concept maps and compute each of the selected measurements for that map. To illustrate the power of XLST, the code to obtain the count of concepts in a map is simply:



BME Experts.xls

	Title	Taxonomy Score	Proposition Count	Three Most Central Concepts	Regulation Cluster Count	Production Cluster Count	Centrality of Concept
2	Concept Map 1		42	Process=6,Genesis of design process=5,Market analysis=5	1	0	Design Process=0
3	Concept Map 2	6	34	Regulatory requirements=5,Process=4,Management skills=4	0	5	Design Process=0
4	Concept Map 3	2	59	scientific needs=7,Market Opportunities and Constraints=6,Genesis of design process=6	0	7	Design Process=0
5	Concept Map 4	5	30	design review=6,Market analysis=5,return on investment=4	0	0	Design Process=0
6	Concept Map 5	6	32	BME Design=8,genesis of design process=6,Technical knowledge=4	0	3	Design Process=0
7	Concept Map 6	5	29	Industry needs=4,Technical background=2,Regulatory requirements=2	0	0	Design Process=0
8	Concept Map 7	5	25	Market Analysis=6,BME Design=4,Customer Needs=4	0	1	Design Process=0
9	Concept Map 8	4	59	Customer Needs=6,Management-selected cross-functional team=6,Prototypes=5	0	3	Design Process=0
10	Concept Map 9	5	37	Market Opportunities and Constraints=6,Design Team=6,Project Engineer=5	0	2	Design Process=0
11	Concept Map 10	5	35	BME Design=7,Product=5,Literature review=4	0	3	Design Process=0
12	Concept Map 11	4	29	BME Design=3,Process=3,Market analysis=2	0	2	Design Process=0
13	Concept Map 12	4	70	BME engineering activity and professional practice=12,BME Design=6,societal concerns=6	0	6	Design Process=0
14	Concept Map 13	4	101	Product=15,Prototype=13,BME Design=13	1	7	Design Process=0

cmap-analysis

Figure 2. Excel spreadsheet with the results of running CmapAnalysis on a set of Cmaps from experts as specified in Figure 1.

```
count( $map/cm:cmap/cm:map/cm:concept-list/cm:concept )
```

where count is a built-in XLST function, $map is the collection of CXL documents, and the remaining text is just the path to the <concept> elements within the XML document structure.

XQuery similarly provides a very concise and expressive language for analyzing the content of XML documents. For example, the code to find the list of propositions involves 'joining' each linking phrase to the list of connections and concepts:

```
for $lp in $map//cm:linking-phrase
let $conn1 :=
$map/cm:cmap/cm:map/cm:connection-list/cm:connection[@to-id = $lp/@id],
$conn2 :=
$map/cm:cmap/cm:map/cm:connection-list/cm:connection[@from-id = $lp/@id],
$cpt1 :=
$map/cm:cmap/cm:map/cm:concept-list/cm:concept[@id = $conn1/@from-id],
$cpt2 :=
$map/cm:cmap/cm:map/cm:concept-list/cm:concept[@id = $conn2/@to-id]
for $i in (1 to count($cpt1)),
   $j in  (1 to count($cpt2))
    return
       <cm:proposition> {$cpt1[$i], $lp, $cpt2[$j]} </cm:proposition>
```

This XQuery function returns a list of propositions represented in XML:

```
<proposition><concept/><linking-phrase/><concept/></proposition>
```

Since the results are also in XML format, they can be used as input to other XQuery calculations. This is exactly how the 'Correct Proposition Count' measurement is implemented. It first obtains the proposition list from the map, joins this intermediate XML result with the user-provided list of correct propositions to identify matches.

Another useful feature of XQuery is the ability to call-out to a procedural language such as Java. The topological taxonomy score is computed by using such a call to a Java method with the current concept map's XML content as a parameter. This allowed us to reuse the Java implementation of the taxonomy scoring that was implemented for use within CmapTools.

The analysis tool defines a 'shell' XQuery algorithm that handles setting up the collection of CXL documents, iterating through this set of maps, invoking each measurement's XQuery code on each CXL map, and organizing the results into a table of rows and columns that Microsoft Excel can understand. Each measurement defines just the XSLT or XQuery code necessary to calculate the value for a single concept map and produces a text or numeric result. Our hope is that this level of modularity will enable others to easily create and share new measurements without needing to understand the code of the analysis tool itself, but rather just the CXL format and the standard XML technologies.

6. Extending CmapAnalysis

The analysis tool contains a directory named ‘measurements’. Each folder in this directory defines one of the groups of measurements that appear in the user interface. Within each of these measurement group folders is an XML file for each measurement. The folder names and file names are used directly by the analysis tool to populate the user interface, so creating a new group of measurements or reorganizing them involves simply creating new folders and rearranging the XML files within.

Measures are defined as XML documents with the following format.

```
<cmap-measure>
  <Label>Avg Words per Concept</Label>
  <Description></Description>
  <DataType>Number</DataType>
  <XQueryExpression>
    if (count( local:concept-words($map)/cm:concept) > 0) then
   (
            round-half-to-even(
            count( local:concept-words($map)/cm:concept/cma:word)
    div
    count( local:concept-words($map)/cm:concept)
            , 5 )
    )
            else 0.0
  </XQueryExpression>
  <XQueryFunctions>
  declare function local:concept-words($map as document-node()) as element(concept-word-list)
  {
  <concept-word-list>
  {
    for $concept in $map/cm:cmap/cm:map/cm:concept-list/cm:concept
            return
    <cm:concept>
    {
     for $i in tokenize($concept/@label, "\s+" )
     return <cma:word>{$i}</cma:word>
     }
    </cm:concept>
    }
  </concept-word-list>
  };
</XQueryFunctions>
</cmap-measure>
```

- *Label*: the default text to use as the column heading for the measure
- *Description*: the text description of the measurement.
- *DataType*: identifies whether the results are a Number or a String (i.e. text). This is used to display the column of results correctly in Excel.
- *XQueryExpression*: the XQuery code that will be executed to compute the measurement. This code is inserted into the ‘shell’ XQuery that the analysis tool defines so that the variable $map will always be defined and contain the XML for the current concept map. The code defined by the measurement computes the value for a single map and the analysis tool takes care of applying this measure to all of the selected maps.
- *XQueryFunctions*: XQuery supports defining functions that can be called from within the XQueryExpression as shown in the example above where the ‘Avg Words per Concept’ expression calls the ‘concept-words’ function to obtain a list of all the words in a given concept. These functions typically return an XML result that is then used by the calling XQuery expression.
- The XQuery code for the analysis shell (analysis-shell.xml) is also provided with the tool for developers to potentially modify or extend to suit their needs. This shell document defines several functions that can be reused and called from within the XQueryExpression or

XQueryFunctions sections of any measurement definition. These functions include obtaining an XML list of propositions and branch points as well as other useful features like finding the list of concepts connected to a given one.

The CmapAnalysis program is open source, and we therefore expect the community to extend its power and usability, as well as integrate the program into other tools. Navas & Chacón (2012) have reported using the CmapAnalysis code as part of the concept map assessment tool in a learning management system. CmapAnalysis can be accessed at: http://code.google.com/p/cmapanalysis/.

7. Future Work

CmapAnalysis is fully operational and in use by researchers and instructors. However, being in its first version the user interface needs to be refined. The dialogue box used to define the measurements for the analysis needs adjustments, and using XML to specify clusters and list of propositions needs to be replaced by a proper graphical dialogue box.

8. Conclusions

CmapAnalysis is a tool that enables the automated assessment of a large number of concept maps utilizing a set of predefined measurements. It is written in Java and thus runs in a large number of platforms, including Windows, OS X and Linux. CmapAnalysis is extensible, allowing the user to define new measurements in XML. The results of CmapAnalysis' processing a set of Cmaps are stored in an Excel spreadsheet that can be further analyzed. CmapAnalysis provides both instructors and researchers with a mechanism for in-depth analysis of concept maps.

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Journal for Educators, Teachers and Trainers
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ISSN 1989 - 9572

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 29 de diciembre de 2012

Fecha de revisión: 15 de enero de 2013

Fecha de aceptación: 04 de febrero de 2013

Cutrera, G.; Stipcich, S. y Chrobak, R. (2013). La dimensión en el análisis del discurso en una clase de fisicoquímica. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 47 – 58.

Journal for Educators, Teachers and Trainers
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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

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Resumen
La distinción entre un saber en ciencias y un saber sobre las ciencias coloca en relieve la importancia del conocimiento sobre diferentes aspectos de la actividad científica. Esta doble dimensión del contenido escolar es recuperada a través de reformas curriculares en la educación secundaria de diferentes países. En este trabajo se analiza cómo un futuro profesor en química vehiculiza nociones sobre la naturaleza de la ciencia a través de su discurso. Se propone y discute una categorización para estas nociones. El proceso de análisis se sintetiza a través del empleo de mapas conceptuales.

Abstract
The distinction between knowledge in sciences and knowledge of sciences, highlights the importance of knowledge about different aspects of the scientific activity. This double dimension of the school content is recovered through the different high school curriculum reforms in different countries. In this work we analyze how a prospective teacher of chemistry, conveys different notions on the nature of science through his discourse. We propose and discuss a categorization of those notions and the process of analysis is synthesized through the use of conceptual maps.

Palabras clave
Naturaleza del conocimiento científico, discurso docente, aprendizaje significativo, mapas conceptuales, formación docente.

keywords
Nature of the scientific knowledge, teacher discourse, meaningful learning, conceptual maps, teacher training.

1. Introducción.

El conocimiento sobre la naturaleza del conocimiento científico (en adelante, NdC) es, en gran parte, un meta-conocimiento que surge de la reflexión sobre la propia ciencia (Acevedo, 2004). Desde hace algunas décadas es un saber que ha recibido una especial atención en el contexto de las didácticas de las ciencias y que, además, se tradujo en su incorporación en numerosas reformas curriculares para la enseñanza de las ciencias.

En este contexto, este tipo de conocimiento nos obliga a distinguir entre un saber en ciencias de un saber sobre la ciencia -este último, referido al conocimiento de la NdC . Mientras que el primero de estos saberes –en ciencias- es transmitido explícitamente por los profesores, el saber sobre la NdC no ha sido incorporado con el mismo carácter a las prácticas de enseñanza en la Física y Química escolares. Son numerosas las investigaciones que ofrecen resultados en este sentido (Bell, 2005; Wallace, C. y Kang, N., 2004 ; Abd-El-Khalick, *et. al.*, 2000).

En otros trabajos se ha advertido respecto de la distancia entre lo que los profesores de ciencias declaran sobre sus concepciones sobre la NdC y la NdC que transmiten en sus prácticas y sobre la relevancia que este conocimiento posee en los aprendizajes de los estudiantes (Osborne, *et. al.*; 2003). A pesar del supuesto ampliamente generalizado en diferentes reformas curriculares, de la existencia de una estrecha relación entre la concepción sobre la NdC que se posee y los tipos de aprendizajes que se promueven en los alumnos, el vinculo NdC-práctica docente ha sido desestimado desde algunos trabajos que discuten la ausencia de investigaciones que ofrezcan una sólida base empírica al supuesto (Acevedo, J., Acevedo, P., Manassero, Mª A., Oliva, J. Mª; Vázquez, A.; 2004).

Estas breves consideraciones ponen en evidencia la complejidad de las relaciones NdC-práctica docente y advierten respecto de cierta precaución al momento de avanzar sobre ciertas hipótesis entre estos vínculos, en particular aquella referida a que las creencias del profesorado sobre la NdC influyen significativamente en su forma de enseñar ciencias y en las decisiones que toman en el aula (Lederman, 1992).

Colocar entre paréntesis estos vínculos no debe obstaculizar la relevancia que el conocimiento sobre la NdC posee en la formación docente. En efecto, el cuestionamiento a estas relaciones NdC-práctica docente establece un horizonte para las expectativas que relacionen la influencia de las representaciones docentes sobre la NdC y los aprendizajes de los estudiantes. Sin embargo, no avanzan respecto de la importancia de éste sobre la ciencia en la formación docente. En este sentido, recordamos que el saber docente implica diferentes dimensiones, entre las cuales, una de ellas es el conocimiento sobre la NdC.

Desde el reconocimiento de esta dimensión, y en términos de Shulman, constitutiva del conocimiento pedagógico del contenido (Shulman, 2005), presentamos este avance perteneciente a una investigación más amplia sobre el discurso docente de practicantes en las materias escolares de Física y de Química.

2. Discurso docente y aprendizaje significativo.

Siguiendo a Vygotsky (1984) la actividad educativa, como constitutiva del propio desarrollo y centrada en la internalización de instrumentos culturales y la interacción social, permite que los estudiantes avancen en sistemas conceptuales que no podrían internalizar por cuenta propia. Esta interacción social es propia de la zona de desarrollo próximo definida en los siguientes términos: *la zona de desarrollo proximal define aquellas funciones que aún no maduraron, pero que están en proceso de maduración, funciones que madurarán, pero que está presentemente en estado embrionario. Esas funciones podrían ser llamadas de "brotes" o "flores" del desarrollo, en lugar de frutos del desarrollo* (Vygotskt, *ob .cit.*, p. 97). En términos de una intervención pedagógica, esta postulación conlleva la idea de que el rol docente es provocar en los estudiantes avances que no ocurrirían espontáneamente. La actuación docente consiste en una interferencia en la zona de desarrollo proximal de los alumnos. Por lo tanto la interacción social que provoca el aprendizaje debe ocurrir dentro de la zona de desarrollo potencial y, al mismo tiempo, debería influir en la delimitación de la frontera de esta zona. Estos límites estarían definidos por el nivel de desarrollo del estudiante y por los procesos de enseñanza que puedan acontecer en sus interacciones sociales.

El lenguaje encuentra un lugar central tanto en la propuesta vygotskiana como en la ausubeliana (Ausubel, 1983). En Vygotsky, a partir de su papel en la internalización del conocimiento, particularmente bajo la forma de instrumentos y signos disponibles construidos en procesos socio-históricos-culturales. Desde el aprendizaje significativo, es explícita la importancia del lenguaje en el intercambio y la negociación de significados en la propuesta de Gowin (1981): *"un episodio de enseñanza-aprendizaje se caracteriza por compartir significados entre alumno y profesor, con respecto a los conocimientos vehiculizados por materiales educativos del curriculum [….] En el caso de la enseñanza de conceptos, cabe al profesor proponerle al alumno situaciones que den sentido a los conceptos y presentar los significados aceptados en el contexto de la materia de enseñanza"* (Moreira, 2010, p. 15). La negociación de significados no sólo es entre alumno y profesor, también entre alumnos. El producto de la relación entre profesor, materiales educativos y alumno está constituido por los significados compartidos: "*La enseñanza se consuma cuando el significado del material que el alumno capta es el significado que el profesor pretende que ese material tenga para el alumno"* (citado en Moreira, 2012). En este contexto de intercambios discursivos, el profesor debe emplear los materiales educativos del currículo y actuar intencionalmente para modificar el significado de la experiencia del estudiante. En ausencia de la interacción triádica mencionada, no sería posible un aprendizaje significativo para el cual, además, Gowin, delimita las responsabilidades de los distintos actores en el proceso de enseñar y en el proceso de aprender.
En este trabajo, centramos la atención en los intercambios discursivos alumnos-profesor en el aula de ciencias. En este artículo presentamos avances de algunos de los resultados parciales en esta línea de investigación, deteniéndonos en aquellos relacionados con la transmisión de saberes vinculados a la NdC.

3. Los mapas conceptuales.

Los mapas conceptuales fueron desarrollados durante el transcurso de las investigaciones educativas realizadas por el Dr. J.D. Novak en la Cornell University (USA), donde se buscaba entender los cambios producidos en las estructuras de conocimiento de los estudiantes durante el aprendizaje de las ciencias. El programa de investigación se basaba en la teoría del aprendizaje significativo de D. Ausubel. La idea fundamental de esa teoría es que el aprendizaje tiene lugar mediante la asimilación de nuevos conceptos y proposiciones por las estructuras conceptuales y proposicionales ya existentes en la mente del que aprende. Muchas veces nos preguntamos sobre el origen de los primeros conceptos. Ellos son adquiridos por los niños desde el nacimiento hasta los tres años, mediante el reconocimiento de regularidades en el mundo que los rodea, comenzando a identificar también las etiquetas conceptuales o símbolos que representan a esas regularidades. Esta fenomenal habilidad es parte de la herencia evolutiva de todos los seres humanos normales. Luego de los tres años, la adquisición de nuevos conceptos y proposiciones están fuertemente mediatizados por el lenguaje, teniendo lugar, principalmente, a través del proceso de aprendizaje por recepción, en el cual los nuevos significados se obtienen formulando preguntas y clarificando las relaciones entre los conceptos y proposiciones existentes y los conceptos y proposiciones nuevos. Este proceso es fuertemente favorecido cuando se puede disponer de experiencias y soportes concretos. De allí la gran importancia de las actividades "hands on" o experiencias de laboratorio en el aprendizaje de ciencias, especialmente para los estudiantes jóvenes, aunque esto también es cierto para los adultos.

Los mapas conceptuales son herramientas útiles que permiten organizar y representar conocimientos. Ellos incluyen conceptos, generalmente encerrados en un rectángulo o círculo, y relaciones entre conceptos o proposiciones, indicadas por una línea de conexión entre dos conceptos. Las palabras sobre la línea especifican las relaciones entre los dos conceptos. Las proposiciones son oraciones que contienen dos o más conceptos conectados por palabras de enlace que le permiten formar un significado. Algunas veces las proposiciones se denominan "unidades semánticas" o "unidad de significado".

Los estudiantes pueden aprender conceptos poco familiares memorizándolos, repitiendo una definición hasta ser capaz de poner las palabras correctas en orden apropiado. Se puede elegir, en cambio, integrar la nueva información con lo que ya se sabe, dando entonces el paso más importante para el logro del aprendizaje significativo.

Elaborar mapas conceptuales es un método que facilita un aprendizaje repleto de significado. Requiere que se realicen decisiones esenciales acerca de: (1) la importancia de las ideas, (2) cómo estas ideas se relacionan unas con otras y (3) cómo estas ideas se relacionan con los conocimientos previos.

Los mapas conceptuales permiten establecer relaciones entre los conceptos en forma explícita y jerárquica, por medio de proposiciones, como ser por ejemplo:

Figura 1: El mapa conceptual más simple que se puede concebir

La figura 1 muestra el mapa conceptual más simple que pueda concebirse: dos conceptos relacionados por un nexo o conector, para formar una proposición lógica. Aun en su simpleza, este mapa refleja principios de la Teoría de la Asimilación, ya que hay un orden jerárquico establecido para cada uno de los conceptos en función de su inclusividad, partiendo del más general al más específico (principio de la **Inclusión** o Subsumsión).

Es evidente que todo mapa puede ser ampliado a medida que se va agregando más significado al concepto en cuestión, como lo muestra la siguiente figura:

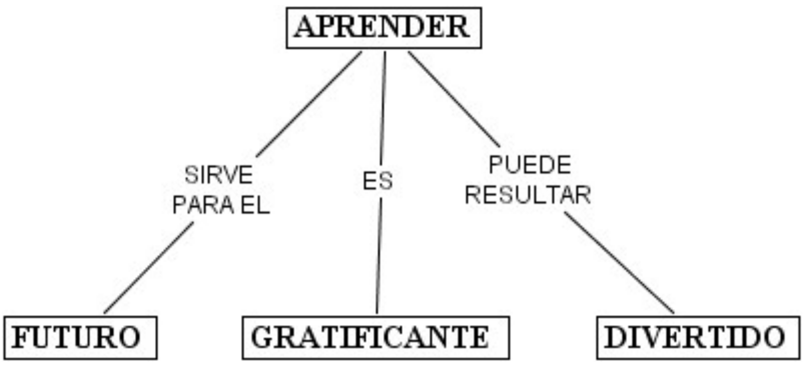


Figura 2: Agregar conceptos aumenta el significado.

Cuantas más relaciones puedan establecerse, más significados adquirirá el concepto, permitiendo, a su vez, una mayor diferenciación del concepto inclusor o subsumsor con respecto a otros conceptos similares (principio de la Diferenciación Progresiva).
Así, frente a un mapa conceptual, guiados por los principios básicos del aprendizaje, docentes y alumnos pueden "negociar" significados y compartirlos en el marco de actividades creativas. Pueden compartirse significados, pero no aprendizajes, ya que éstos son competencia exclusiva del que aprende.

4. Metodología

La unidad temática, a la que corresponde la clase analizada, es denominada “gases” y fue organizada en cuatro clases. La dos primeras clases de la unidad fueron destinadas a la presentación y al trabajo de los contenidos en los niveles macroscópico, simbólico y submicroscópico (Johnstone, 1982). Durante la tercera clase los alumnos resolvieron una guía de actividades y durante la cuarta y última clase los alumnos resolvieron una evaluación escrita. Cada una de las tres primeras clases fue analizada episódicamente.
A continuación presentamos el análisis de uno de los dos episodios en los que dividimos la tercera clase de esta unidad didáctica. El primer episodio corresponde al inicio de la clase. En el segundo, los estudiantes resuelven una guía de actividades sobre el tema “gases” y el practicante responde a

sus consultas. A continuación nos detenemos en el análisis de este último episodio correspondiente a la segunda clase de la unidad didáctica. Nos interesa el análisis de las intervenciones del practicante durante el mismo en tanto están centradas en las ayudas que ofrece a los estudiantes para la resolución de las actividades. Caracterizamos a estas intervenciones –tal como lo mostramos en el siguiente apartado del trabajo- en términos de "indicios".

Complementamos el análisis de la clase con el empleo de mapas conceptuales. Consideramos a los mapas conceptuales como una estrategia que vehiculiza la negociación de significados entre quienes compartimos esta investigación y, en tanto esto último, como un medio interesante para expresar nuestro conocimiento sobre los tópicos estudiados, organizar los conceptos más significativos así como también sus relaciones. Es en la interacción personal, en el contexto de la construcción colaborativa de los mapas conceptuales, donde descansa parte de su potencial como estrategia facilitadora de la investigación (Novak y Gowin, 1988). Es frecuente pensar a los mapas conceptuales en el contexto de las relaciones entre los procesos de enseñanza y los de aprendizaje. En nuestro caso, los asumimos como estrategia en el proceso de investigación durante el cual se constituyen nuestros aprendizajes. En este contexto, el empleo de mapas facilitó los procesos de negociación de significados entre pares, favoreciendo e proceso de investigación. En el apartado siguiente presentamos dos mapas conceptuales que sintetizan dos instancias en el desarrollo de este trabajo. Una de ellas, referida a la distinción entre tipos de indicios; la restante, referida a la tipología de una de estas categorías de indicios, inferida a partir del análisis del habla del practicante.

5. Análisis episódico.

Durante el primer episodio de la clase se desarrollan actividades preliminares que involucran tanto asuntos de clase (Lemke, *ob. cit.*), como el recurso a una estructura directiva o instruccional (Lemke, *ob. cit.*) destinada a organizar la gestión de la clase y por medio de la cual el practicante da precisiones referidas a su organización en diferentes instancias. Por un lado, respecto de qué actividades resolverán en esta primera parte de la clase y cómo trabajarán (*"[…] Cada grupo va a hacer el punto 1 que es el mapa conceptual y el punto 3 que es explicar las afirmaciones"*; línea 5); por otro, indicando que estas actividades serán calificadas (*"[…] Entonces vamos a hacer esas dos actividades aquí, en grupo, y van a ser calificadas aparte ¿de acuerdo?"*; línea 6). En este caso, además, la estructura directiva incluye una justificación sobre la selección de las actividades a realizar en esta primera parte de la clase (*"[…] El punto 3, en general, no lo han respondido cuando entregaron la guía individual y el mapa conceptual, en general, tampoco lo han hecho. Entonces vamos a hacer esas dos actividades aquí, en grupo, y van a ser calificadas aparte ¿de acuerdo?"*; línea 6)

A los efectos del presente trabajo, tal como indicamos más arriba, nos interesa el segundo de los dos episodios en los que dividimos la clase. Incluye la realización de tareas por los alumnos, sea individual o en grupo, previamente indicadas por el practicante durante el primer episodio de esta misma clase. Durante la resolución de tareas, el practicante recorre el aula consultando dudas de los alumnos. Organizamos el análisis de este episodio considerando las intervenciones del practicante a demanda de los alumnos.

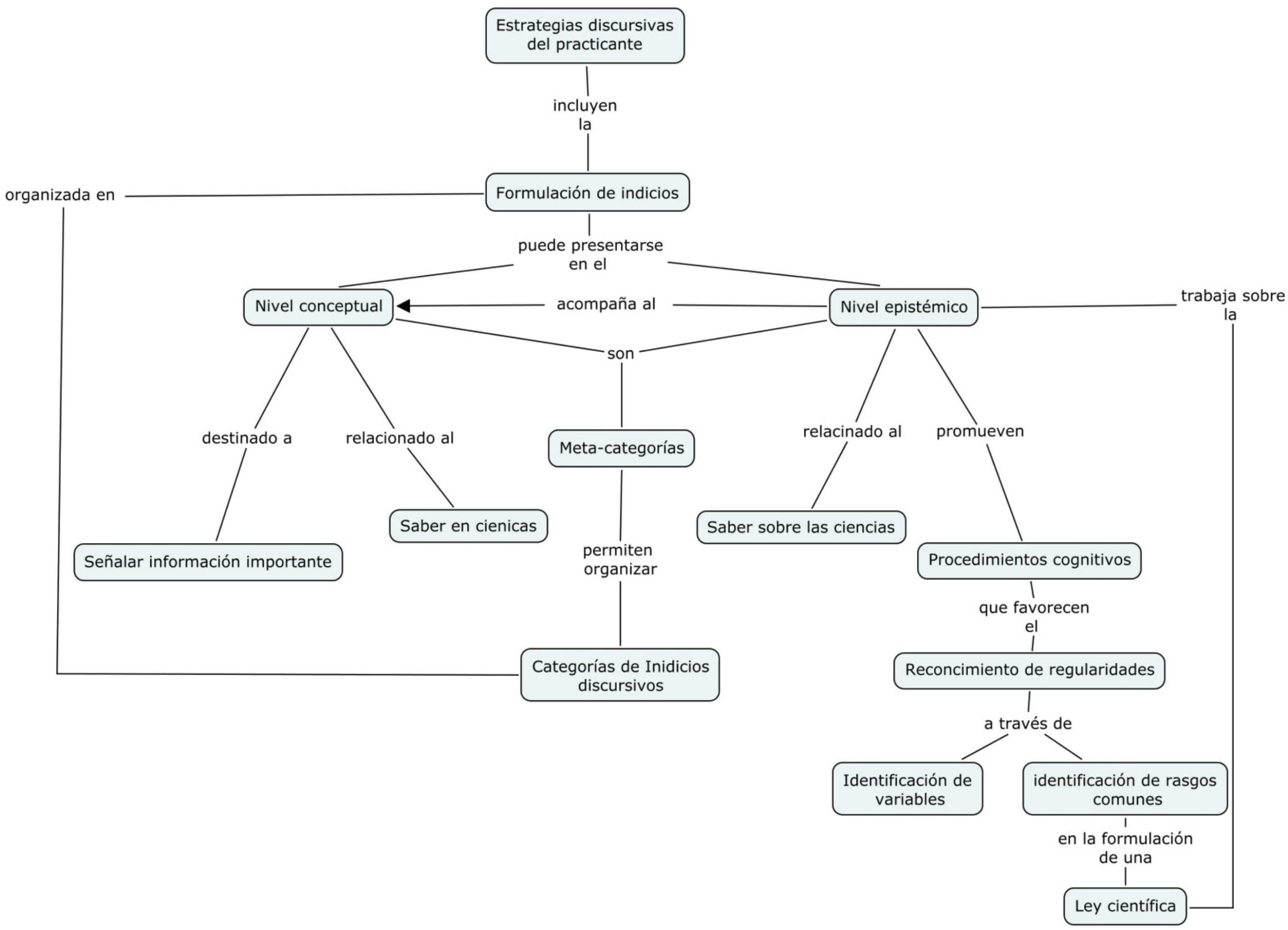
Estas intervenciones pueden describirse y analizarse en términos de una estrategia centrada en la formulación de indicios. El análisis de las intervenciones del practicante durante esta clase, sugiere la pertinencia de considerar una diversidad de indicios, según se sigue del análisis presentado en este episodio. En tal sentido, y por un lado, la formulación de indicios es una estrategia desarrollada por el practicante, diferenciada de otras, atendiendo a su finalidad. Por otro, también, el análisis de las intervenciones sugiere presentar y analizar una clasificación interna a esta estrategia.

Si bien no todas las intervenciones del practicante durante esta clase pueden ser leídas en términos de esta estrategia centrada en la formulación de indicios, el empelo de indicios para facilitar la resolución de la tarea a los alumnos, ocupa un lugar importante –en términos del porcentaje total de estrategias utilizadas- durante esta clase. Seguidamente, describimos y analizamos las variantes que esta estrategia presenta a partir de las intervenciones del practicante.[1]

[1] Para los análisis presentados en este episodio, además de las citas propias de esta clase 3, también se utilizan citas pertenecientes a la clase 2. De no indicarse lo contrario, las citas extraídas corresponden a la clase 3. De pertenecer a la segunda clase, esto se especifica indicando el número de clase, a continuación del número de línea.

Lemke (*ob. cit.*) utiliza el término “señalar información importante” para referir a aquella estrategia destinada a asignar una importancia relativa a una relación temática o patrón. El empleo de esta estrategia –tal como es definida por Lemke- permite explicitar y poner en relieve información conceptual y, por lo tanto, su contexto de aplicación es el ámbito conceptual. Sin embargo, y considerando las intervenciones del practicante durante este episodio, “señalar información importante” no sólo es restringida, en tanto estrategia, al dominio conceptual. El practicante, por ejemplo, utiliza estrategias destinadas a identificar qué ley de los gases –de las trabajadas- modela una situación determinada y esta estrategia señala información relevante para la resolución de la actividad. Sin embargo, no podría clasificarse como un ejemplo de la estrategia “señalar información importante” porque no trabaja, al menos directamente, sobre un patrón temático. La intervención del practicante está centrada en el reconocimiento de la ley a partir de indicios de naturaleza epistémica. Esta última denominación –posiblemente amplia en su alcance- pretende dar cuenta del nivel en el que se utilizaría la estrategia –nivel gnoseológico-. No es empleada en el nivel de las relaciones conceptuales que constituyen el patrón temático –sea del alumno o del profesor-; es utilizada en el contexto de la estructura de la ley. Más precisamente, en el reconocimiento de la ley a partir de su estructura lógica. Esta diferencia nos sugiere la precaución de no confundir a estas estrategias con aquella denominada “señalar información importante” y utilizar otra denominación para este grupo de intervenciones del practicante: “estrategia centrada en la formulación de indicios. Posiblemente puedan reconocerse ejemplos de intervenciones que presentan como estrategia general –en el sentido de más amplia- el señalar información importante y que, además, en su desarrollo necesite y utilice la formulación de indicios como estrategia intermedia.

Estos indicios pueden incluir tanto el señalamiento de información importante –en el sentido mencionado por Lemke- como indicaciones de procedimientos cognitivos para la resolución de actividades. En este trabajo centramos nuestra atención en el nivel epistémico de la formulación de indicios. En el siguiente mapa conceptual (mapa conceptual 1) pretendemos desarrollar esta distinción:



Mapa conceptual 1: Clasificación de las estrategias centradas en la formulación de indicios.

Como mencionamos más arriba, la formulación de indicios ocupó gran parte de las estrategias docentes utilizadas por el practicante durante esta clase. Sin embargo, no fue utilizada con la misma frecuencia durante los intercambios con el grupo de alumnos. Su empleo estuvo reservado a las interacciones con alumnos durante la realización individual o grupal de las actividades.

Para el trabajo con las leyes de los gases el practicante ofrece indicios destinados al reconocimiento de la ley en situaciones de aplicación de la misma, también proporciona indicios destinados a identificar rasgos estructurales de las leyes con las que se trabaja e indicios destinados a construir una explicación.

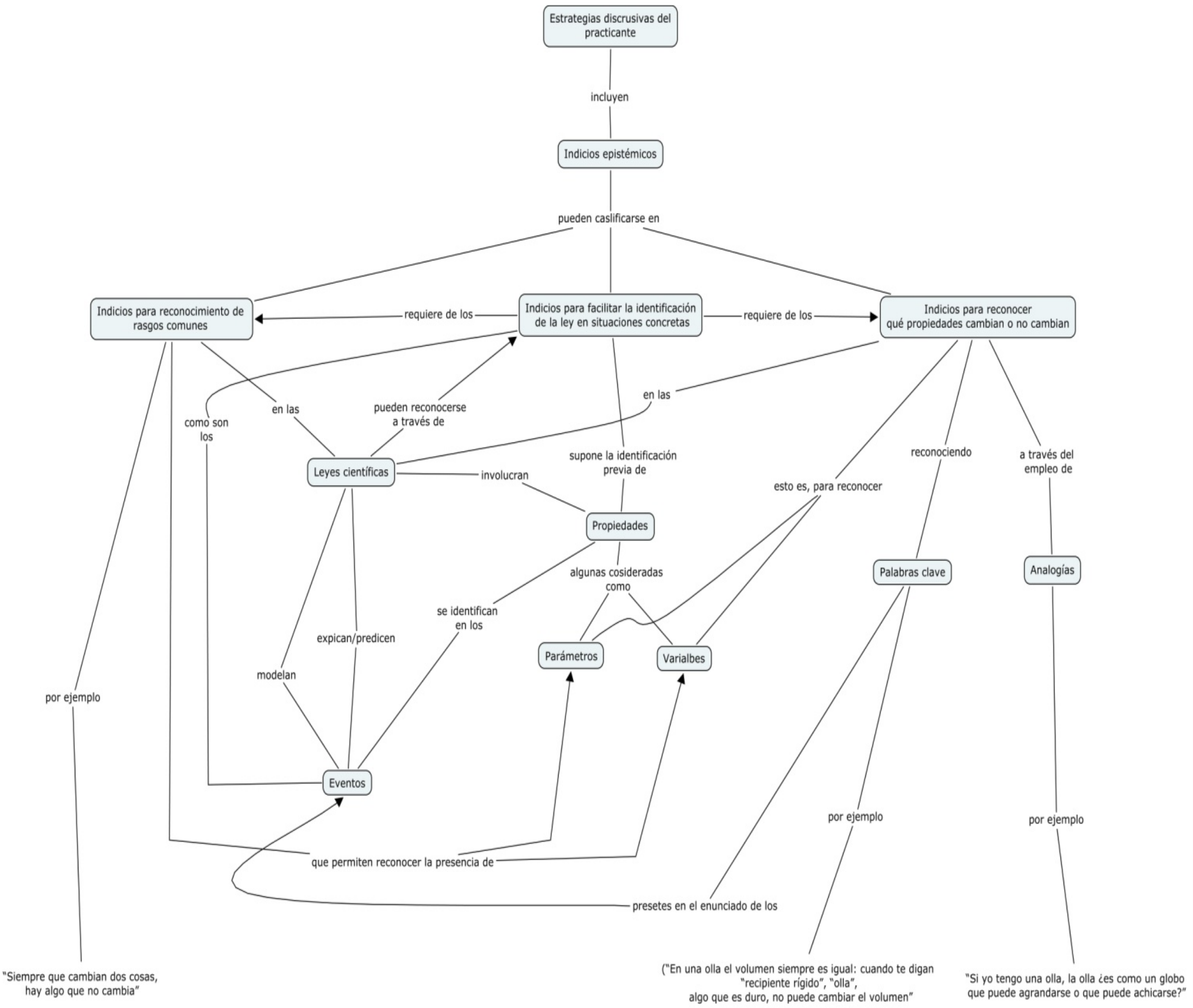
En el contexto de la clasificación propuesta, un primer grupo de indicios refiere al reconocimiento de rasgos comunes presentes la estructura de las leyes trabajadas; en particular, que las generalizaciones trabajadas implican un conjunto de tres propiedades de los gases, dos de las cuales son variables relacionadas funcionalmente entre sí mientras que la tercera de ellas, permanece constante (*"Una mantiene constante una cosa, otra otra y otra otra"*, línea 15; "*Siempre que cambian dos cosas, hay algo que no cambia",* línea 30; *"[….] son tres leyes y tienen que ver qué cambia en una y qué cambia en otra",* línea 30). En algunas de sus intervenciones el practicante es explícito respecto de este conjunto de propiedades, dos de las cuales varían y la restante permanece constante. El uso del plural al referir a las propiedades que cambian y del singular en el caso restante, son indicadores frecuentes en las intervenciones del practicante ("*Bueno, primero, primero lo importante es siempre es encontrar qué ley es. Para ver qué ley es tenemos que ver qué variables cambian y cuál se mantiene constante.*"; línea 78) Por lo tanto, resulta más sencillo identificar qué propiedad no se modifica durante la transformación frente a la necesidad de identificar dos propiedades que sí lo hacen.
Es necesario aclarar que las formulaciones de las leyes que el practicante presentó a los alumnos no hacían explícita la constancia en la masa del gas. Por este último motivo, es que hacemos referencia a tres propiedades. Durante el desarrollo de la segunda clase, también identificamos la presencia de este tipo de estrategia. Las indicaciones que el practicante realiza en el contexto de esta clase de indicios alternan, indistintamente, entre la recomendación de identificar qué propiedad no cambia (*"Primero hay que identificar lo que no cambia"*; línea 48; *"[….] en una olla a presión qué es lo que se mantiene constante?"*, línea 48) o en centrar la atención en el reconocimiento de las propiedades que varían (*"Primero, primero identificá qué variables cambian",* línea 257, clase 2; *"[…] Siempre hay que ver primero qué variables cambian"*; línea 323, clase 2) o, indistintamente, tanto en las propiedades que cambian como en aquella que no lo hace (*"Por eso es importante que vean qué son…qué cambia y que no cambia. Siempre tengan en cuenta eso"*, línea 54; "*La cuestión de esos tres es darse cuenta de qué cambia y qué no*", línea 245, clase 2). En este sentido es que el practicante no privilegia ninguna de estas modalidades al utilizar este tipo de indicios. Este tipo de indicio, en cualquiera de sus modalidades, no permite identificar de qué ley se trata; da pistas respecto de la estructura común al conjunto de leyes trabajadas. Opera en un nivel que podemos llamar –y según comentamos más arriba- epistémico, denominación que utilizamos para diferenciarlo de aquel indicio que trabaja en el nivel conceptual. Este último –conceptual- es el nivel en el que se identifica la ley partir del reconocimiento de las propiedades que cambian y de aquella que permanece constante; es el nivel de análisis necesario para la resolución de las actividades. Esto explicaría por qué el empleo de un indicio en el nivel epistémico acompaña siempre al nivel conceptual. La relación inversa, sin embargo, no necesariamente es válida. El practicante puede dar indicios en el nivel conceptual sin recurrir al empleo de indicios en el otro nivel. El nivel epistémico es, posiblemente, utilizado con el propósito de ofrecer regularidad en la aparente diversidad que el alumno puede encontrar entre las leyes. Permitiría encontrar cierta unidad en la diversidad. Esta unidad, este orden, debería imponerse al momento de identificar la ley (*"Primero, ¿cuáles son las variables? Siempre hay que ver primero qué variables cambian"*; línea 323, clase 2).

Un segundo grupo de indicaciones está orientado a facilitar la identificación de la ley que permite, por ejemplo, modelar una situación concreta (*"¿Qué ley es ésta [….]? Bueno, acá cambia el volumen y la temperatura. Listo, es Charles. Eso es lo primero que tenés que hacer"*; línea 27). Esta identificación requiere tanto del reconocimiento previo de las propiedades del gas en la situación bajo estudio, como del reconocimiento de aquellas propiedades que, además, son variables en el evento. Esta doble exigencia –identificación de las propiedades y de las variables- permitiría, conocida la estructura común a este grupo de leyes, inferir de qué ley se trata. Por lo tanto, y retomando lo comentado en el párrafo anterior, estos dos grupos de indicaciones, consideradas simultáneamente, facilitarían el reconocimiento de la ley que modela un determinado evento. El primero de estos dos grupos de indicaciones -referido al reconocimiento de rasgos comunes sobre la estructura de las leyes- corresponde a un nivel de generalidad mayor. En el contexto de una situación determinada, el reconocimiento de las propiedades y su clasificación en "variables" y "no variables”, permite concluir la ley que subsume al evento, si aceptamos la existencia de una estructura común al grupo de leyes trabajadas. El alumno podría reconocer la ley si identifica, para la situación de aplicación de la misma, las tres propiedades del gas, qué propiedad no cambia y, sabiendo además, que las dos restantes serán las relacionadas funcionalmente por la ley. Este razonamiento supone, entonces, un implícito: que las leyes trabajadas relacionan dos variables de tres propiedades del gas permaneciendo constante la restante. Este implícito es propuesto por el practicante, en ocasiones, como un indicio durante la explicación y, por lo tanto, es explicitado. En un pasaje de este episodio, el practicante le explica a un grupo de alumnas cómo reconocer que el volumen, en una situación determinada, no cambia. Una vez, reconocido, continúa: *“Ya, allí casi ya encontraste la ley. Por eso es importante que vean qué son…qué cambia y qué no cambia. Siempre tengan en cuenta eso. Listo, ya encontraste que el volumen no cambia, ¿qué cambia? La temperatura y la presión”* (línea 54). En este pasaje el practicante emplea ambos niveles de indicios de manera explícita. En otras intervenciones, en cambio, el indicio correspondiente al nivel epistémico, permanece sin explicitar. En el pasaje anterior (línea 54), es interesante notar que el énfasis colocado por el practicante en la identificación en la propiedad, que se modifica durante la transformación, deja de lado el reconocimiento del cambio en las propiedades restantes. Esta modalidad en la que el practicante utiliza este indicio, reduce el análisis del evento a una de las propiedades, infiriendo la variación de las restantes por la aplicación de la regla ya mencionada, esto es, que podrá identificarse la ley si se reconoce, para la situación de aplicación de la misma, de las tres propiedades del gas, qué propiedad no cambia y, sabiendo además, que las dos restantes serán las relacionadas funcionalmente por la ley. La aplicación de esta regla propuesta por el practicante simplifica la identificación de la ley a expensas de disminuir en el análisis de la situación. Otro tipo de indicio es utilizado por el practicante para facilitar al alumno tanto el reconocimiento de las propiedades que cambian como de aquellas que no lo hacen. Si el primer tipo de indicio refería a facilitar la identificación de la estructura general de las leyes trabajadas, el segundo indicio lo hacía en términos del reconocimiento de la ley, este tercer tipo de indicio permite clasificar, en el enunciado de la situación de aplicación de la ley, a las propiedades según varíen o permanezcan constantes. Así, estas pistas proporcionan indicadores para inferir propiedades que no cambian en un gas, cuando la formulación de la situación no es explícita al respecto.

La aplicación de las leyes a la explicación de eventos cotidianos, permite al practicante seleccionar partes del enunciado del evento referidas a propiedades de objetos conocidas por el alumno y que pueden ser utilizadas en la identificación de variables y parámetros. En esta tercera clase, durante el intercambio comunicativo con una alumna, el practicante intenta guiar a ésta en el reconocimiento de la propiedad que, para el evento enunciado en la actividad -“*Si en una olla a presión no hay válvula de seguridad que permita que salga el vapor, la olla puede explotar al cocinar”-,* permanece constante. Formula una analogía incluyéndola en una pregunta (*“Si yo tengo una olla, la olla ¿es como un globo que puede agrandarse o que puede achicarse?”*; línea 54). A través de esta pregunta, la analogía propone la comparación olla-globo, respecto de una propiedad como es la posibilidad de deformación. Al incluir la comparación en una pregunta, el practicante deja abierta la posibilidad de diferenciar el comportamiento de los objetos ante la expansión del gas contenido. El empleo de un análogo supone que ciertos rasgos son transferibles de este al tópico. En este caso, interesa la diferencia respecto de un rasgo y no su similitud. En tal sentido, la pregunta facilita el énfasis en lo disímil del comportamiento. En este caso, el practicante responde a la pregunta –sin esperar la respuesta de la alumna- y continúa con otro indicio para reconocer al volumen como aquella propiedad de la mezcla de gases que no cambia en este evento *(“En una olla el volumen siempre es igual: cuando te digan “recipiente rígido”, “olla”, algo que es duro, no puede cambiar el volumen”*; línea 54). Este último indicio supone una regla obtenida a partir de la generalización de la situación particular del evento de la actividad. El practicante recurrió a una comparación para identificar, en la situación particular, qué propiedad del gas (o mezcla de gases) permanece constante. El indicio, en este caso, es cierta propiedad del material del recipiente que contiene la mezcla de gases. Por lo tanto, siempre que esta propiedad esté presente en el recipiente que contiene el gas (o mezcla de gases), el volumen, durante su transformación, permanecerá constante.

Ambos indicios –el empleo de una comparación y la generalización-, procuran identificar qué propiedades del gas (o mezcla de gases) permanecen constantes y cuáles no. En un primer caso, la identificación se procura a través de una comparación; en el segundo, por medio de una generalización que permitiría identificar que el volumen del gas no cambia por la presencia de ciertas palabras en el enunciado, palabras que remiten a una propiedad del recipiente que contiene al gas o a la mezcla de gases. En tanto indicios que permitirían la identificación de las variables de un gas en una determinada situación, contribuirán al desarrollo del segundo de los indicios trabajados –aquél que facilitaría la identificación de la ley en situaciones concretas-. Se puede decir, entonces, que el primer y tercer indicio, facilitarían la identificación de la ley en una situación determinada. La siguiente intervención del practicante puede ejemplificar esta última relación: *"Bueno, primero, primero lo importante es siempre encontrar qué ley es. Para ver qué ley es tenemos que ver qué variables cambian y cuál se mantiene constante. En una olla que es dura ¿qué es lo que no va a cambiar?"* (Línea 78). Durante la misma, el practicante ofrece pistas a la alumna en un doble sentido: explicitando la estructura de las leyes trabajadas, estructura compartida independientemente de las variables que relacionen ([….] "*lo importante es siempre encontrar qué ley es. Para ver qué ley es tenemos que ver qué variables cambian y cuál se mantiene constante*") y, además, ofreciendo indicios para identificar qué propiedad permanece constante ("[….] *En una olla que es dura ¿qué es lo que no va a cambiar?*"). Este doble conjunto de indicios constituyen la estrategia discursiva del practicante para facilitar el reconocimiento, de parte, del alumno, de la ley que permita modelar la situación problema.

La tipología propuesta y el análisis desarrollado para los indicios en el nivel epistémico se sintetiza en el mapa conceptual que mostramos seguidamente (mapa conceptual 2):



Mapa conceptual 2: Clasificación de los indicios epistémicos.

6. Consideraciones finales.

Los análisis de las interacciones discursivas en el aula constituyen una prolífica línea de investigación en didáctica de la Física y de la Biología, pero no así en didáctica de la Química. Por otra parte, estas investigaciones son abundantes en descripciones y análisis de saberes en ciencia pero, significativamente menos desarrolladas en el saber sobre la ciencia. En este trabajo avanzamos en esta última línea y pretendemos colocar en relieve la importancia que los aspectos relacionados a este último tipo de saber tienen en el discurso docente durante las interacciones discursivas en el aula.

El análisis de una clase centrada en la resolución de actividades por los alumnos y sus consultas al practicante, permitió indagar en estrategias discursivas docentes que, en el contexto de las clases restantes –centradas en la exposición del practicante- se presentaron cuantitativamente menos relevantes. Estas estrategias consistieron en indicios más o menos explícitos que el practicante ofreció a los estudiantes para la resolución de las actividades. La categorización de estos indicios en términos de dos metacategorías –conceptuales y epistémicos- nos permitió dar cuenta del alcance del conjunto de indicios empleados por el practicante. La frecuencia con que ambos tipos de indicios se presentaron durante las intervenciones del practicante fue similar, lo que indica que ambos tipos de saberes –en ciencia y sobre la ciencia- tuvieron protagonismo comparable durante las intervenciones discursivas. Este último aspecto pone de manifiesto la importancia de hacer explícita la reflexión durante la formación docente respecto del conocimiento sobre la NdC. En particular, la diferenciación de la meta-categoría epistémica en diferentes indicios muestra la variedad de posibilidades en que puede manifestarse la NdC desde el discurso docente. La diferenciación entre los dos tipos de indicios nos permitió una lectura de ciertas intervenciones discursivas del practicante re-significadas desde una perspectiva que evita homogeneizarlas bajo una misma categoría. En efecto, la delimitación que proponemos entre ambas metacategorías impone una lectura diferencial de ciertas interacciones discursivas que, en ausencia de la misma, podrían ser homologadas desde un indicio conceptual.

Estas modalidades encontradas para la meta-categoría epistémica no pretende ser exhaustiva más allá de los limites de esta investigación, y nos abre la posibilidad de indagar, por un lado, en su presencia y, por otro, en sus variantes en otros contextos del discurso docente.

Los procesos de construcción discusión, presentación y reconstrucción del conocimiento producto de este investigación encontraron en la construcción de los mapas conceptuales, procesos muy favorecedores del aprendizaje significativo. Los mapas conceptuales permitieron vehiculizar la presentación del conocimiento haciendo explícito de manera simple y visible disponible el proceso de construcción del conocimiento en esta investigación. Encontramos, entonces, en su empleo, una estrategia para el proceso de meta-análisis del proceso de investigación.

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Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

ISSN 1989 - 9572

Concept mapping for learners of all ages

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 23 de diciembre de 2012

Fecha de revisión: 21 de enero de 2013

Fecha de aceptación: 31 de febrero de 2013

Gallenstein, N. (2013). Concept mapping for learners of all ages. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 59 – 72.

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Abstract
Concept mapping is an inquiry technique that provides students at all ages with opportunities to demonstrate learning through performance. A concept map refers to a graphic/visual representation of concepts with linking connections that show various relationships between concepts (Novak & Gowin, 1984). Assessment is an ongoing process integrated with instruction across subject areas. The National Council of Teachers of Mathematics (NCTM) emphasizes that assessment should focus on both the enhancement of student learning as well as serve as a valuable tool for making instructional decisions (NCTM, 2000). Assessment activities can take on a variety of forms, one being performance tasks. In this manuscript, an explanation of concept mapping is provided for learners ages 3 – 12 along with several examples of concept maps for young learners, including examples from an assessment project in the subject area of mathematics. Also presented are the numerous benefits of the concept mapping technique for both students and teachers.

Resumen
Los mapas conceptuales son una técnica de investigación que provee a los estudiantes de todas las edades la oportunidad de demostrar el aprendizaje a través de su representación. Un mapa conceptual nos lleva a una representación gráfico-visual de los conceptos, con enlaces que muestran relaciones entre distintos conceptos (Novak y Gowin, 1984). La evaluación es un proceso continuo e integrado en la enseñanza de cada materia. El National Council of Teachers of Mathematics (NCTM) pone énfasis en que la evaluación debería centrarse tanto en la mejora del aprendizaje como en servir como una herramienta valiosa para la toma de decisiones en la enseñanza (NCTM, 2000). Las actividades de evaluación pueden tomar formas muy variadas, siendo una de ellas la realización de tareas. En este artículo se ofrece una explicación de los mapas conceptuales para estudiantes de edades comprendidas entre los 3 y los 13 años, junto con varios ejemplos de mapas conceptuales para niños y jóvenes, incluyendo algunos de un proyecto de evaluación en el área de matemáticas. También se describen los numerosos beneficios del uso de mapas conceptuales tanto para estudiantes como para profesores.

Keywords
Concept maps, inquiry, early childhood, primary, elementary, learners, mathematics.

Palabras clave
Mapas conceptuales, investigación, primera infancia, educación primaria, aprendices, matemáticas.

1. Introduction

As children experience the world around them, they interpret their environment and form ideas about phenomena. While many of children's interpretations of phenomena are correct, many are incorrect. As children mature, their interpretations of phenomena change, yet while young, children have many preconceptions and misconceptions about their world. Young children often attempt to assimilate new experiences to their existing schemes, which can result in misconceptions rather than accommodate knowledge from their newly acquired experiences. An important task for teachers is to design experiences that provide opportunities for students to correct their preconceptions and misconceptions. The task of the teacher is to facilitate the learner's continuing accurate construction of old and new schemata (Kellough et al. 1996). Yet, once a concept is thought to be correct, it is often challenging for educators to change a young child's mind concerning what he/she perceives a situation to be. Considering that children's beliefs influence their receptiveness to new information, educators are always eager to try instructional strategies that will assist learners in changing their misconceptions and accepting accurate explanations of phenomena (Howe & Jones, 1993). Concept mapping has been shown to be an excellent tool for facilitating learners' assimilation and accommodation of knowledge and helping students change their misconceptions (Kellough et al, 1996).

In this manuscript, an explanation of concept mapping along with the benefits for learners and teachers is provided along with several examples of concept maps representing various age levels and subject areas.

2. Concept Mapping

Concept mapping was developed by Joseph Novak (1984), a science education researcher, who was interested in strategies that assist students learn how to learn. Novak's concept mapping technique was based on David Ausubel's theory of meaningful learning, whereby a learner links new concepts to previously experienced concepts. Novak's concept mapping technique has been successful in helping students change their misconceptions about their world by clarifying connections between concepts (Kellough et al, 1996). Concept mapping is often used by science educators on the elementary and secondary level but it is also effectively used with other subject areas and with younger learners. Concept mapping facilitates conceptual building as well as accurate understandings of prior and new knowledge.

A concept map refers to a graphic/visual representation of concepts with linking connections that show various relationships between concepts. A concept map serves as an organizational tool of knowledge from the most general to the most specific. Usually, concept maps are represented in a hierarchical format, with the more general concepts at the top and specific supporting concepts toward the bottom. When constructing a concept map, learners should be instructed to place the most general term/idea at the top of their concept map and connect the remaining concepts below the main idea. For example, the concept of a plant is related to the concepts of leaves, stems, roots, flowers, air, water, sunshine, etc. (Daugs, 1993). When constructing a concept map using words, learners can be instructed to write the word "Plant" at the top of their concept maps and connect the other suggested concepts below the word plant. They can then draw lines connecting the concept terms while writing linking words (usually verbs) on the lines to show their perceived connections (See Figure 1). An arrow placed at the end of each connecting line signifies the flow of each idea, usually stated in short sentence form. In referring to the diagram, you will notice that the last word of one thought is also used as the first word for the following connected thought. For example, "Plants have leaves" would then be followed by and connected to "Leaves can be green". Another example, this time using pictures and objects, is of an Analog Clock (Gallenstein & Larmon, 2012). In referring to the Analog Clock concept map (See Figure 2), you will also notice that the last word of one thought is also used as the first word for the following connected thought. For example, "An analog clock has a short hand” would then be followed by and connected to "A short hand shows the hour".

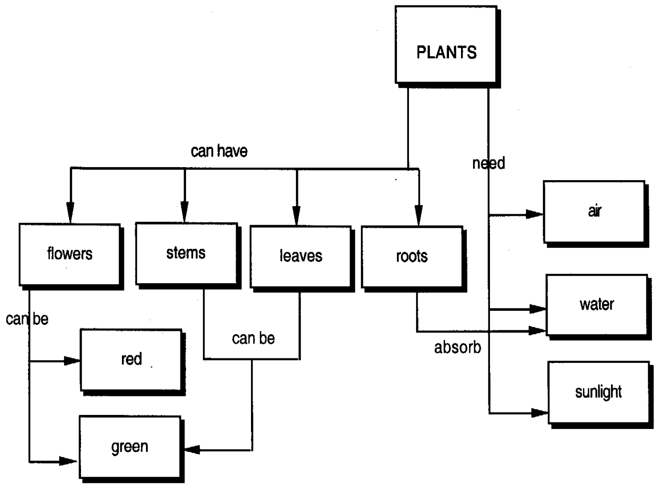

Figure 1. Plants

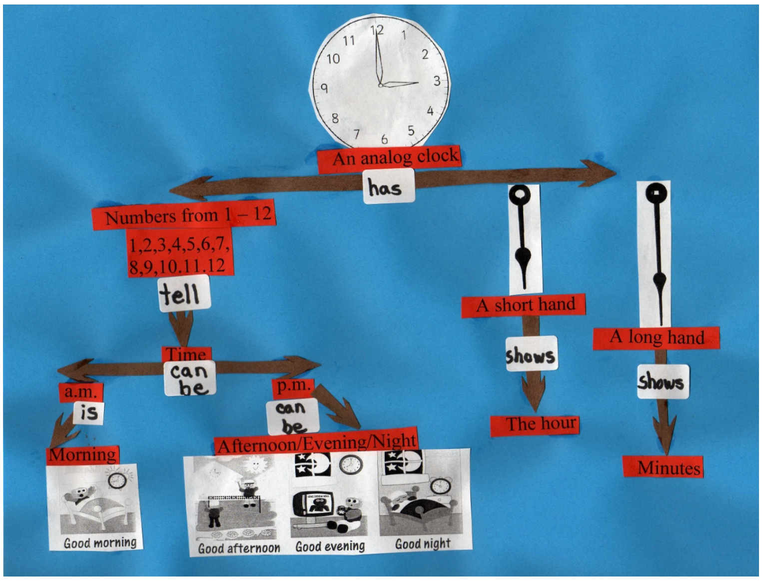

Figure 2. Analog Clock – Primary Grades, Ages 5 – 8

Allowing children to work cooperatively while exploring their world provides them with opportunities to discuss their experiences. Often a child's peer will have a different perception of a particular experience. When this occurs, children can listen to each other, discuss their conceptions, and work toward an accurate understanding of the phenomenon. Educators should design and facilitate experiences in order that children can acquire correct conceptions of their world.
Educators can design hands-on, minds-on learning opportunities in order for students to experience for themselves accurate conceptions of phenomena that were determined to be previously misconceived through the use of concept maps. Through the process of assimilation and accommodation, students who originally held inaccurate beliefs about phenomena can often clarify their thinking and experience equilibration. But, educators need to understand that changing children's misconceptions is not an easy task. It often takes time and patience. Educators must listen carefully to their students and provide many opportunities for questions and discussion that accompany hands-on, minds-on learning.

3. Concept Mapping for All Ages

Concept mapping, as currently represented in most textbooks, is an appropriate technique for upper level students who have reading and writing skills. We often don't think of concept maps as something that is appropriate for younger learners. Yet, concept mapping can be adapted for young learners, providing them with many of the benefits it does their older counterparts.

Young learners can participate in creating concept maps on their appropriate learning and developmental levels and in a variety of subject areas through the use of objects (concrete level) and/or pictures (pictorial/representational level). For example, children are provided with opportunities to see logical connections with new material and previously acquired knowledge. Also, concept mapping promotes critical-thinking skills through the use of observation, comparison, classification as well as problem solving and decision making. In addition, teachers can use concept maps to introduce or conclude a topic or as an activity within a lesson/unit. They also provide teachers with valuable information in assessing students' learning progress (Gallenstein, 2005).

Charlesworth and Lind (2010) recommend that materials used for conceptual activities meet children's level of development. "For each concept included in the curriculum, materials should be sequenced from concrete to abstract and from three-dimensional (real objects), to two-dimensional (cutouts), to pictorial/representational, to paper and pencil" (p. 43). Children must be provided with opportunities to manipulate and move materials in order to understand the concepts emphasized before introducing paper and pencil activities.

Concept maps for young learners uses manipulative objects or pictures appropriate for children's level of development. Rather than using only words (symbolic/ abstract level), young children can create concept maps by arranging objects (concrete level) and/or pictures (pictorial/representational level) in a format with general concepts at the top and supporting concepts positioned below them. Connections can be made between concepts through the use of laminated paper arrows, string/yarn, pipe cleaners, footprints mapping the path, etc. The teacher can write the children's suggested linking words on the laminated arrows as they share their thoughts. The arrows show the flow of ideas on the concept map and provide students with opportunities to "read" the completed concept map story for understanding. Students can also make new connections by rearranging the items, allowing for diverse perspectives to be expressed. Very young children will experience success with concept maps with three-dimensional objects or pictures. As students' literacy skills progress, however, teachers can build more complex concept maps with objects, pictures, picture word cards, and words only. In addition, software programs, such as *Kidspiration* (seeInternet Resources), provide opportunities for children to create concept maps with pictures or words.

Following, are examples of concept mapping techniques appropriate for children's various developmental levels, beginning with the concrete level (actions on objects) and leading to the pictorial/transitional level (pictures) (Gallenstein, 2003). These examples should provide you with practice building concept maps.

3.1. Concrete Concept Map

- Topic/Theme: Animals
- Grade Level(s): Preschool - Second
- Ages: 3-8
- Created by: Natalie Richards, Melanie Graham, and Janell Bachelier
- Materials: A large blanket for the floor, small/medium/large sentence strips for labels and arrows, large pictures of various living environments (e.g., water, land, sky), and a variety of different bean bag animals (e.g., bear, bird, fish, etc.)
- Procedures: (Note: This project will be presented as a learning activity to follow a unit that has been presented to students about the environment and in what places different types of animals might live.)
    - Begin by spreading out the blanket and asking students to sit on the floor around the edges.
    - Once students are seated, begin to place all of the various bean bag animals around on the blanket.
    - Ask, "Looking at all of these things here, can you tell me what they all are?" (They're bean bag animals!) Ask, "What kind of bean bag animals are they?" "What do they represent?" (different kinds of animals)
    - Display the sentence strip with the word "ANIMALS" (and a large picture with a variety of animals) on it at the very top of the blanket and share, "Remember how we have been talking about different kinds of animals and where they might live?"

Well, today I'd like you to help me organize these animals and put them together (group them) according to where they might be found."
  - Ask, "Who can tell me where one of these animals might live?" (A fish lives in water.) Place an arrow with its base at the word ANIMALS and point it toward the picture of "water". Write the word "lives in" on the arrow strip. Have the student place the fish bean bag on the water picture.
  - Continue with each of the other animal bean bags. Ask each student to share where each animal can be found (habitat). Students should place each animal bean bag in the appropriate habitat.
  - Next, have students investigate the animals in each of the habitats that they have grouped and encourage them to create other groups by looking at the similar characteristics of the animals. Assist them with arrows and linking words.
  - When all of the possible groups have been formed, ask for a volunteer to "tell the story" of the animals by following the arrows along the map. Model an example for the students first so that they have an understanding of what you would like for them to share.
- Extensions:
  - Categorize the animal groups even farther as to where they can be found such as at the zoo, home, farm, etc.
  - Focus on only one habitat at a time such as animals found on land, in water, or in the air.
  - Students can string animals together and create an ANIMAL mobile concept map.
  - Place animals and habitat words in a learning center for further investigation.

3.2. Concrete/Pictorial Concept Map
- Topic/Theme: Germs
- Grade Level(s): Kindergarten - Second
- Ages: 5-8
- Created by: Aimee Jordan and Tiffany Rohrer
- Materials: Towel, water bottle, tissues, cough drops, soap, a traced hand on a note card, band-aids, pictures of family, food, cut yarn strips, poster board, and note cards
- Procedures: (Note: This project will be used after a unit on germs has been presented.)
  - The teacher will ask students to share what they have learned during their unit on germs.
  - After the students are paired, the teacher will distribute objects and a word card with the name of each object on it to each pair of students. (E.g., water, soap, towel, hands, sneeze, cough, cut, food, band-aid, etc.).
  - Students will have time to observe their object with a partner and talk about how the object relates to germs.
  - Students will then share with the class what their object is and how it relates to germs. - The teacher will explain to the students that they will make a word map showing how the words (objects) relate to germs.
  - The teacher will guide students by listening to their suggestions and giving clues when needed. (E.g., Giving a linking word such as "spread by" and letting students figure out who has objects that spread germs.)
  - Students will physically make a concept map by lining up in groups and using yarn and linking words to connect their objects/words to the word germ.
  - When completed, students will place their objects/words and yarn on the floor and observe what they have created.
  - Students will then explain their concept map on germs and tell how and why the yarn connects the objects.
  - Encourage students to think of other ways that the objects/pictures might be connected.
  - The teacher will listen to the students' explanations in order to evaluate if students connected the objects/words correctly and record their accomplishments on a checklist.
- Extension:
  - Place concept mapping materials in a learning center for students to further explore various connections between the objects/words.
  - Following are photographs of concept maps appropriate for children's various developmental levels. The mathematics concept maps that follow were designed by elementary pre-service teachers and implemented in actual classroom settings. (See Figures 3 – 11).

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Figure 3. Time with Clock – Primary Grades, Ages 5 – 8

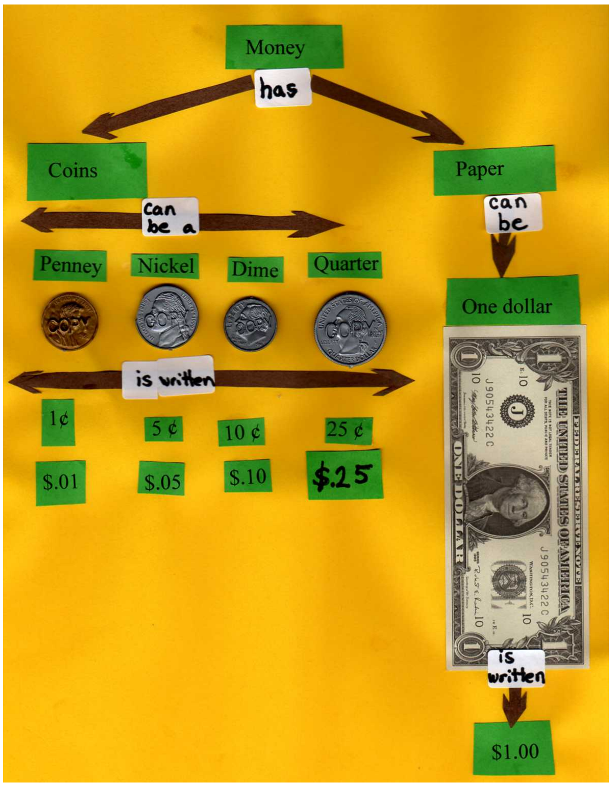

Figure 4. Money – Primary Grades, Ages 5-8

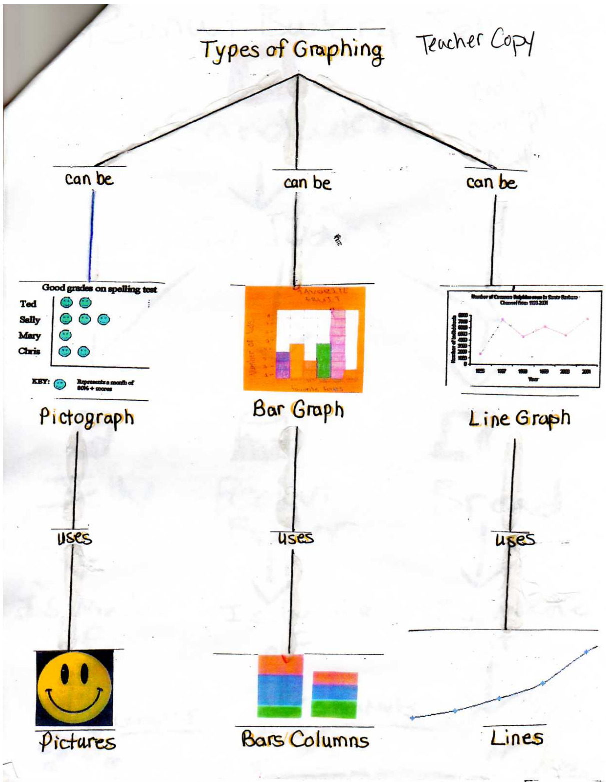

Figure 5. Types of Graphs – Primary, Ages 5 – 8

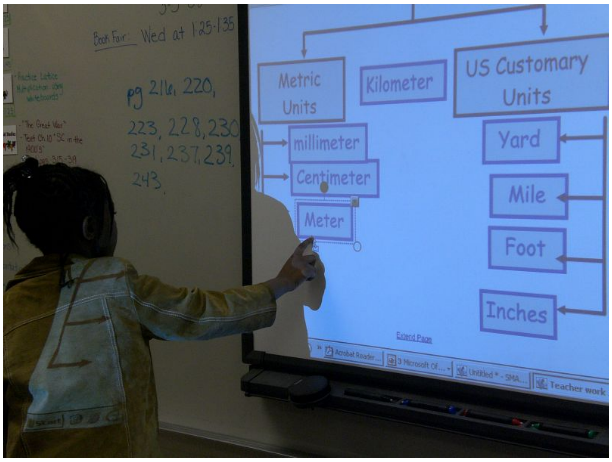

Figure 6. Units of Measure – (Smart Board Application) Grade 3, Age 8

Figure 7. Geometry – Grade 3, Age 8

Figure 8. Fractions - Grade 3, Age 8

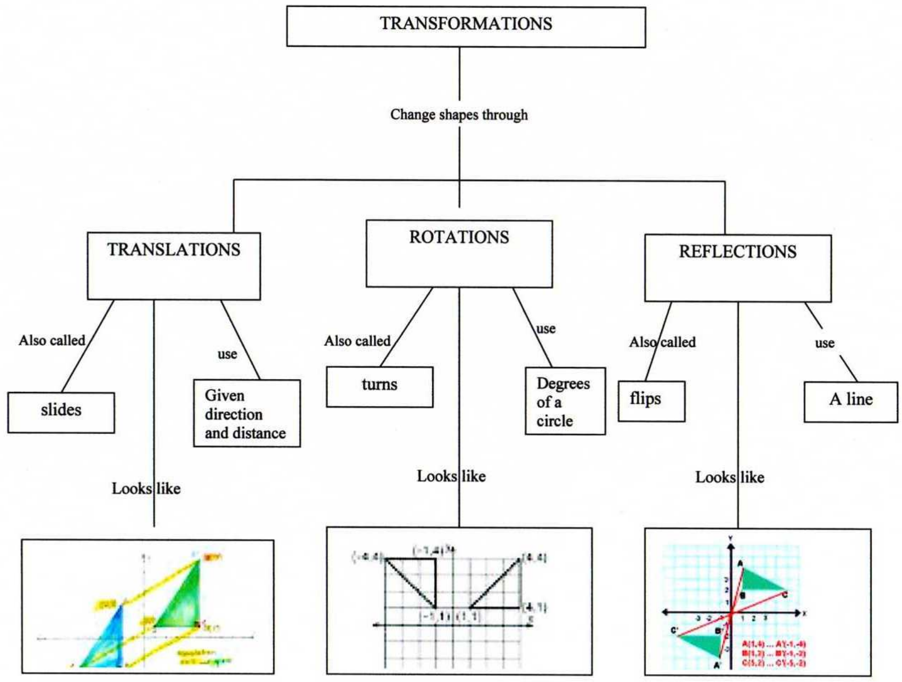

Figure 9. Transformations – Grades 3 – 5, Ages 8-10

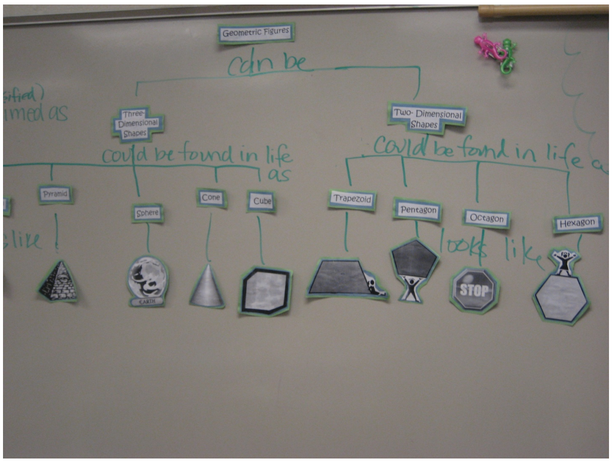

Figure 10. Geometric Figures (Laminated Words & Pictures with Magnetic Tape) Grade 5, Age 10

Figure 11. Metric Measurement - Fifth Grade, Age 10

4. Concept Mapping as an Assessment Tool

Assessment is an ongoing process integrated with instruction (NCTM, 2000). In 1995, the National Council of Teachers of Mathematics (NCTM) published *Assessment Standards for School Mathematics*. In 2000, these standards were reinforced in the NCTM's *Principles and Standards for School Mathematics.* NCTM emphasizes that assessment should focus on both the enhancement of student learning as well as serve as a valuable tool for making instructional decisions (NCTM, 2000).

Assessment activities can take on a variety of forms, one being performance tasks. "To assess learning, the teacher must prepare activities, projects, and tasks that the student performs in order to learn, and from which assessment information can be captured" (Troutman and Lichtenberg, 2003, p. 274). Students can demonstrate their knowledge acquisition by explaining, demonstrating, drawing and acting out. Concept mapping is a technique that provides students with opportunities to demonstrate learning through performance.

Through the use of concept maps, students have opportunities to organize their thoughts in a graphic/visual format, while connecting concepts, and linking prior knowledge to new knowledge. Concept maps also provide students with opportunities to think about their own thinking as they reflect on what they know or what they need to have clarified. Additionally, through students' visual representations and sharing of knowledge, teachers can assess and determine if students' concept connections are accurate. When misconceptions are evident, students with accurate conceptions can often clarify misunderstandings within their learning groups, which is in line with Vygotsky's theory of the Zone of Proximal Development, whereby a more competent student or an adult facilitates accurate conceptual understandings. Also, children's conversations while creating concept maps can lead to the development of language used to describe scientific and mathematical concepts (Kellough et al. 1996). With the development of concepts and their relationships, additional concepts can be learned.

5. Concept Map Project with Elementary Students

In a concept mapping project on the topic of geometry that I conducted with children ages 9-11, the following comments were heard (Gallenstein, 2011). "Oh, I see", explains one student. "It's like a domino effect. One word affects the other and then the other and then the other." "I need a match for this word" was followed by, "It's right here." And, "I've got angles", shared one child. Followed by, "I need angles right here", responded another. These comments were shared by fourth and fifth grade students while they investigated the topic of geometry through the construction of mathematics concept maps.

On two separate days, students in both a fourth and fifth grade class participated in a mathematics concept map activity centered on geometry. The activity served as a post-assessment for the fourth grade students and a pre-assessment for the fifth grade students. Both classroom teachers arranged their students into heterogeneous groups, with each group consisting of 3-5 students. The following materials were provided to each group.

<u>Concept Map Materials</u>:

- **<u>Word cards</u>**: Geometry; Shapes; Two Dimensional; Three Dimensional; Quadrilaterals; Trapezoid; Rhombus; Pentagon; Hexagon; Octagon; Parallelogram; Square Pyramid; Rectangular Prism; Sphere; Cylinder; Cube; Cone; Square; Rectangle; Triangular Prism; Face; Edge; Vertex; Flat side; One pair of parallel lines; Two pairs of parallel lines; Solid figure with length, width & height; Plane figure with length, width & height; Two faces meet; Three or more faces meet; Three sides; Four sides; Five sides; Six sides; Eight sides; Angles; Right angle; Acute angle; Obtuse angle; 90°; Greater than 0° and less than 90°; Greater than 90° but less than 180°; 4 right angles; 4 equal sides; One pair of parallel sides; Opposite sides equal & parallel; One picture each of a triangle, rectangle, square, pentagon, hexagon and octagon
- **<u>Objects</u>:** One pattern block each of a triangle, square, rhombus, trapezoid, hexagon, diamond/parallelogram; marble, dice; blue translucent plastic cube, square pyramid, rectangular prism, cylinder, sphere; rectangular prism cardboard food container, metal enclosed soup can
- **<u>Concept Connectors</u>:** 7-inch by 1-inch strips of white paper, 4-inch by 1-inch strips of white paper trimmed at one end to a point (arrows)

Before beginning the activity, both classes were provided with an overview of concept mapping and with basic instructions on how to design concept maps. Students were informed that there is no one right way to design a concept map, and that each group's final map may differ from the other versions. Pictures of two completed concept maps on different concepts were displayed in the classroom for reference.

As a class, students reviewed how to work as a cooperative learning group, while emphasizing that all ideas should be valued. After the groups were assigned space to work, each group was presented with an envelope of word cards. Students were then instructed to lay all of the word cards out for everyone in their group to see. Then, as a group, they were asked to decide on a concept card from their packet that could be placed at the top of their map. This word card would serve as the general concept that would include all of the other concept word cards. The students were then informed to sort the concept cards into groups in order to begin organizing their concept maps. Most groups, although making accurate connections, took more time to agree on the arrangement of the word cards and often changed the placement of the words when they felt they had a better idea. (See Figure 12.)

Figure 12. Geometry Assessment Project: Beginning to Organize Grade 5, Age 10

After the groups constructed fairly organized formats, pictures, pattern blocks, three-dimensional blue plastic translucent objects, and relevant objects were provided to each group. Because of the organization of their maps, some groups were easily able to place the shapes into their constructed maps. Other groups rearranged their maps somewhat to accommodate the shapes (See Figure 13). One student held up the marble and mentioned that her group had already been given a plastic sphere so they did not need the marble. She was encouraged to add the marble to their group's map. Her group then cleverly decided to place the marble inside the plastic sphere. They also placed the dice inside the plastic cube and then correctly positioned both the sphere and cube on their concept map. (See Figure 14.)

Figure 13. Geometry Assessment Project – Reorganizing to Fit Concrete Objects Grade 5, Age 10

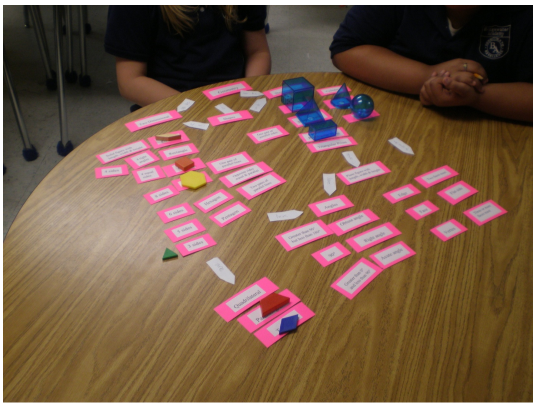

Figure 14. Geometry Assessment Project – Final Project Grade 4, Age 9

The shapes provided all of the groups with an opportunity to clarify their thoughts and solidify their connections with the concept word cards. After the shapes were provided, each group received a handful of paper strips and arrows that they could use to link the concepts together. Most of the linking words that the students chose to include in their concept maps were "has, is, are, can be, includes, equals, and measures". (See Figures 15 & 16).

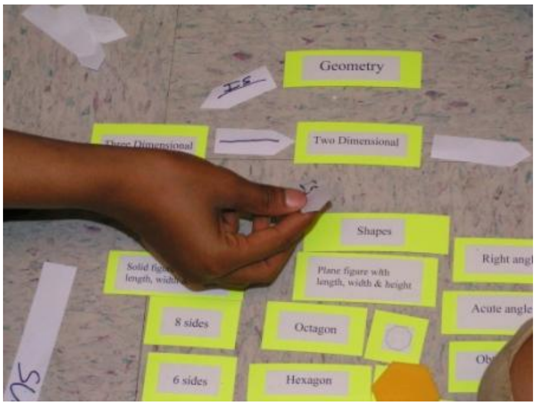

Figure 15. Geometry Assessment Project: Adding Linking Terms Grade 5, Age 10

Figure 16. Geometry Assessment Project – Adding More Linking Terms Grade 5, Age 10

After most of the work was completed and class time was nearing the end, volunteers in the fourth grade class were asked to read their concept maps aloud for their classmates. While each concept map was being read, all class members gathered around and followed along with what their classmates shared. In the fifth grade class, students as a group were asked to shift to a different group's concept map and investigate how each map was alike and different. Not only were the students in all of the groups able to see how the maps differed in concept connections and construction, the concept maps also served as reinforcement to their knowledge. For example, when reviewing one of the concept maps, one student pointed to one connection and exclaimed, "That's what we were trying to figure out." Another student was impressed with the other group's concept map and responded, "Wow!" In viewing another map, one student responded, "Yeah, they got it all. They got everything!" (See Figure 17.)

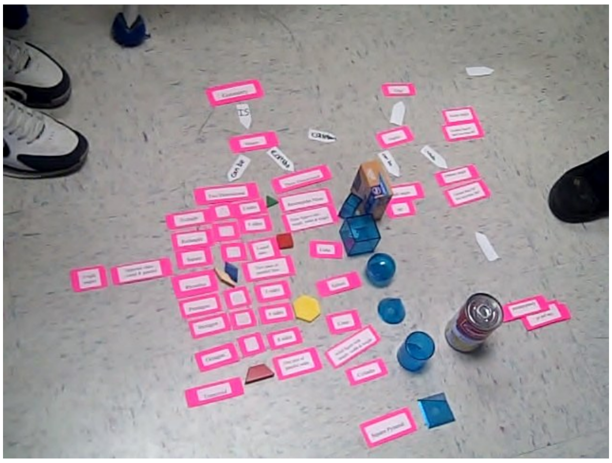

Figure 17. Geometry Assessment Project – Final Project Grade 5, Age 10

Teachers can use concept mapping as an effective learning tool for assessing their students' understandings through the creation of concrete and/or graphic/visual representations. Both of the teachers whose students participated in this concept mapping project witnessed first-hand the value of including concept mapping as a pre- and post-assessment tool in the mathematics curriculum. They have a clearer understanding of their students' needs in relation to understanding geometry and are better prepared to address them. Furthermore, both teachers commented on how enthusiastic their students were about their experiences with the concept mapping project. They also were very impressed with the level of success their students experienced with cooperation, organization, problem-solving, decision making and critical thinking.

6. Items to Consider When Constructing Concept Maps

1) Introducing Concept Mapping: In order to ensure success, when introducing concept mapping activities to preschool-grade 6 students, begin by constructing a group concept map. This can be completed on the chalk/white board, an overhead projector, an ELMO, a Smart Board, or by creating larger materials for a class project that could be constructed cooperatively on the floor.
2) Materials: Provide objects and word cards in which your students will experience success. Appeal to the concrete, pictorial/representational, and symbolic/abstract levels of your students. Start with a workable amount of materials. Later, challenge your students by adding more concepts to the pool of materials.
3) Space: When arranging students in groups, be certain that students have enough space to arrange all of their word cards and objects into a concept map. For example, students seated at a round table or on the floor are able to share easier and work more efficiently while those using their desk tops might struggle because of space constraints. Also, be certain that the students' workspaces are clear from distractions so the word cards and objects are clearly visible.
4) Group Size: Student participation is heightened when groups are smaller; 2-3 students per group would be appropriate.
5) Arrangement: If possible, arrange students in a "U" shape in order for them to fully participate and experience success with the activity. All students should be able to read and see the concept cards and objects while constructing the map.
6) Time: Be certain that you allow enough time for all students to become fully involved in the concept mapping process. Respect the various learning levels and abilities of your students. Consider placing the concept map materials in a learning center for further investigation.

7. Benefits of Concept Mapping Activities

Numerous benefits exist for learners as they participate in concept mapping activities. Teachers who promote the use of concept mapping techniques also benefit. Following, are ways in which both young students and their teachers benefit when concept mapping is incorporated into the curriculum (Gallenstein, 2003). Benefits for Students:

- Improves student concept constructions (Martin et al, 2001).
- Helps to clarify misconceptions.
- Connections between concepts provide for more meaningful learning.
- Provides opportunities to see logical connections between ideas.
- Provides opportunities for students to construct and make sense of their knowledge.
- Relates new material to previously acquired learning.
- Shows relationships among smaller and larger concepts (Martin et al, 2001).
- Organizes thoughts from general to specific.
- Acts as a motivator for learning while viewed as a game connecting ideas.
- Addresses all learning modalities: visual, auditory, tactile/kinesthetic.
- Associations and connections made between/among concepts.
- Builds self esteem as students experience success with various connections.
- Emphasizes diverse perspectives through the acceptance of various appropriate formats on the same topic.
- Provides opportunities for students to organize their thoughts and information in a concrete/visual format through grouping.
- Provides opportunities to sort and categorize information/topics.
- Promotes critical thinking skills such as observation, comparison, classification.
- Provides problem solving and decision making opportunities.
- Promotes and values both cooperative learning and independent work.
- Provides brainstorming opportunities.
- Reinforces and strengthens language and literacy skills.
- Strengthens communication skills.
- Provides opportunities for self-disclosure.
- Students learn that there are many correct ways to process similar information.
- Assists in developing an understanding of a variety of linking words that can connect concepts.
- Opportunities to express how concepts are linked while clarifying any misconceptions.

- Because concept map outcomes can differ, students build confidence in their personal abilities to express themselves (through links and cross links).
- Opportunities to communicate connections between different classes within the same category.
- Draws on personal experiences of how concepts connect.
- Provides opportunities to discover similarities in objects/pictures/words.
- Provides a concrete way for students to show mental connections between concepts in a similar category.
- Shows different relationships between ideas.
- Provides opportunities for students to manipulate concepts physically and mentally.
- Provides opportunities for students to play an active role in their learning by representing how concepts are connected.

Benefits for Teachers:

- Provides opportunities to analyze students' thinking.
- Can be used as a pre and post assessment instrument.
- Can be used to introduce or conclude a topic - or as an activity within a lesson/unit.
- Encourages educators to become more open minded and flexible with students' various interpretations and perspectives.
- Can be used as an organizer for units/lessons/activities.
- Used for both informal and formal assessment - formative and/or summative assessment.
- Allows a teacher to observe gaps in students' knowledge in order to facilitate correct conceptions (connections).
- Provides opportunities to implement new or additional learning experiences.
- Provides for various learning formats: whole class instruction, learning center, or interactive bulletin board.
- Used in many subject áreas.
- Provides opportunities for subject integration.

8. Concluding Thoughts

Concept mapping provides children with opportunities to become actively involved in their learning while linking knowledge to long-term memory. Through the use of concept maps, children have opportunities to organize their thoughts in a concrete and/or graphic/visual format, while connecting concepts and linking prior knowledge to new knowledge. Related concepts become connected rather than fragmented. Concept maps also provide children with opportunities to think about their own thinking as they reflect on their conceptual understandings. Additionally, teachers can use concept mapping as an effective learning tool for assessing learners' understandings through their creation of concrete and/or graphic/visual representations.

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Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

ISSN 1989 - 9572

Experiencias de éxito en la aplicación de Mapas Conceptuales en la carrera de Ingeniería en Computación, México

Successful experiences in the application of Concept Maps in Engineering in Computing, Mexico

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 15 de enero de 2012

Fecha de revisión: 10 de febrero de 2013

Fecha de aceptación: 25 de febrero de 2013

Guardian, B; Veloz, J.; Rodríguez-Moreno, I. A. y Veloz, L. (2013). Experiencias de éxito en la aplicación de Mapas Conceptuales en la carrera de Ingeniería en Computación. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 73 – 84.

Journal for Educators, Teachers and Trainers
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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

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Resumen

Hoy en día hallamos una enorme cantidad de trabajos relacionados con nuevos modelos y estilos de aprendizaje e instrucción en el área de ingeniería. En el caso de la carrera de Ingeniería en Computación que se imparte en el Instituto Politécnico Nacional (IPN) México, existe un grupo de trabajo liderado por un Experto de talle internacional cuyos procesos de éxito y trabajo al respecto, son reflejados en el presente texto a través de experiencias obtenidas en los últimos 8 años con alumnos y profesores, generando así, los requerimientos y herramientas para el mundo globalizado y la sociedad del conocimiento en que nos encontramos. Las experiencias obtenidas se encuentran en asignaturas como la Teoría de Autómatas (TA), los Compiladores (Cs), Análisis de Algoritmos(AA), Redes de Computadoras (R), Inteligencia Artificial (IA), Programación (P), Proyecto de Titulación (PT) y Planeación estratégica (PE) principalmente, entre otras para facilitar la comprensión de conceptos y aplicaciones por parte del alumno y consideramos que mediante la estrategia de enseñanza usando mapas conceptuales (MMCC) desarrollados por J. Novak los resultados han sido favorables en dinamismo, comprensión y generando aprendizaje significativo a largo plazo, proporcionando así, elementos sólidos para su ejercicio profesional. Se indican propuestas obtenidas por profesores y ejercicios desarrollados por profesores y alumnos.

Abstract

Today there is an enormous amount of work related to new models and styles of learning and instruction in the field of engineering. In the case of the engineering degree in computing that is taught in the Mexico National Polytechnic Institute (IPN), there is a working group led by an expert of international waisted whose success and work thereon, processes are reflected in this text through experiences gained in the last 8 years with students and teachers, thus generatingthe requirements and tools for the globalised world and the knowledge society in which we find ourselves. Lessons learned are in subjects as the theory of automata (TA), compilers (Cs), analysis of algorithms (AA), (R), Artificial Intelligence (AI), computer programming (P) networks, degree project (PT) and strategic planning (PE) mainly, among others to facilitate the understanding of concepts and applications by the student and believe that through the teaching strategy using concept maps developed by j. Novak results have been favorable in dynamism, understanding and generating meaningful learning in the long term, providing well, solid elements for your professional practice. Listed proposals obtained by teachers and exercises developed by teachers and students.

Palabras clave

Aprendizaje Significativo, Mapas conceptuales, Aprendizaje en Ingeniería, Aprendizaje en Computación, Evaluación de aprendizaje en Ingeniería.

keywords

Meaningful learning, Concept Maps, Engineering Learning, Computer Learning, Learning evaluation on Engineering.

1. ¿Qué son los mapas conceptuales (MMCC)?

De una manera general los mapas conceptuales MMCC son diagramas que indican relaciones entre conceptos clave o entre palabras que usamos para representar conceptos (Moreira M. 1997). La teoría de éstos se basa en: la teoría cognitiva de David Ausubel (Ausubel 1978) y es una técnica desarrollada y propuesta por Joseph Novak y colaboradores en la Universidad de Cornell (González F. 2008). Los MMCC son instrumentos poderosos para describir estructuras de conocimiento disciplinar a través de jerarquías conceptuales o de significados, partiendo de reglas generales hacia las más especificas de manera clara y sin olvidar el sentido interpretativo y explicativo de quien lo produce o elabora. Otra significativa característica de los MMCC es la inclusión de enlaces cruzados, que son proposiciones entre conceptos que corresponden a diferentes segmentos del mapa conceptual (MC), estas relaciones fundadas en un cuerpo de conocimientos previos bien organizados, nos permiten evaluar la capacidad creativa de los alumnos. A su vez los MMCC admiten la detección de los llamados errores conceptuales (EECC) o concepciones alternativas (González, Moron y Novak, 2001), que forman parte de la estructura cognitiva del alumno, y a través de los EECC, el estudiante interpreta la nueva información que lo conduce a interpretaciones erróneas que desvirtúan la realidad aún a pesar de que el material o la información no los contengan. Así los MMCC auxilian para forjar de forma explicita tales errores y tras su reconocimiento, disponerse a promover el cambio conceptual. Cabe mencionar que la estructura bidimensional de los MMCC nos deja observar de manera mas clara las relaciones de significados que maneja o son parte del alumno que muy frecuentemente aparecen ocultas o no explicitas en su estructura lineal poco creativa y que, con esta representación gráfica, aumenta las probabilidades en función de los conocimientos previos, de incorporar nueva información, aprender significativamente y construir conocimientos.

Es primordial señalar que los MMCC son un buen apoyo para el profesor y auxilian en la estructura del conocimiento para así poder enseñarlo reflejando como consecuencia un aprendizaje de calidad.

2. ¿Por qué usar mapas conceptuales en ingeniería en computación?

En la ESIME- Culhuacan del Instituto Politécnico Nacional en México se imparten las carreras de: Ingeniería en Comunicaciones y Electrónica e Ingeniería en Computación en las cuales asignaturas como Teoría de Autómatas, Compiladores, Análisis Algoritmos, Inteligencia Artificial, Proyecto de Titulación, Programación entre otras son parte y se fundamentan en modelos matemáticos que dieron origen a las computadoras actuales, por lo que, se consideran asignaturas formales o disciplinares y que impactan en el resultado y aplicación de asignaturas subsecuentes y en el ejercicio profesional de los alumnos, además, algunas asignaturas se instruyen a profesores en un par de diplomados de especialización por lo que también estas estrategias se manejan por adultos, algunos inclusive de la tercera edad. Por consiguiente al ser de igual forma asignaturas teóricas, las definiciones, demostraciones y elementos fundamentales abundan, dando como resultado dificultad de asimilación o aprendizaje significativo en el estudiante y quedando solamente el memorístico a corto plazo sobre todo siguiendo sistemas de enseñanza tradicional, los cuales, todavía encontramos en nuestra institución. De este modo con la propuesta de emplear los mapas conceptuales en el proceso de enseñanza se ha logrado un aprendizaje duradero orientado al estudiante de ingeniería en computación y que le sirva para toda la vida, a la vez, se ha conseguido incentivar el auto - aprendizaje mediante el conocimiento y la utilización de estas herramientas, así como, observar, adaptarse y modificar sus resultados. El número de profesores que imparte las asignatura es reducido y se está capacitando en ésta técnica y otras más a mayor número, lo cual, permite que se vaya adoptado esta herramienta de éxito meta - cognitiva y queden convencidos por las consecuencias en su mayoría, que es una alternativa extraordinaria; así mismo, por ser varias las asignaturas en que se produce el uso de ésta herramienta, trascienden las características de superación y oportunidad para adoptarse como un objeto útil en todas las demás asignaturas de la carrera aún si el profesor no lo aplica o no lo sabe emplear.

Las asignaturas de Teoría de Autómatas, Compiladores, Análisis de Algoritmos, Inteligencia Artificial, son asignaturas matemáticas – informáticas, las de Redes de Computadoras, Programación, Proyecto de Titulación y Planeación Estratégica, son informáticas, que estudian y contienen elementos base de la computación y por contener abstracciones y formalismos, al alumno les resultan tediosas y difíciles, existe un alto índice de reprobación e inspira poco la creatividad. A pesar de lo anterior a lo largo de los últimos 8 años se ha intentado dinamizarla mediante la creación de ejercicios virtuales, aplicaciones de Internet y uso de animación en flash entre otras herramientas, haciendo énfasis en los ejercicios para dinamizar la asignatura correspondiente. Se lograron avances ya que la respuesta del alumno ahora es creativa y las clases y conceptos manejados actualmente no son tediosos, sin embargo, el aprendizaje formal no se mejoraba y lo consideramos fundamental y base para varias asignaturas de la carrera de Ingeniería en Computación en ESIME - Culhuacan.

Mediante la aplicación y estructuración de los conceptos abstractos estudiados, analizados y propuestos, mediante la técnica de MMCC, se obtuvieron buenos resultados en varias áreas y temas como: Lenguajes Regulares, Maquinas de Turing, Algoritmos, Análisis sintácticos, Planeación Estratégica y métodos de Simulación Artificial, que no habían sido abordadas positivamente y obteniendo un aprendizaje más duradero, que le sirva al alumno posteriormente en su conocimiento y aplicación real, de los elementos que abarca su carrera y se proyecte también proporcionándole ésta herramienta para que la traslade a otras asignaturas y la incorpore a su bagaje para su desarrollo profesional y crecimiento personal. También, al emplear estas estrategias se fomentó una cultura de trabajo en equipo, motivadora y que producía placer a la hora de aprender, convirtiendo el tradicional concepto de “tortura” en **cultura divertida y provechosa**.

3. ¿Cómo se incluye la herramienta de MMCC en el proceso enseñanza-aprendizaje?

Las instrucciones para realizar los mapas se emplean al inicio del curso y fueron construidos durante el proceso de aprendizaje y al final de cada tema general. En el caso de algunos temas, como en los lenguajes de programación, se aplicaron para que los alumnos tuvieran una referencia entre sus expectativas iníciales de conocimiento y sus resultados, al finalizar el estudio de éstos. Como un gran apoyo se cuenta con el programa informático CmapTools (Cañas et al., 2004) creado en el prestigioso *Institute for Human and Machine Cognition* (IHMC) que permite construir, compartir y criticar conocimientos basados en MMCC. Tiene un editor de uso sencillo, el usuario fácilmente construye su mapa conceptual y relaciona los medios (vídeo, imágenes, sonidos, mapas, etc.) y sus iconos con los nodos (conceptos). La arquitectura distribuida del sistema permite que los diversos medios y mapas se almacenen en diferentes servidores en una red, y que se pueda acceder desde cualquier nodo en la misma. Partiendo de un punto de vista pedagógico, la construcción de conocimiento usando esta herramienta resuelve un problema común provocado por el fácil acceso a Internet: son tantos los recursos disponibles sobre cualquier tema que es sumamente sencillo copiar y pegar imágenes, texto etc. en su propio documento.

Como se muestra a continuación en los siguientes ejemplos podemos notar como comenzaron sus mapas, las deficiencias y algunos conceptos erróneos (figura 1) y su progreso final (figura 2) producto de un razonamiento mas elaborado y de un dominio más profundo en el tema.

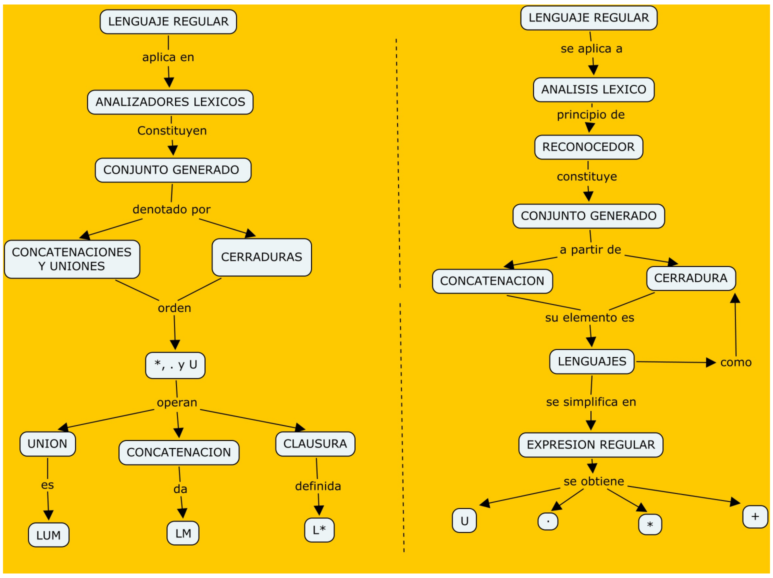

Figura 1. Mapa conceptual sobre las diferencias de reconocimiento y contenido en Lenguajes Regulares realizadas por alumnos de Teoría de Autómatas.

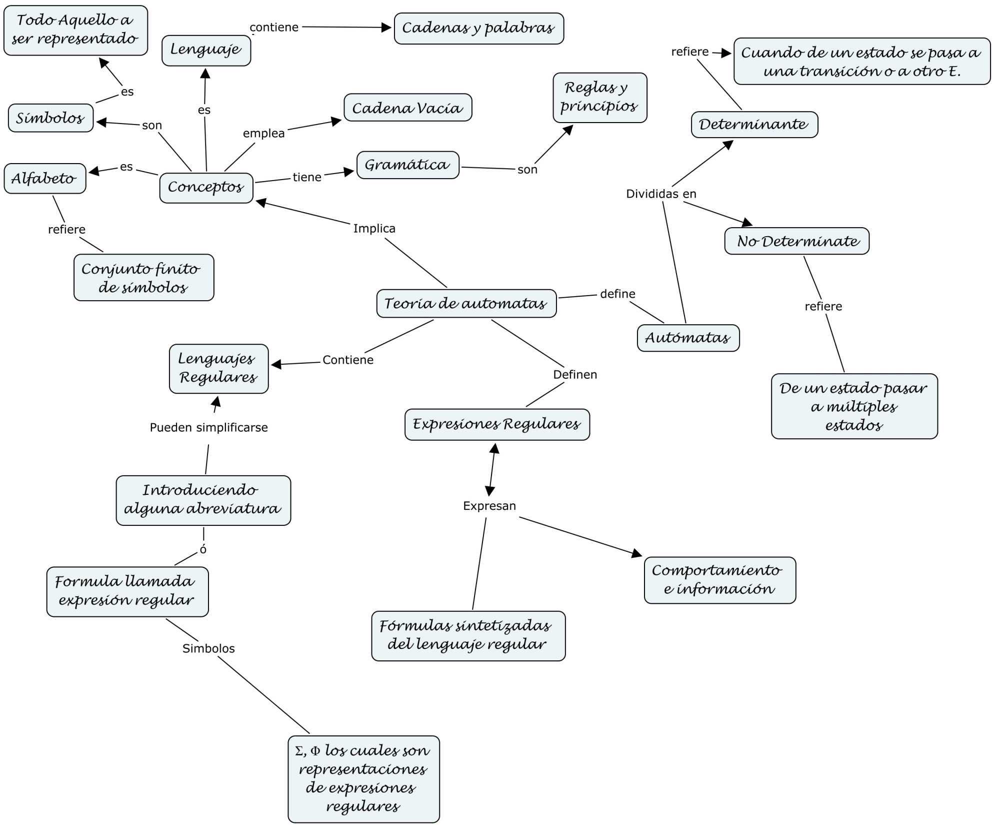

Figura 2. Mapa conceptual final acerca del tema Lenguajes Regulares realizado por un grupo de alumnos de la asignatura de TA.

Otro ejemplo se presenta cuando a fin de poder fortalecer, incrementar los conocimientos y experiencias de los participantes aplicando los principios de la Planeación Estratégica con MMCC que a través del ejercicio frecuente se realiza con mayor facilidad y amplia el panorama de aplicación de todo conocimiento, ya que en el mundo globalizado actual demanda profesionistas con un alto perfil de calidad.

Es importante señalar la oportunidad de reunir a un grupo con diferentes características para poder colaborar entre sí, el total que abarca este estudio es de 240 en dos grupos de control, este se forma con algunas variables relevantes como diferencias de edad, disciplinas, estudios, actividades profesionales adicionales y el factor común: todos son profesores universitarios.

Podemos observar en la figura 3 un mapa conceptual inicial que con algunas pequeñas observaciones estaría balanceado y completo, sin embargo, es uno de los resultados de las prácticas realizadas en el proceso de cambio, el cual, evoluciona a medida que se practica y conoce mejor la herramienta de CmapTools.

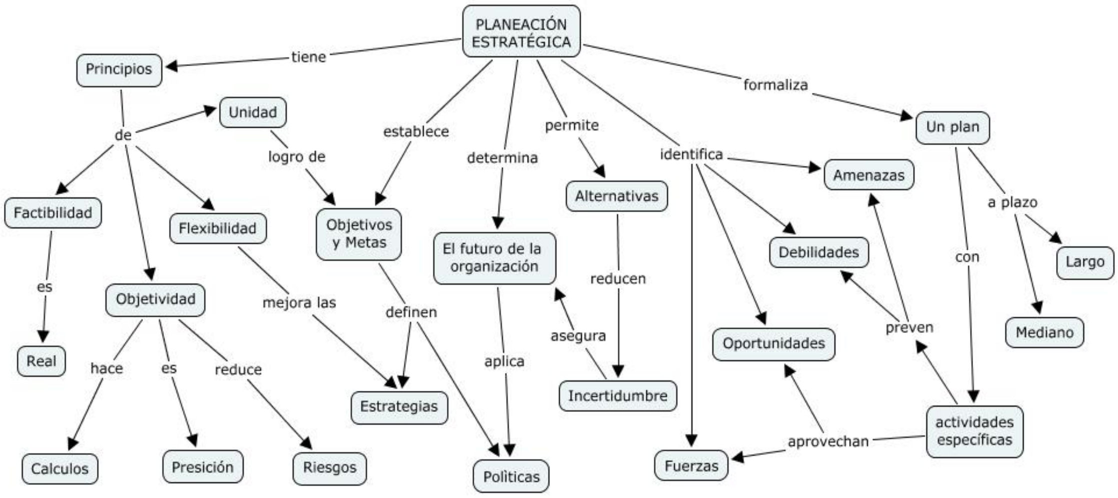

Figura 3. Mapa conceptual sobre planeación estratégica.

Detectamos en grupos multidisciplinarios en general, patrones de comportamiento en la enseñanza que aplican, con técnicas de décadas anteriores de forma muy arraigada, sin embargo, con el empleó del proceso de enseñanza considerando que “El ritmo de la introducción del MMCC depende de las condiciones locales de la escuela, del nivel del alumno y de la dificultad de la asignatura” (Gonzalez 2008) se expusieron los beneficios de adquirir el conocimiento en forma más fácil y dinámica con pequeñas prácticas muy concretas, estableciendo un código común para una buena comunicación entre educandos y aplicados en Planeación Estratégica. Cabe señalar que el promedio de participantes Maestros es de 19 años ejerciendo la docencia.

En el caso de profesores que son mayores a los 50 años de edad, fue un factor determinante convencerles de la aplicación de Aprendizaje Significativo a través de la herramienta de MMCC por la resistencia al cambio y sobre la nueva metodología que ellos tenían que aprender para poder enseñarla en la universidad en las especialidades que ellos imparten, no obstante, al probar sus primeros y propios resultados se consigue en poco tiempo la motivación suficiente para utilizar poco a poco herramientas automatizadas.

4. ¿Qué tipo de aprendizaje generamos?

El mapa conceptual del programa completo resultante, muestra de manera general el contenido de la asignatura y los elementos que la conforman en Teoría de Autómatas obtenido de una manera aprendida significativa por los alumnos en la figura 4, y el de la asignatura de Compiladores en la figura 5.

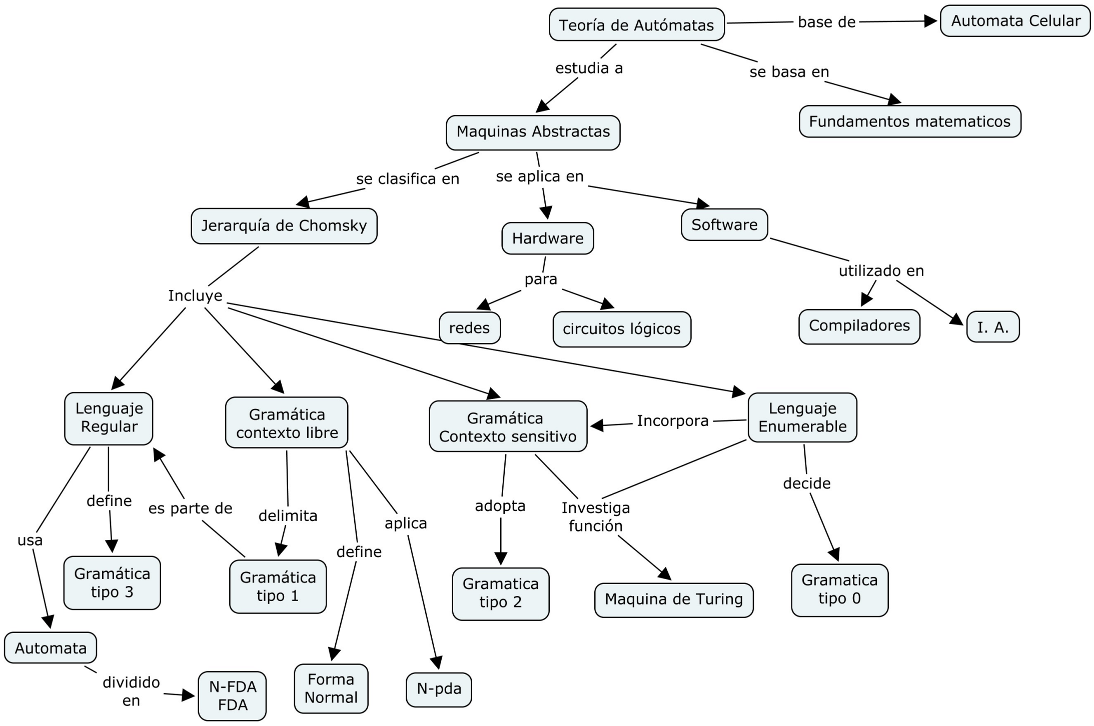

Figura 4. Mapa conceptual del Marco Conceptual de la asignatura de Teoría de Autómatas, elaborado como en ESIME-Culhuacan México.

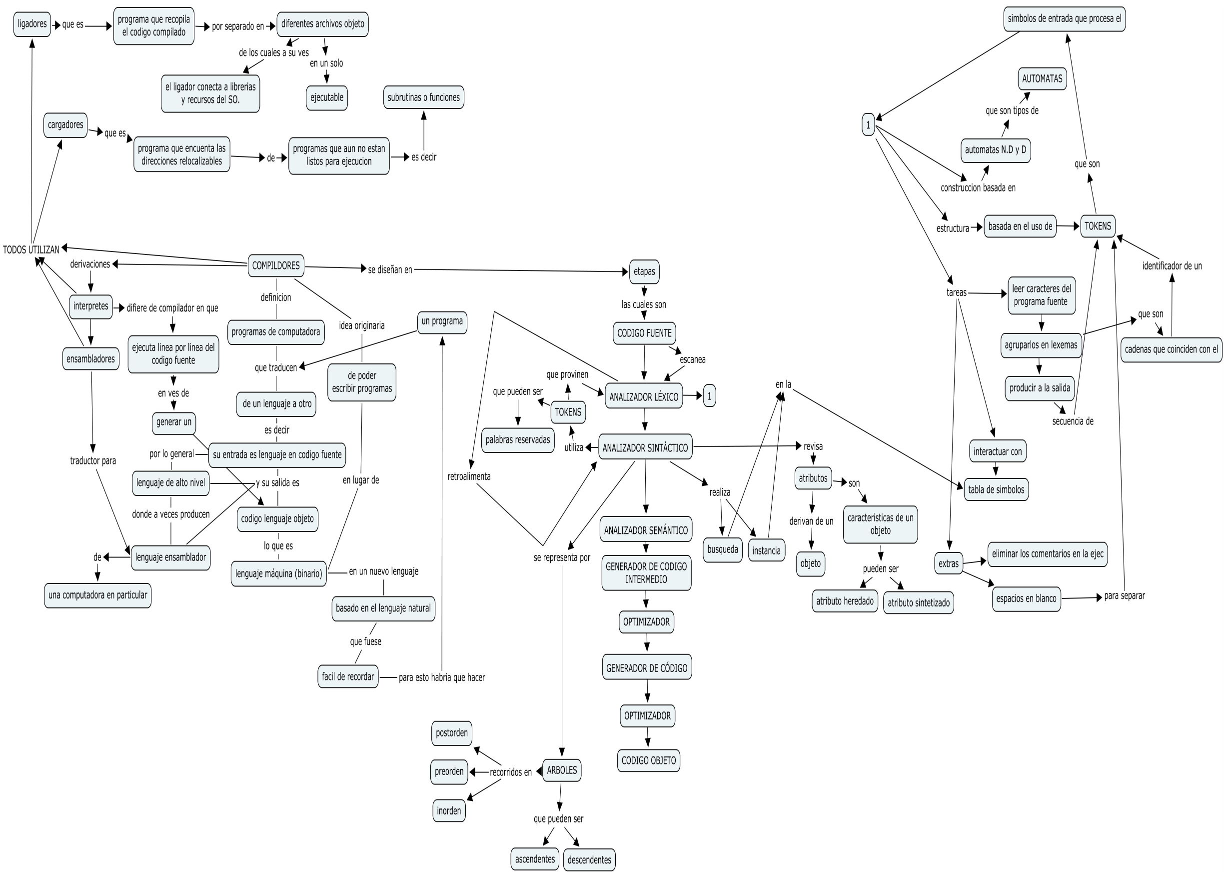

Figura 5. Marco Conceptual de Compiladores propuesto, elaborado como mapa conceptual en ESIME-Culhuacan México.

Además se fue construyendo y reconstruyendo a manera de ensayo por los profesores y se comparó con el que generaron los alumnos para analizar el grado de profundidad y claridad que tuvieron respecto al de los profesores; hubo mucho entusiasmo y expectativas al ponerlo en práctica y obtener los resultados estimados. De igual manera actualmente se trabaja para que mayor número de asignaturas incorporen la técnica de mapas conceptuales para su instrucción y se analicen los resultados obtenidos.

En la siguiente figura 6, se muestra a continuación los primeros resultados de MMCC elaborados por los estudiantes acerca del tema de los Lenguajes y Gramáticas de Contexto Libre, donde notamos todavía, la falta de conceptos claros y desarrollados, la dificultad para explicar con sus deducciones estos mismos, la confusión de algunos al entender los mapas como diagramas de flujo y organigramas, las proposiciones son simples en algunos casos y en la mayoría se presentan confusas, revueltas o copiadas de la fuente obtenida, las palabras de enlace son simples y repetidas, sin embargo la jerarquización es excelente en la mayor parte de los casos por lo que se puede comenzar por trabajar con las estructuras a las que están acostumbrados a desarrollar y desentrañar gradualmente los enlaces y proposiciones al cuestionarlos acerca de los elementos manejados, lo cual, hacen de una manera efectiva, elocuente y clara además de que emplearlos como medio de repaso y ensayo pre – examen, lo que no se trataba en ocasiones anteriores con la respuesta a los cuestionarios y exámenes escritos en este caso que reflejan buenos resultados al obtener mayor calificación, mayor participación, grande esfuerzo intelectual, integración de equipos, creatividad y entusiasmo.

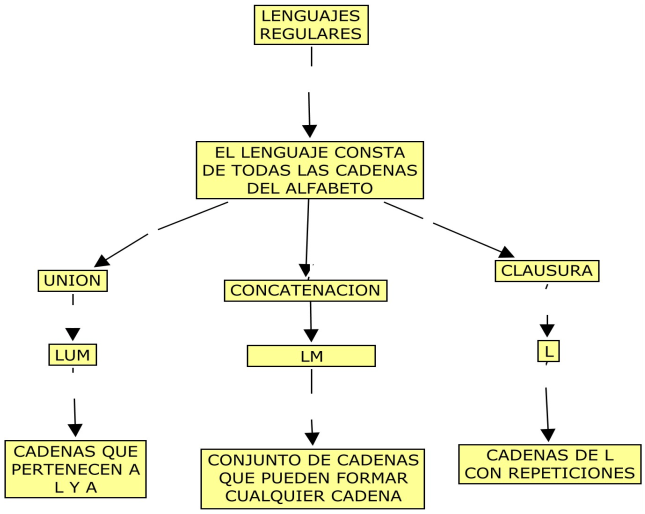

Figura 6. Diagrama confundido por los alumnos como un mapa conceptual.

Notamos también en los primeros mapas elaborados por alumnos de Teoría de Autómatas en referencia al tema de los Lenguajes Regulares, los cuales resultan simples, pues todavía no contienen enlaces elaborados y además en este ejemplo se hace notar diferencias de apreciación y contenido más detallado en la parte derecha de la figura, igualmente que al explicarlo o exponerlo todavía muestran bastante inseguridad y se vacila en los conceptos matemáticos, lo que resulta y merece mayor atención.

En los casos mostrados en la figura se hace notar la confusión comentada anteriormente al enredar un diagrama de flujo con un mapa conceptual, más por costumbre que claridad porque después de haberse corregido se llega al mapa correcto con las reglas elementales.

Al indicar la metodología que se tiene que seguir, la ayuda para obtener más información, la guía para alcanzar un resultado de aprendizaje y los elementos del aprendizaje significativo, los ha sorprendido y entusiasmado por estar acostumbrados a ser receptores y conseguir sólo una calificación respecto a sus tareas y trabajos como aprobación o rechazo del esfuerzo. En cambio de ésta forma alienta y estimula también a los profesores, quienes seguimos trabajando y esforzándonos para alcanzar las metas propuestas y retroalimentar en qué grado de funcionamiento se encuentra esta estrategia y la medida se adaptará acorde con el tipo de asignaturas y su contenido. De lo anterior nos queda claro también que los alumnos tratan de ser abstractos y no explícitos por la influencia de la literatura relacionada a la Teoría de Autómatas y cuando se explica mediante el uso de mapas, cuesta trabajo en un principio desarrollar y buscar relaciones entre niveles diferentes y examinar las palabras de enlace adecuadas en vez de sustantivos simples.

La figura 7, es prototipo del mapa sugerido completo y profundamente desarrollado con un mayor número de relaciones propuestas por un profesor experto de Teoría de Autómatas, con el cual, a través de un diagrama destaca correctamente los puntos de oportunidad entre la labor elaborada y conseguida por los estudiantes y el objetivo de aprendizaje.

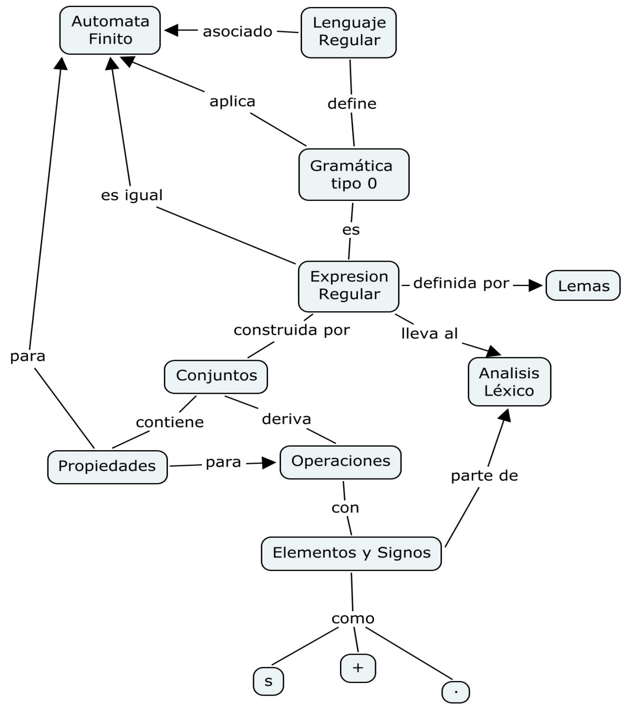

Figura 7. Mapa conceptual del tema Lenguajes Regulares elaborado por alumnos.

A su vez se muestra el mapa conceptual resultante de la asignatura de Compiladores para el tema Tokens construido colaborativamente por maestros y alumnos en la figura 8.

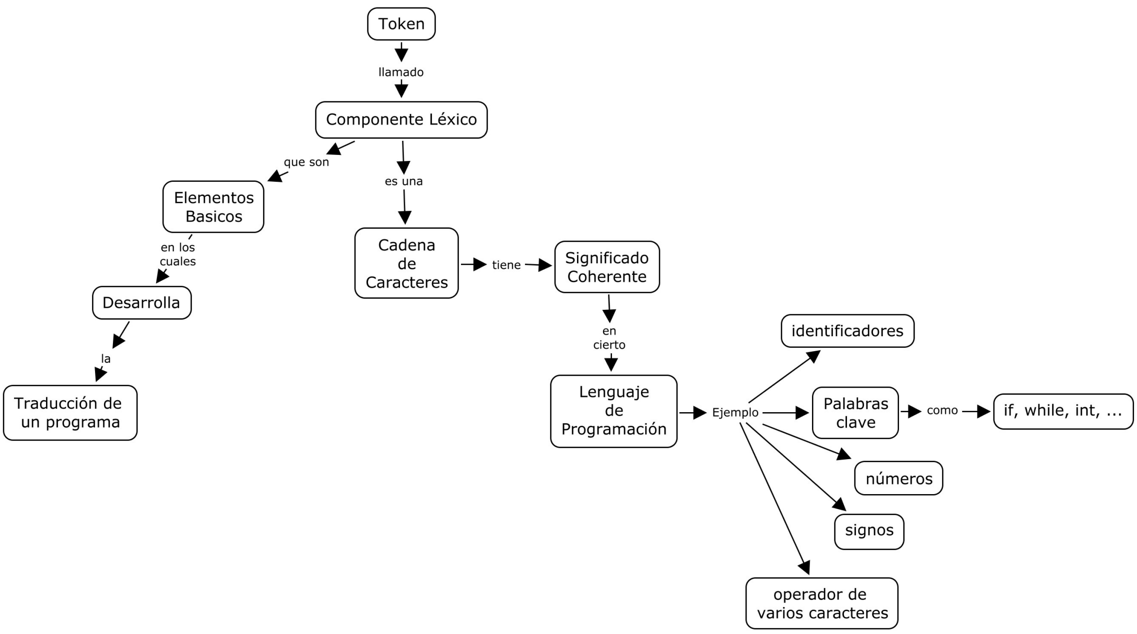

Figura 8. Mapa conceptual de Token construido colaborativamente alumnos – maestro, primera reflexión.

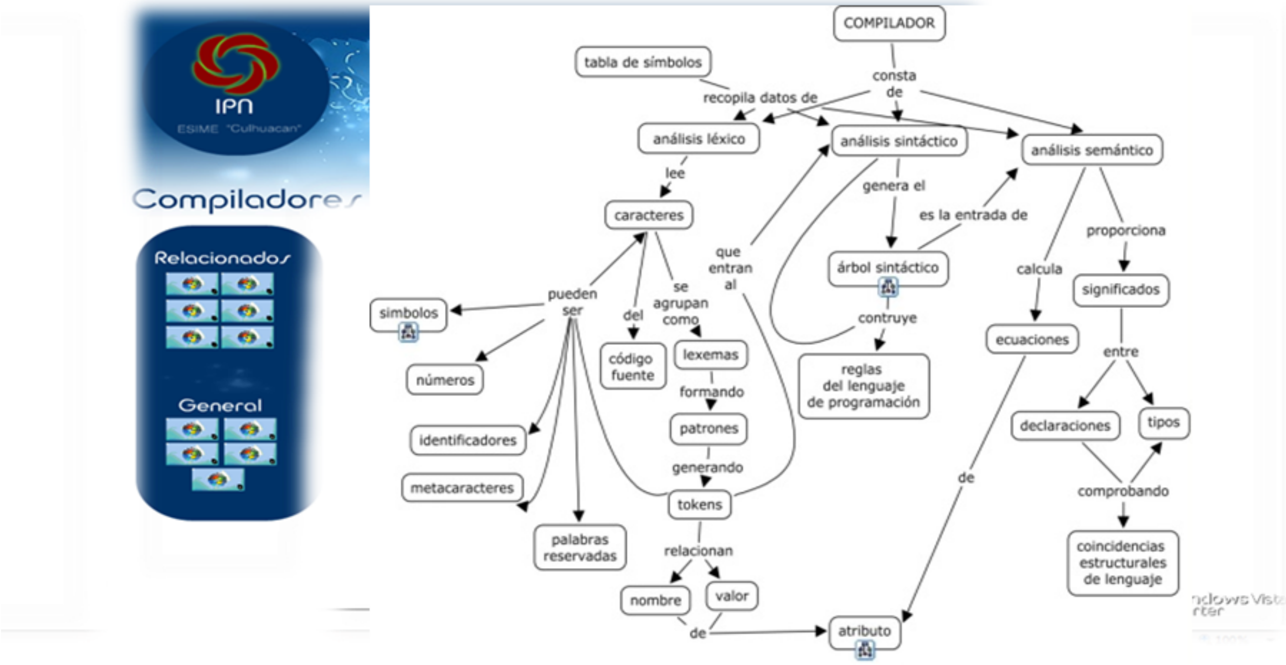

Figura 9: Pagína web de la asignatura Compiladores y su modelo de conocimiento representado como mapa conceptual.

En la última evaluación se realizó un proyecto de trabajo el cual comprendió en hacer una página web académica en donde ellos explicaran y dieran a conocer desde su perspectiva con los conocimientos adquiridos a lo largo del semestre que eran los compiladores, su importancia y la relación con las diversas asignaturas que así lo contemplaran. En la Figura 9 siguiente se muestra el mapa inicial que elaboraron sólo alumnos para la página web.

El mapa de compiladores integrado en la página web final realizado por alumnos muestra una notable mejoría en la elaboración y en la asimilación de conceptos.

Por otra parte, se hace necesario comentar algunos datos que se obtienen del caso práctico como el hecho de que contamos con los apoyos de los diferentes participantes que tienen un nivel de estudios universitario en disciplinas relacionadas con las Ciencias sociales, Administrativas, Informática, Ingenierías en comunicaciones, Computación, Mecánica y algunas otras en menor proporción, sin embargo a pesar de la diversidad, la Sintaxis de Programación aplica para los distintos materiales de todas las disciplinas al elaborarlos ordenadamente y aprovechando los Mapas Conceptuales, se obtuvieron excelentes resultados en las dinámicas de Aprendizaje Significativo con los alumnos y en las evaluaciones que se realizan comparadas con los grupos de control, como se muestran en las tablas siguientes:

49%	**Mujeres**
43%	Mayores a 50 años de edad
16	Experiencia promedio en años
67%	Aprobados sin PE y MMCC
86%	Aprobados con PE y MMCC

51%	**Hombres**
57%	Mayores a 50 años de edad
20	Experiencia promedio en años
65%	Aprobados sin PE y MMCC
85%	Aprobados con PE y MMCC

Tabla 1 Resultados por género de la comparación de aprovechamiento de PE mediante MMCC y sin uso de ellos.

Por último a fin de poder fortalecer e incrementar los conocimientos y experiencias de los participantes aplicando los principios de la Planeación Estratégica con MMCC a través del ejercicio frecuente, estos se realizan con mayor facilidad y se amplia el panorama de aplicación de todo conocimiento, ya que en el mundo globalizado actual, se demanda a profesionistas con un alto perfil de calidad.

5. Conclusiones

En la generación de proyectos de trabajo adoptaron como elemento fundamental el uso de los mapas conceptuales integrando en cada uno de ellos una misión y visión muy particular desde su punto de vista.

Se propició una democratización de roles cuando se llevó a cabo el trabajo en equipo y se superó la resistencia al cambio, esto es, los alumnos al sentirse motivadas adquirieron medidas positivas que se reflejaron en sus trabajos de clase, así mismo, en la elaboración de sus mapas conceptuales facilitaron la adquisición y comprensión de conocimientos.

Los logros obtenidos transformaron la clase tradicional a evolutiva, ya que al integrar la técnica de enseñanza-aprendizaje con los mapas conceptuales los alumnos y las alumnas superaron la clásica clase de apuntes numerosos copiados de los pizarrones generados por el docente a mapas construidos por ellos que facilite y fomente su aprendizaje significativo.

A fin de dar continuidad a los trabajos que ya se han realizado desde educación básica y establecer el uso de la Planeación Estratégica usando MMCC en las Universidades, es necesario actualizar a los docentes.

En las pruebas prácticas realizadas a través de los presentes casos, se comprobó que a pesar de la resistencia al cambio y del escepticismo debemos romper paradigmas en la enseñanza tradicional, la actualización en la aplicación de las nuevas tecnologías como CmapTools, los MMCC y la Planeación Estratégica aplicada correctamente, dan resultados satisfactorios en la enseñanza de hoy y la auto-preparación para el mañana.

El lograr que los docentes apliquen la difusión y enseñanza de los mapas construidos por ellos mismos y en conjunto con los alumnos ponen de manifiesto indudables mejorías.

Si consideramos que la Planeación Estratégica con los Mapas Conceptuales como un reflejo de la forma en que los alumnos tienen estructurado el conocimiento, podemos aseverar que ahora conocen más y mejor. Como resultado los alumnos están en superior situación y dispuestos para futuros aprendizajes.

La utilización del software CmapTools ha involucrado activamente para este caso a los alumnos (docentes) en la construcción de conocimiento, facilitando además el aprendizaje colaborativo y uso de TIC's.

7. Trabajo actual y futuro

En el presente se esta trabajando en un par de asignaturas más Metodología de la investigación y Sistemas Expertos, cuyos profesores se han enterado de los resultados obtenidos aplicando estas técnicas de aprendizaje y también el mismo grupo esta realizando un par de proyectos de investigación, sobre aplicaciones para el desarrollo web y trabajando con estudiantes de posgrado de la maestría en microelectrónica que se imparte en el mismo campus.

La construcción de significados es un hecho individual y es el alumno quien decide el grado de esfuerzo que pone para éste logro, sin embargo, estamos colaborando para que mas profesores ayuden a sus alumnos a lograr tal esfuerzo y que puedan construir y reconstruir sus esquemas personales en el plano conceptual de forma tal que formen y perfeccionen su competencia cognoscitiva.

Por último cabe mencionar que también trabajaremos los EECC mas profundamente, comenzando desde los primeros semestres hacia los finales de la carrera buscando la autocorrección y fomentando el aprender a aprender elemento fundamental del aprendizaje significativo y que seguramente nos reportara valores cuantitativos y cualitativos de mayor calidad y satisfacción observados en los cambios presentes en cuanto a creatividad, actitud, participación y aprovechamiento.

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Journal for Educators, Teachers and Trainers
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ISSN 1989 - 9572

Lessons learned across a decade of knowledge modeling

Las lecciones aprendidas en una década elaborando modelos de conocimiento

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 18 de diciembre de 2012

Fecha de revisión: 20 de enero de 2012

Fecha de aceptación: 10 de febrero de 2013

Hoffman, R. y Beach, J. (2013). Lessons learned across a decade of knowledge modeling. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 85 – 95.

Journal for Educators, Teachers and Trainers
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Abstract
I review lessons learned in the creation of knowledge models composed of Concept Maps. The models were developed in studies of expertise in a variety of domains including weather forecasting, clinical oncology, and terrain analysis. Lessons learned pertain to a number of methodological issues, such as the measurement of the effectiveness of knowledge elicitation methods, issues in organizing, resourcing and navigating large sets of Concept Maps, and issues in comparing computer performance to that of humans.

Resumen
Se hace una revisión de las lecciones aprendidas en la creación de modelos de conocimiento compuestos de mapas conceptuales. Los modelos fueron desarrollados en estudios sobre el conocimiento experto en una amplia gama de dominios, incluidos los de pronóstico del tiempo, oncología clínica y análisis del terreno. Las lecciones aprendidas se refieren a una serie de cuestiones metodológicas tales como la medición de la eficacia de los métodos de elicitación del conocimiento, los problemas en la organización, los recursos y la navegación en grandes conjuntos de mapas conceptuales y los problemas en la comparación del rendimiento de los ordenadores en relación con el de los seres humanos.

Keywords
Concept mapping, expertise knowledge, knowledge modeling

Palabras clave
Mapas conceptuales, conocimiento experto, modelos de conocimiento

1. Introduction

"Knowledge models" are integrated sets of Concept Maps of expert knowledge. NUCES modeled the knowledge of an expert at nuclear magnetic resonance imaging for ventricular function (Ford et al., 1991). The "Return to Mars" project integrated knowledge for the NASA Center for Mars Exploration (Briggs et al., 2004). El-Tech was a knowledge model for debugging and repair of a particular kind of electronic data recorder (Coffey et al., 2003). The Launch Vehicle Systems Integration Model was of the knowledge of a NASA specialist in the Centaur launch vehicle (Coffey, Moreman, & Dyer, 1999). A variety of additional topics have been the subject for modeling: the field of social network analysis, processes in organic chemistry, event logic and causation, engineering in the electric utilities, and the psychophysiology of balance. In this paper, I briefly describe a few projects that highlight some heuristics for model development that emerged during the research.

2. System To Organize Representations in Meteorology

At the Naval Training Meteorology and Oceanographic Facility (Pensacola Naval Air Station) there were a number of senior civilian forecasters who were expert at predicting severe weather. Hundreds of CMaps were made, providing detail on such topics as the use of weather radar, forecasting for thunderstorms, hurricanes, fog and turbulence. (See http://hcs-metoc.apl.washington.edu/hsmetoc_library/pdfs/hoffman_paper.pdf).

The knowledge model STORM included the CMaps that referred to weather of significance for aviation in the Gulf Coast (i.e., turbulence, thunderstorms, etc). The CMaps were resourced with the material in the *Local Forecasting Handbook*. Trainee forecasters studied the model to prepare to qualify as forecasters. Shortly after STORM was finalized, the facility was downgraded to a detachment and the senior civilian forecasters took that opportunity to retire. Were it not for the Concept Maps we had made, all of the experts' knowledge and heuristics would have been lost.

The project involved comparing methods of knowledge elicitation for their effectiveness (see Hoffman et al., 1995; Shadbolt & Burton, 1990). Methods used in the STORM project included protocol analysis, workspace observations, the Critical Decision Method (CDM), the Knowledge Audit, CMapping, and the Cognitive Modeling Procedure. The methods were compared in terms of efficiency, gauged in terms of Total Task Minute (TTM; time to prepare to run a procedure, plus time to run the procedure, plus time to analyze the data) relative to the yield (number of propositions for use in a knowledge model). The methods also identified dozens of leverage points and also yielded behaviorally validated models of the reasoning of expert forecasters (see Hoffman, 2008). Knowledge modeling using CMapping resulted in thousands of propositions covering domain knowledge. The Critical Decision Method yielded a number of richly populated case studies with associated Decision Requirements Tables. Along with short video clips in which expert forecasters discussed forecasting procedures, all of these results from cognitive task analysis were hyperlinked into the knowledge model.

We conducted over 60 hours of CMapping interviews. Full protocol analysis of a single knowledge modeling session took a total of 18 hours to collect and analyze the data. The results confirmed a finding from previous studies (Burton et al., 1990) that protocol analysis (i.e., transcription and functional coding of audiotaped protocol statements, with independent coders) is too time consuming and effortful to have an effective yield. Rather than doing a protocol analysis it would be far more efficient to simply go back and do more CMapping. The total effort taken to develop, refine, and validate knowledge models can vary by orders of magnitude depending on the knowledge elicitation method employed. A rule of thumb we developed is that CMapping can have a yield of 2.0 informative propositions per TTM. Any method having a yield of less than one proposition 1.0 TTM is arguably inefficient.

Another lesson learned was that CMapping mates very well with the CDM. This structured interview method is highly effective as a method for generating rich case studies (Hoffman, Crandall, & Shadbolt, 1998). Previous studies had suggested that the CDM procedure takes about two hours, but those evaluations looked only at session time. The present study involved a more inclusive measure of effort, TTM. We found that for interviewing expert weather forecasters the CDM took about 10 hours per case. The cases are rich because weather phenomena can span days and usually involve dozens of data types and scores of data fields. More importantly, expert forecasters' memories of cases can be remarkably detailed.

3. Thailand National Knowledge Base Demonstration Project

This project demonstrated how the model development process might be conducted at a large scale. Thailand's long-term economic potential depends, in part, on its traditional crafts including silk manufacture. A slide set about Thai silk had been created by Thai field researchers who had interviewed village elders and photographed their activities. We relied on this resource set to create a small knowledge model. This had a CMap for each of a number of silk patterns. The CMaps were resourced with photographs (e.g., of the of weaving, dyeing and other processes) and with text pieces that had been created from the textual material in the original slide set.

A lesson learned in this project had to do with the use of color and backgrounds. Our previous heuristic had been that backgrounds should not contain any high-frequency graphical elements or textures, since the CMap itself (nodes and linking lines) consists of high-frequency graphical elements. Furthermore, it was felt that background images could be distracting. In the Thai silk model, a photo of each silk pattern served as the background for the CMap that described it. The images were adapted graphically to make it look as if one were viewing bolts of cloth in a store display. Next, the concept nodes, text, and linking lines were set in highly contrasting colors.

The effect of these graphical manipulations was that the CMap seemed to stand out from its silk pattern background. Furthermore, our use of contrast suited the Thai aesthetic, which includes the use of multiple contrasting patterns and sharply contrasting colors. A screen shot is presented in Figure 2.

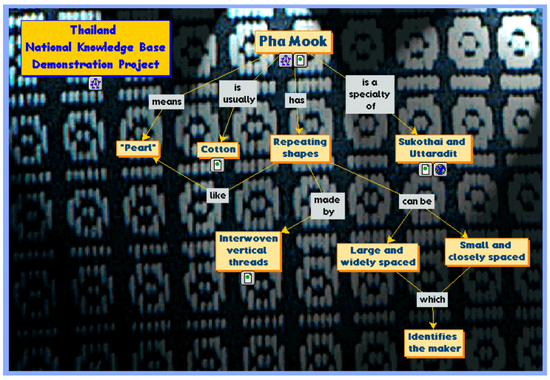

Figure 2. A screen shot from the Thailand National Knowledge Base Demonstration Project.

We still acknowledge the heuristic that such flourishes as background and use of color (in nodes, text, linking lines, etc.) should be used with caution. It is tempting for individuals to use color, for instance, to code nodes according to certain categories. In our experience, once a person begins using color to represent categories, the encodings get too complex and a legend becomes necessary.

4. Representation of Conceptual Knowledge (ROCK) in Terrain Analysis

Difficulty in coping with terrain is a major challenge for military planning and operations. Expert-level knowledge about terrain is presented in documents discussing landforms, soils, rock types, etc. (i.e., Hoffman, 1983; Mintzer & Messmore, 1984). These documents contain photo interpretation keys for landforms of all types, topographic maps, aerial photographs, and text that describes terrain and discusses implications (e.g., trafficability). As traditional documents, the material is neither useable nor useful to the warfighter. We dubbed the process of creating a knowledge model from archived material the process of "knowledge recovery." The Terrain Analysis Data Base (TADB; Hoffman, 1983) is a corpus of about 1500 proposition-like statements about terrain. These had been derived from documentation analysis and structured interviews with expert terrain analysts at the US Army Corps of Engineers. For example, some high-level information about Dunes was represented in the TADB as: *Deserts: Sand and gravel soils; Usually arid climate; Desert varnish tones; Occasional silt soils; Usually with dunes.*

The knowledge model consisted of 150 CMaps, containing of 3,341 concepts, 1,634 linking phrases, and 3,352 propositions (e.g., “deserts usually include dunes”). The CMaps contained an average of about 22 propositions. ROCK was the largest knowledge we had made up to that time. There were multiple CMaps about dunes, terrain over different types of bedrock, effects of climate, and so on. The model's sheer size raised issues about it usefulness. We applied a known principle in the field of psychology, that in information search and perception redundancy is helpful for (understanding, memory encoding). This idea was manifested in our adoption of redundant methods for navigating among the ROCK CMaps.

We created a number of "Top Maps" that organized all the CMaps within terrain categories (e.g., climates, drainage patterns, soil types, rock types, etc.). We also created a number of "Maps of Maps" in which the nodes were all the top nodes in all the Concept Maps. In these Top Maps and Maps of Maps, all nodes that represented top nodes in other Concept Maps were colorized. A highest level CMap was created, called "The Representation of Concept Knowledge in Terrain Analysis." This provided high-level explanatory concepts and served as the user's gateway into the knowledge model. The top concept node in each Concept Map (i.e., its main topic) was hyperlinked to the "Representation of Knowledge" CMap and also to the Map of Maps and the Map of Top Maps. Finally, we created a "piece" of a Concept Map that we called a Navigator. This was added into every Concept Map in the upper left-hand side. This showed how the given Concept Map fit into its subordinating hierarchy of Top Maps. Using the Navigator Cmap Piece, users can navigate up to super-ordinate Top Maps.

While this may all sound confusing, it approximated our goal, which was to enable the user to get from anywhere in the knowledge model to anywhere else in a maximum of two clicks, and never "get lost in hyperspace." An example ROCK Concept Map, bearing its Navigator, is shown in Figure 3.

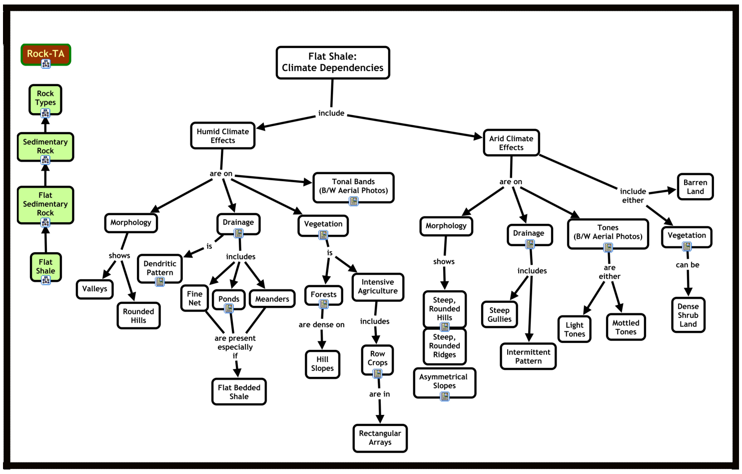

Figure 3. A representative Concept Map from the terrain analysis knowledge model "Representation of Conceptual Knowledge."

The Concept Maps were fully resourced with aerial photos, interpretation keys, text, all of the propositions from the Terrain Analysis Data Base, all of the declarative (versus procedural) knowledge from the Army Field Manual for Terrain Analysis, and all of the data elements tables and photos from the Procedural Guide for Surface Configuration. This process made it clear how resourcing is a non-trivial exercise (for some process recommendations, see Coffey & Hoffman, 2003). It is not solely a matter of combinatorics, because one needs to use each resource in more than one place, and for more than one reason, so each resource might exist under multiple labels or names. The purpose of the resourcing was to enhance the functionality of the model. Our vision for this was that the knowledge model could be used in two ways:

1) “Here is where I am going (e.g., as seen in topographic maps)—what will I see and find when I get there?” In one use context, the unit of action has been issued orders, and can use the model to get expert information about the terrain.
2) "Here is what I see from where I am—what are the implications of this terrain?” In this use context, the model is used to search and discover the rock type, soil type, and other terrain elements that would affect the operation.

What makes it possible to use the knowledge model in these two ways is the Navigator and search feature in *CmapTools* that relies on the propositional structure of the CMaps. Thus, for instance, if one searches the knowledge model for “dune and steep slope” the search engine will find and open the CMap about star dunes (which are a kind of dune that has steep slopes), permitting a comparison of the current view with example terrestrial and aerial photos.

The ROCK Concept Maps were produced at a rate of between 0.25 and 0.22 propositions per TTM. This number falls considerably short of the benchmark for effective knowledge elicitation. Indeed, the yield of 0.2 propositions per task minute is roughly equivalent to that for protocol analysis. The meaning of this calculation should be considered in light of the fact that the participating local terrain analysis "expert" in the Concept Map Refinement stage happened to also be a proficient CMapper. No doubt, the refining a set of Concept Maps would have taken even longer had this not been the case, and the yield of propositions even lower than 0.2 per minute. In light of these considerations, the moral of our results is clear for any organization that in confronting issues involving the loss of expertise (see Hoffman & Hanes, 2003): *Knowledge recovery is costly.* One is better off capturing knowledge in a usable and useful form as a part of the organization's on-going knowledge management program, rather than finding oneself in a position of losing expertise because of retirement, and "wasting" knowledge because it is represented in older forms of media (i.e., hardcopy text) that are not easily compatible with newer hypermedia forms and formats.

5. The TNO Business Model

A number of people who apply Concept Mapping in business contexts have noted that group Concept Mapping often sets the stage for situations where people realize that they have been using the same words but not the same concepts (see Cañas & Novak, 2011). Insights invariably follow, at least in the cases that have been cited. Our experience in the TNO project fit this general description.

TNO, the Netherlands Organization for Applied Scientific Research, conducts research in the public interest in areas including defense, security and safety, environmental and geosciences, and information technology. One of its business units is TNO Human Factors. Its staff includes about 150 researchers. In their periodic Technology Position Audit (TPA). personnel review their progress since the previous evaluation, taking into consideration such things as changes in funding mechanisms and priorities. They re-evaluate the unit's capabilities, competencies, ambitions, and goals. As the time for the 2009 TPA approached, an opportunity arose for conducting a process of knowledge elicitation to support the preparation of the self-evaluation report. Participants were seven senior researchers representing the Departments within the Human Factors business unit.

Total time spent in Concept Mapping was 450 min. The Concept Maps included a total of 420 concepts formed into 440 propositions. Thus, the yield was 440/450 = 0.98 propositions per task minute. Much of the session time had been devoted to describing Cmapping and the *CmapTools*, explaining the process of hyperlinking Concept Maps and resources, and explaining the strategies used by the facilitator and the Cmapper to manage the sessions. Ordinarily, these activities are conducted in a workshop-like context and not in the knowledge elicitation sessions themselves. With this in mind, a yield of 0.98 is considered to be a reasonable yield. This determination should be taken in light of the fact that it was not the purpose of this activity to result in a complete set of refined Concept Maps. The intent was to delibertely leave some work unfinished so that TNO personnel might gain experience and practice at the process.

In the opinion of TNO, the Concept Maps proved useful in the preparation for the TPA. Cmapping forced the departments to be explicit about their ambitions, plans, and product portfolio. Knowledge that had been tacit was made explicit. Differences among the departments could be harmonized by using a common framework provided by the Concept Maps. The Concept Mapping process allowed all of the departments, for the first time, to capture and share their understandings of their business models to achieve a common purpose.

For example, the participants engaged in discussion of such concepts as "adaptation," "societal impact," and "short-term market potential." Pointers to a need for improved shared understanding of a business model included disagreements about what is important, subtle differences in the interpretations of key concepts, and even disagreement about what the key concepts are. A striking emergent was the lack of shared understanding of the meanings of such basic terms as “goal” and “ambition.” Considerable time was spent getting the CMaps right about these notions.

This CMapping activity was suggestive of how this can be conducted to describe business models, and how those can be used as templates to support integration across business units. The use of

CMaps to represent the business model of an organization is an application that has claimed success (Novak, 1998), and the emergence of disconnects in the understanding of fundamental concepts is a phenomenon that has been noted.

6. Developing Information Infrastructure for Cancer Treatment

This project was a collaboration with the H. Lee Moffitt Cancer Center and Research Institute, to develop a information repository that would support data extraction and meta-analysis for knowledge discovery in the treatment of cancer. Part of the activity would be to integrate clinical notes made by attending physicians, oncology specialists, and others involved in patient care. A capability for automated language processing was necessary because conversion to digital format of 30,000+ clinical notes would be very time consuming. The language understanding capability would have to be adapted to the terminology and telegraphic style that is utilized (e.g., *Patient is status post liver biopsy, Patient recurred with liver metastasis, Patient was staged as an early T1 N0 squamous cell carcinoma, Patient presents with pain*). How well would the language understanding system compare to the human in terms of identifying the propositions that are in a clinical note? To address this question, a set of clinical notes were turned into propositional diagrams. The question of how well CMaps represent the ideas expressed in text has been researched within the Concept Mapping community (e.g., Villalon, Calvo, & Montenegro, 2010). Helfgott and Novak (2010) demonstrated how Concept Maps and Concept Map-like diagrams can be used to represent medical clinical information, to describe such things as blood pressure and its measurement, the medical decision making processes, and anatomical structures and their clinical indicators.

Some clinical notes we analyzed were brief—100 or so words. Some were comparatively long (500 or more words). Text pieces of that size will contain many dozens of propositions, far too many to be included in a single CMap. Our heuristic from the STORM project was that once a Concept Map grows to having more than about 35 concepts (or about 35-40 propositions) it becomes too large to be viewed without scrolling. Most clinical notes had "Patient" as either the explicit or implicit topic of the concept, so many of the propositions would be like the examples above. This would mean large numbers of propositions all linking out from the concept node "Patient," and this too would make for a very ungainly Concept Map.

Most assertions in the clinical notes include temporal references. This sequence had to be included in the analysis, but this meant that we would be making process diagrams. We had developed a heuristic for making process diagrams in the STORM project, in which we made diagrams describing the formation of storms. The heuristic was to embed the process inside a Novakian CMap that uses propositions to provide the "explanatory glue" that is often left implicit in process diagrams. But this heuristic would not work for the clinical notes. An example of, the format we finally settled upon is presented in Figure 4, and Figure 5 shows a close view of a portion of this diagram.

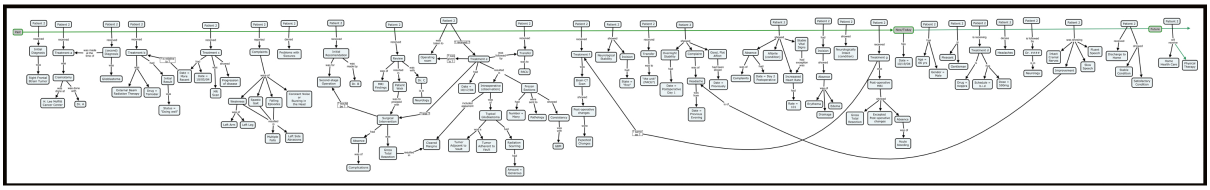

Figure 4. A representative diagram created to capture all of the propositions in a clinical note.

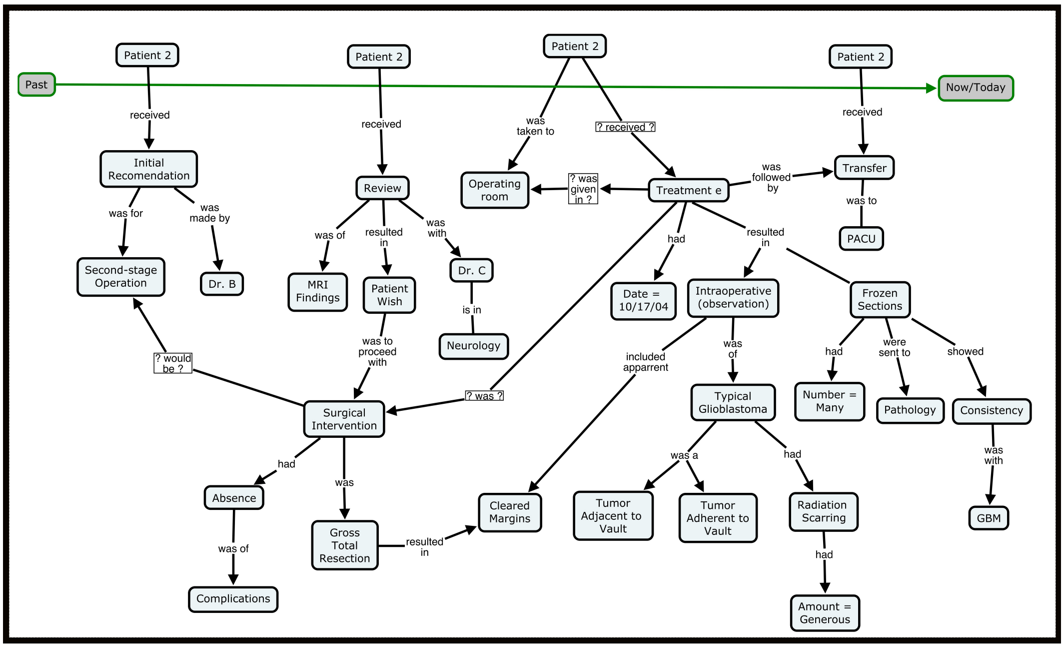

Figure 5. A closer view of a portion of the Figure 4 diagram.

We analyzed 46 clinical notes for 10 patients. The resulting 59 diagrams had over 3,000 propositions. It took a total of 48.5 hours to draft, verify and finalize all the Concept Maps, for an efficiency of 1.04. We felt that this was reasonable given the unusual nature of the diagrams we had to create.

The natural language understanding system used in this project was called TRIPS (UzZaman & Allen, 2010). How well would this make the sorts of bridging inferences that a human makes when reading text (e.g., "Patient x is male. He is 63 years of age.")? TRIPS identified 93% of the keywords (concept-terms) and 59% (range of 40% to 93%) of the propositions in the human-generated CMap versions of the clinical notes. This latter figure requires some explication. TRIPS does not generate propositions, in the sense of ordered triples, it generates tree structure representations of sentences using its specialized syntax and grammar (e.g., for the representation of temporal relations). Consequently, concepts in a meaningful diagram (made by a human) that would be in a proposition can be distanced from one another in the tree structure generated by TRIPS. Perhaps the easiest way of understanding this is that a TRIPS representation always has "sentence" as the top node in a tree, and everything branches downward from that. An example is presented in Figure 6. Reading upwards from "her" (the patient), this says that <her, has, breathing>, <breathing, is, stable>. The patient "her" is linked to both stable and breathing, with no intervening nodes. Thus, we could not simply count propositions identified by TRIPS. We had to have a criterion, which was that the two concept-terms in a proposition were linked (meaningfully connected) and were close to one another in the TRIPS downward-branching representation. Propositions were considered to be properly output if there were zero to three nodes separating the keywords. The clinical notes that resulted in the poorest TRIPS performance were ones that were composed of run-on sentences, incomplete sentences, syntactic deviants, etc. that caused problems for the TRIPS system.

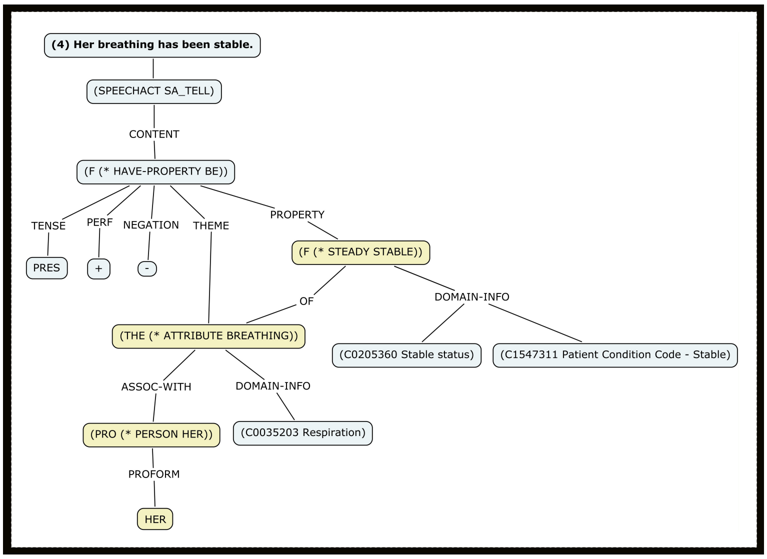

Figure 6. A portion of a TRIPS analysis of a clinical note. The two concepts that appeared as a proposition in the Concept Map are highlighted.

The lesson learned is that comparing human-generated Concept Maps to computer analyses can be anything but straight-forward. Calls for software systems that can automatically generate good Concept Maps from free text have been raised many times in the past, and we still see such calls occasionally. The issue is not how can such computer systems be created, but how far can such systems go in making half-way decent Concept Maps, that a human can then refine?

Another lesson learned is that diagramming of processes, procedures, cycles, event structures, etc. is possible and *CmapTools* is very useful, though resulting diagrams can to deviate from the Novakian form. That being said, our heuristic is to remain vigilant that process descriptions are faithful to certain cardinal aspects of Concept Maps. Our initial heuristic—about embedding the process description inside a Concept Map—is still viable. But as diagrams become more dependent on the representation of temporality (e.g., to describe unfolding events, as in our clinical notes CMaps), there can be "Novakian pieces" within the larger diagram.

7. Conclusions

Some of our heuristics have remained stable over these decades of knowledge modeling, such as the caution about the use of graphical flourishes and color, the size of good CMaps, and ways in which CMaps should use space and meaning (see Crandall, Klein, & Hofman, 2006). Our ideas about knowledge elicitation have matured significantly. We have an empirical base for making claims about the effectiveness and efficiency of CMapping relative to other knowledge elicitation methods. We have an understanding of how Concept Mapping marries well with other knowledge elicitation methods, to enable researchers to paint a complete picture of expert reasoning and knowledge. Our appreciation for the scale and scope of expert knowledge and the scale and scope for knowledge models has grown. For even the most critical or tacit knowledge of an expert, one can expect a knowledge model to need over of 100 Concept Maps. Therefore, modeling efforts need to have a clear focus. Our ideas about how to use *CmapTools* have been challenged and our heuristics have been refined, especially regarding the diagramming of processes and events.

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Journal for Educators, Teachers and Trainers
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ISSN 1989 - 9572

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Mapas conceptuales y el problema fundamental de moverse entre las estructuras de conocimiento

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 20 de noviembre de 2012

Fecha de revisión: 15 de diciembre de 2012

Fecha de aceptación: 29 de diciembre de 2012

Kinchin, I. (2013). Concept mapping and the fundamental problem of moving between knowledge structures. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 96 – 106.

Journal for Educators, Teachers and Trainers
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Abstract
A concept map provides a 'snap shot' of a student's understanding that is frozen in time by drawing it out on paper or on a computer screen. However, to represent the dynamic state of student learning, concept maps either need to emphasise dynamism (through the phrases that are chosen to act as links within the propositions that form the map), or need to be viewed as a single perspective on a more complex situation that can only be fully appreciated by considering movement between knowledge structures (e.g. through sequential mapping over time, or by indicating relationships between map structures that represent complementary learning contexts). The recognition of the importance of movement between knowledge structures needs careful management, whether teaching is conducted as a face-to-face activity or (increasingly) as a digital/online activity. Existing models of e-learning development (such as the TPACK model) can be modified to accommodate a multiple perspectives view. When the purpose of teaching is the promotion of students' ability to move between knowledge structures (rather than acquiring a single structure), the purpose of producing a concept map changes and becomes part of a wider dynamic process of learning, rather than providing a static record of what has already been learnt.

Resumen
Un mapa conceptual ofrece una "instantánea" del entendimiento de un estudiante, la cual se congela en el tiempo al dibujarla sobre un papel o en una pantalla de ordenador. Sin embargo, para representar el estado dinámico del aprendizaje de los estudiantes, los mapas conceptuales necesitan enfatizar dinamismo (a través de las frases que son elegidas para actuar como enlaces dentro de las proposiciones que conforman el mapa), o necesitan ser vistos como una perspectiva única de una situación compleja que sólo puede ser apreciada en su totalidad al considerar el movimiento entre estructuras de conocimiento (por ejemplo, a través de la construcción de mapas secuenciales en el tiempo, o indicando las relaciones entre las estructuras del mapa que representan contextos de aprendizaje complementarias). El reconocimiento de la importancia del movimiento entre estructuras de conocimiento requiere un manejo cuidadoso, sea cual sea la enseñanza se lleve a cabo como una actividad cara-a-cara o (como ocurre cada vez más) como una actividad digital / en línea. Los modelos existentes de desarrollo de e-learning (tales como el modelo TPACK) pueden ser modificados para acomodar una vista de perspectivas múltiples. Cuando el propósito de la enseñanza es el fomento de la capacidad de los estudiantes para moverse entre las estructuras de conocimiento (en lugar de la adquisición de una sola estructura), el objetivo de producir un mapa conceptual cambia y se vuelve parte de un proceso dinámico de aprendizaje más amplio, en vez de proporcionar un registro estático de lo ya aprendido.

Keywords
Complementary knowledge structures, qualitative analysis, structural transformation.

Palabras clave
Estructuras complementarias conocimientos, análisis cualitativo, transformación estructural.

1. Introduction

"*Moving from a linear structure to a hierarchical structure and back again is in some ways the fundamental educational problem.*"
Novak and Symington (1982: 08)

This comment by Novak and Symington offers an important insight to the ways in which concept mapping may be used to support learning, and also offers a method of linking the educational theory that underpins concept mapping with other contemporary learning theories (Kinchin, 2012a). The important point to make is that this line from Novak and Symington starts with the word, '*moving*'. It is this movement that needs to be conveyed within concept maps if they are to address this '*fundamental educational problem*'.

There are numerous potential benefits to be gained from mapping knowledge (e.g. Wexler, 2001), but it cannot be assumed that they will all be realised in every intervention that employs maps. As Tzeng points out:

> "*concept maps with different strategic orientations may lead to the formation of different mental representations … therefore, instructors need to know exactly what they intend… to determine whether the design of their concept maps effectively conveys their instructional objectives*". Tzeng (2010: 143)

Therefore, there needs to be a clear rationale for mapping and the way it will be employed. Concept mapping can be implemented in a variety of ways that may allow the students or research subjects various degrees of freedom in terms of structure and content (Cañas *et al.*, 2012), with consequences for the resulting map structures. Restricting freedom (by determining concepts to be included or layout to be adopted) will give a higher degree of standardisation of maps, and this is more important when they are being used as a research tools as it allows maps to be compared. Development of maps in 'free form' may be more important when they are being used as a learning tool.

Concept maps can illustrate the difference between a student's emergent understanding and experts' agreed knowledge. However, unless the underlying structure of the discipline has been made explicit during a programme of instruction (e.g. Donald, 2002), there is no reason to suggest that the morphology of the student map should simply represent a smaller version of the expert map. There may be a 'tipping point' in a student's learning (possibly through the acquisition of a 'threshold concept' – Meyer and Land, 2003) where the acquired content may start to show some transformation towards the agreed expert structure.

Clariana (2010: 119) considers that the tasks involved in the creation of a concept map leave markers described as '*cognitive residue*' within the map. These include the *selection* and *grouping* of concepts; *identifying propositions* and *adding linking phrases* to show the meaning of the proposition and finally revising the map to reflect both the *structure of [the learner's] knowledge* and an *internalized graphic grammar*. The key is to get the right balance between the idiosyncratic nature of personalized knowledge construction in the form of an agreed visual grammar that is intelligible to others. However, as a note of caution, it is clear that students can be wrestling with the construction of new understanding whilst also 'testing' the grammar of the concept map, such that what may appear to an observer to be a mess may be a powerful learning tool for the student constructing the map (Johnstone and Otis, 2006).

Concept mapping seems to offer the most valuable contribution to student learning where the mapping task mirrors the actions undertaken to practise the discipline being studied (Di Carlo, 2006). So, for example, in the teaching of physiology, students who are encouraged to construct concept maps are actively integrating the components of the subject and identifying causal relationships between them in a way that also typically reflects the desired learning outcomes of a physiology course (Henige, 2012).

2. Complementary structures

Whilst there has often been a tendency to score maps to provide a clear and simple way of recording a student's progress, there needs to be some caution with this approach as the reduction of the rich insights to a student's learning offered by a map in this way has the potential to lose vital information. For example, studies that look only at the '*proportion of correct ideas produced in the concept map*' (e.g. Karpicke and Blunt, 2011: 773) fail to acknowledge that some concepts are more important than others in the construction of understanding (Mintzes and Quinn, 2007), or that students who may include a lot of correct information in their maps may not always include the most important terms or, indeed place those key terms in the most appropriate space on the map (Clariana and Taricani, 2010). It is also clear that students who produce 'poor' concept maps can fall equally into the first and fourth quartiles of normal assessment regimes (Johnstone and Otis, 2006). This is because some of the poor maps can indicate students have a weak grasp of the ideas under discussion whilst other (more knowledgeable students) can produce an apparently poor map as this may be sufficient for them to act as a 'set of keys' to retrieve information from their memory and support their reasoning strategies. This suggests that concept mapping may be viewed primarily as a learning tool rather than as an assessment tool (Johnstone and Otis, 2006). In most scoring protocols, there is an underlying assumption that bigger equals better. But with this starting point, one can be misled when expert maps can be smaller than novice maps of the same subject. This occurs because experts can select the key concepts and explanatory links that are economical in presentation. A more nuanced appreciation of student understanding that goes beyond the quantity of information recalled and requires an acknowledgement of the structure and quality of maps to complement the content that is included.

Qualitative analyses of concept maps have resulted in the proposal to consider them by reference to their gross morphology, as spoke, nets, chains (Kinchin, Hay and Adams, 2000) and cycles (Safayeni *et al*., 2005) figure 1. These structures have been shown to be indicative of particular learning orientations. Spokes tend to offer no more insight to understanding than a bulleted list and are often accompanied by static linking phrases. Chains appear to correlate with rote learning and tend to be learned as a complete sequence that is resistant to development. Networks seem to be most closely associated with meaningful learning, especially when the linking phrases are dynamic and explanatory. The cycles offer the greatest degree of dynamism and are often linked with iterative learning processes in which the meaning of concepts can evolve with each turn of the cycle. These structures each have their roles to play in student learning and they are not mutually exclusive as one structure may evolve into another over a period of time so that a spoke structure may develop into a chain or a network as the student's understanding is elaborated in response to further learning.

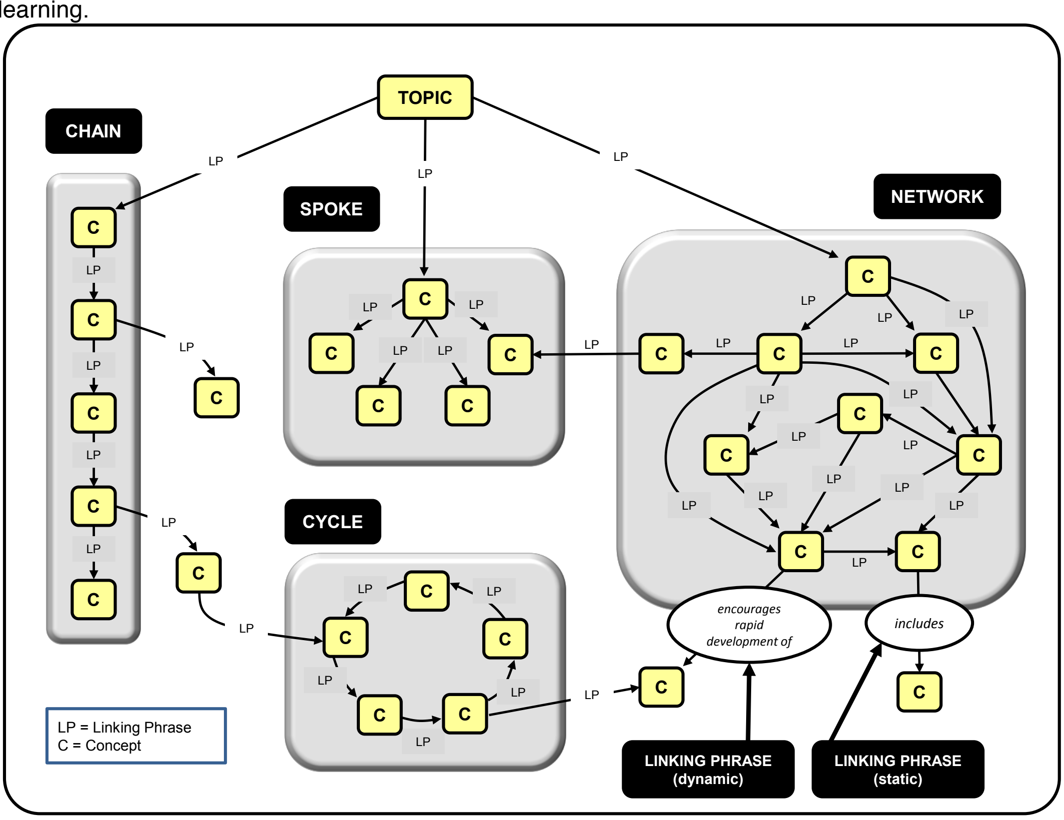

Figure 1: The features of concept maps that include chain, spoke, cycle and network morphologies (modified and re-drawn from Popova-Gonci and Lamb, 2012).

It is also clear that whilst some structures are more or less contextually appropriate in a given situation, the student needs to appreciate this and to construct understanding accordingly. With this perspective has emerged the idea of "*the expert student*" as "*one who recognises the existence and complementary purposes of different knowledge structures, and seeks to integrate them in the application of practice*" Kinchin (2011: 187). Part of this appreciation is concerned with the relationship between processes and products of learning (Kandiko and Kinchin, 2012), and the relationship between theory and practice.

The important distinction between procedural and conceptual knowledge has been explored by Schneider and Stern (2010) who analyse the various theoretical viewpoints on the causal interrelations between these kinds of knowledge: summarised as *unidirectional* (concepts-first or procedures-first), *bidirectional* (iterative) or *no causal relationship* (inactivation). Conceptual knowledge is usually viewed as general and abstract whilst procedural knowledge is seen as practical knowledge that is often automated and tied to specific problem types. Figure 2 shows how the procedural and conceptual components of understanding may be illustrated using concept maps. The top map (A) was produced by an expert in the field of dental anaesthesia. Here was can easily see what it is that she wants her students to be able to do (illustrated by the chain of yellow concepts on the left). But for the students to understand what they are doing and to be able to control this chain so that it may evolve over time, it is important that it is closely associated with an understanding of the process (summarised in the network of blue concepts on the right).

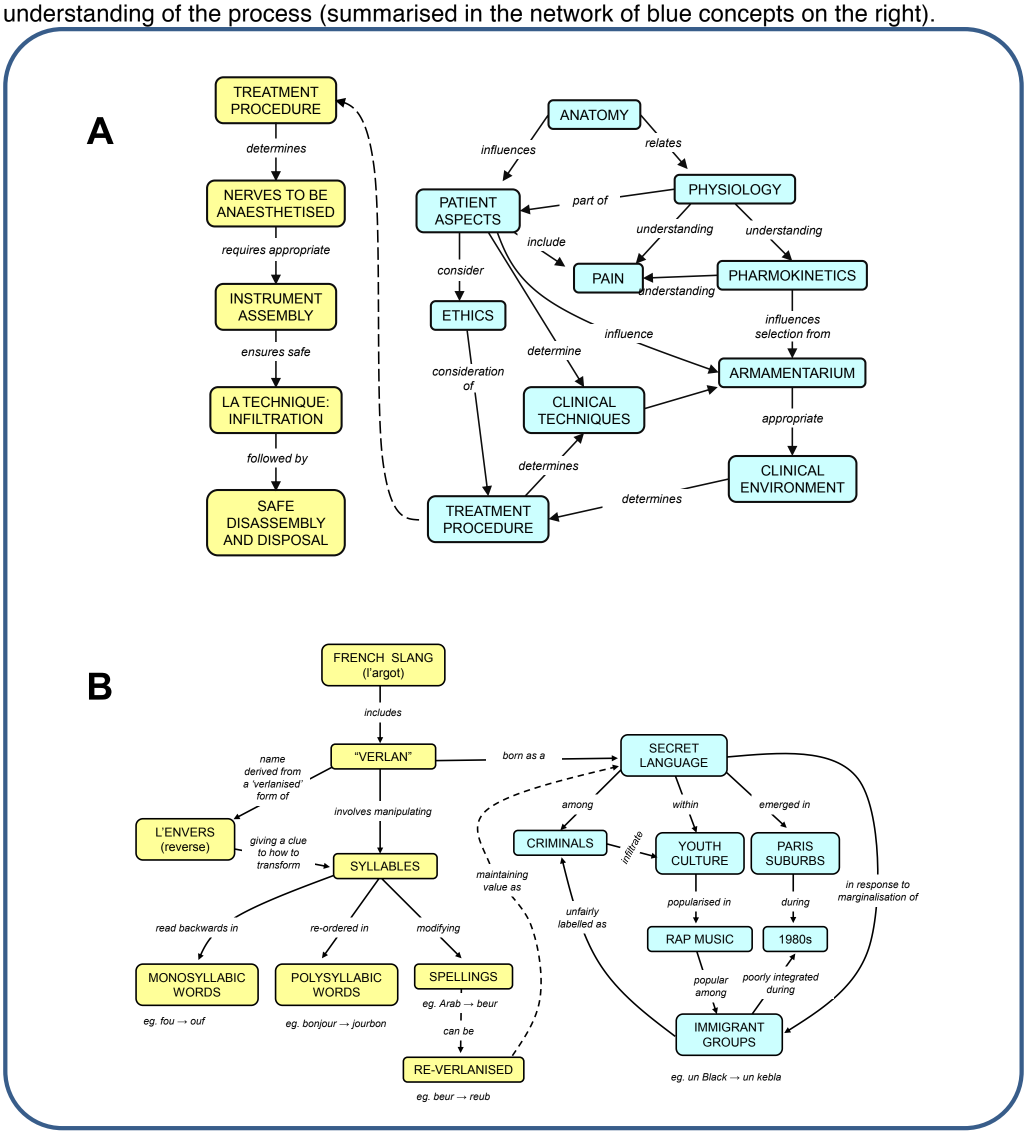

Figure 2: Complementary linear (yellow) and network (blue) structures can appear within a concept map, indicating the procedural and conceptual components of understanding. Part A: an 'expert' map of dental anaesthesia; Part B: a student map of French slang.

The lower map (B) was produced by a student during a lecture on French grammar. Here we can see the emergence of a similar dual structure in which the practice of French slang ('verlan') is illustrated by the yellow concepts on the left and the underlying social context for this language use is described by the network of blue concepts on the right. In comparing the two maps (A & B) we can see that the expert map (drawn by the dental teacher) has a clearer distinction between the procedural and the conceptual. The chain of practice (yellow) is well-rehearsed and made as simple as possible. This in an indication of expert practice in a context where speed of action is crucial. In contrast, her network of understanding is rich and tightly integrated as she has reflected upon her knowledge and her teaching in some depth. In comparison, the student's map of French grammar is not so well-developed in as much as the chain of practice (yellow) is not as simple (therefore, offering less certainty in use) and the network of understanding (blue) is not as highly integrated as the network in map A. This student has not had the same amount of time for consolidation and reflection as the expert – it was drawn during the lecture. Therefore, the map is not as well-developed, showing an emerging structure rather than an expert structure.

An additional reason for the greater level of distinction between the chain and the network in dentistry is that the elements of the chain (clinical practice) and the elements of the network (clinical science) are taught by different sets of teachers, at different times and in different physical spaces. This emphasises the separation. In the French class, however, the teaching of the chain and the network were undertaken by the same teacher within a single class – allowing the teacher to relate the two components for assimilation by the students. Kinchin and Cabot (2010) have claimed that one of the attributes of professional experts is that they are able to oscillate meaningfully between the linear and the hierarchical. Whereas practitioners can move between these structures in a seemingly automated manner, expert teachers need to be able to reflect on these transitions and provide ways to make them explicit and accessible for their students. Tsui (2009) has termed this '*practicalizing theoretical knowledge*' and '*theorizing practical knowledge*' and considered this ability to be one of the distinctive qualities of expert teachers.

3. Knowledge structures in the digital classroom

As an increasing proportion of teaching occurs within a digital/online environment, it is important to ensure that the pedagogical principles developed in face-to-face teaching are not lost or neglected as practice is transferred from analogue to digital settings, as the focus can be diverted from students to the computer technology they are using. The TPACK (Technology, Pedagogy and Content Knowledge) framework has been proposed by Koehler and Mishra (2009) as means to consider the interacting elements of technology, content and pedagogy in order to inform the development of technology-enhanced learning. This offers an excellent medium in which to consider the interactions of the key elements. The typical depiction of the TPACK framework as a two dimensional representation (i.e. length and width, but no depth) portrays a mono-layer of possible interactions between the three main elements (Figure 3):

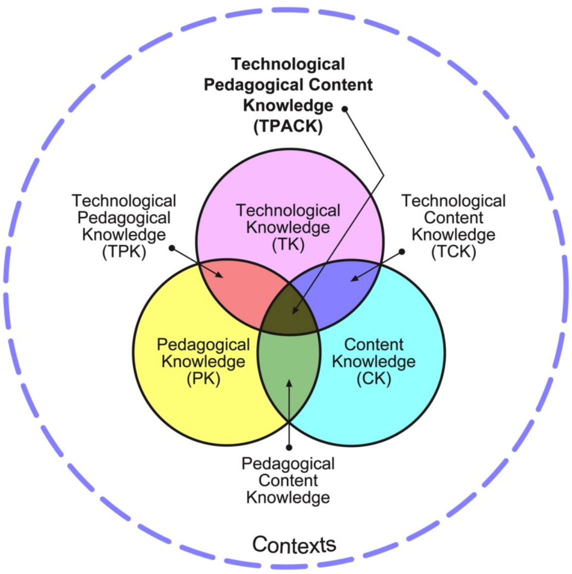

Figure 3: The TPACK framework (from http://tpack.org/ with permission)

Howard and Maton (2011: 193) comment on the TPACK framework as an example of '*models that list what knowledge is of, but which do not then analyse the forms taken by that knowledge'*. They go on to comment that '*what is required is a means of not only seeing knowledge but also moving beyond empirical descriptions of knowledge practices to analyse the principles underlying those practices*' (*ibid.*: 194). This perceived weakness of the TPACK model can be addressed by applying a knowledge structures perspective through concept mapping, which provides a mechanism to enhance the utility of the framework by revealing these underlying practices (Kinchin, 2012b).

A knowledge structures perspective suggests that the two-dimensional model represents only the surface view of the interactions between the three elements, concentrating on the linear structures that define them (i.e. the mechanisms and processes that are made public and recognizable by all concerned), and so blurring the relationship between procedural and conceptual knowledge. For example, the actors inhabiting each of the model segments (academic developers, e-technologists and teachers/researchers in the disciplines) are defined by their observable actions (academic development; production of technology solutions; delivery of content in the class). However, underpinning each of these characteristic actions (defined as *linear chains of practice* by Kinchin and Cabot, 2010), are knowledge bases that provide the understanding for the development for these actions (defined as *networks of understanding* by Kinchin and Cabot, 2010). If the surface view was the only level of the model, then interactions between the three areas would be difficult as a meaningful exchange of information is hindered by the linear nature of the knowledge structures involved – leading to a non-learning outcome (as described by Kinchin, Lygo-Baker and Hay, 2008). However, for each of the three sectors visible in the surface view of the TPACK model (Figure 3), there is another level that underpins those observable actions. This level is taken for granted by those who occupy a particular sector of the model (academic developer, e-technologist, teacher/researcher), but may be invisible to occupants of the other sectors, or to students. By making the underlying level of the model explicit to all, this issue may be overcome (Figure 4):

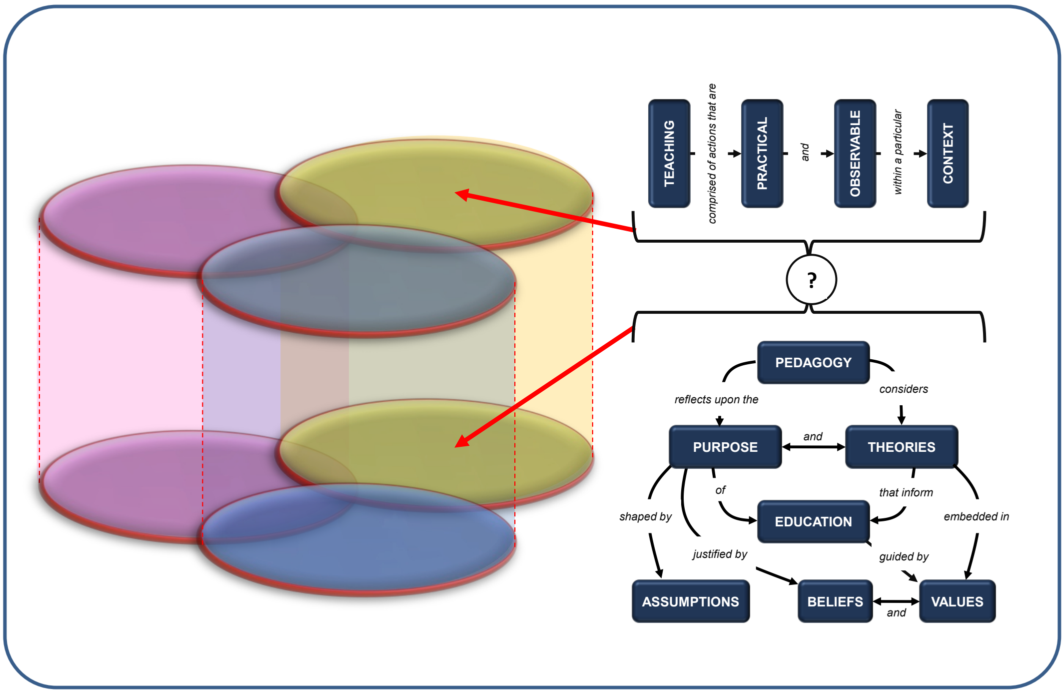

Figure 4: An oblique view of the TPACK framework to reveal the lower layer (composed of hierarchical networks of understanding) that is often obscured by the surface layer (composed of linear chains of practice). Structural components of the pedagogical knowledge section are shown as an example.

Within figure four, we can see that the circle representing pedagogical knowledge can be viewed as a bilayer. The top layer (usually visible to the outside observer and the focus of attention for colleagues working within a disciplinary area – Yiend *et al.*, 2012) consists of the procedural knowledge that consists of the linear practice of teaching. The underlying circle (often obscured from external view) consists of the underlying values, beliefs and assumptions that contribute to an understanding of pedagogy.

Adding this extra dimension to the TPACK model allows for the better alignment of the evolution of e-learning to other contemporary theories of learning and curriculum development such as Bernstein's sociology of education (e.g. Czerniewcz, 2010), Ausubel's assimilative learning theory (e.g. Kinchin, Lygo-Baker and Hay, 2008), and Meyer and Land's threshold concepts theory (e.g. Kinchin and Miller, 2012). This is achieved by considering the multiple perspectives that the authors cited above would describe respectively as, "*interactive discursive planes*" (Czerniewcz, 2010), or "*complementary knowledge structures*" (Kinchin, Lygo-Baker and Hay, 2008; Kinchin and Miller, 2012). It also re-asserts the underpinning role of pedagogy in the development of innovative teaching approaches (Kinchin, 2012a; 2012b). When TPACK is viewed in this way, it becomes apparent that its applicability goes beyond the subset of teaching that is often characterized as technology-enhanced learning, and its more general relevance to university teaching becomes apparent. The artificial separation of *e-learning* from *everything else* then becomes redundant as the implicit dominance of technology within the model gives way to the explicit recognition of the essential underpinning provided by pedagogy. This addresses the call made by Clegg, Hudson and Steel (2003: 51) to re-focus attention "*away from the functionality of e-learning environments back to the core relations between students and teachers*".

The previous lack of recognition of the underlying layer of the TPACK model also provides a possible explanation for the way in which e-learning has been reported to have failed to deliver the anticipated disruption of traditional teaching practices. For example, Blin and Munro (2008: 488) describe the dominant use of virtual learning environments (VLEs) to present, *"static", content-based resources such as web pages and lecture notes*', whilst Hemmi *et al*. (2009: 20) are critical of '*a conservative dependence on pre-digital metaphors, signs and practices*' in which the '*structural linear hierarchies of the commercial VLE relate to a logic associated with analogue writing technologies*'. When public linear discourses are seen to dominate the traditional discourse of non-learning (as described by Kinchin, Lygo-Baker and Hay, 2008), the conceptual, hierarchical knowledge structures that tend to be held more privately by stakeholders in the TPACK framework (teachers, e-learning technologists and academic developers) can be overlooked. However, the interaction between the linear and the hierarchical is where the observer is likely to find novel applications that will, in turn, provide the impetus for disruption that appears to have been absent from the application of many innovative ICTs in higher education (e.g. Conole *et al*., 2008).

Acknowledging the structure of the underlying layer of the TPACK model through concept mapping has implications not only for the design of e-learning materials, but also for modes of teaching and assessment. Teaching can no longer be seen as the transmission of a single perspective, but must support the students' conceptual movement between linear and hierarchical knowledge structures (as discussed by Novak and Symington, 1982). In the application of digital technologies to teaching, Kaipainen *et al.,* (2008: 477) concluded that a single perspective should be regarded as a '*transient'* and '*partial'* view of a complex environment, and that a '*more profound comprehension emerges in the course of an iterative process of exploring the data from alternative perspectives*'.

4. In Conclusion

Student learning does not occur in a vacuum. It has a context in which the student makes sense of what is going on. This is why 'controlled experiments' can be difficult to design in the field of classroom teaching. By controlling the environment to make it replicable, it is difficult to retain the ecological authenticity that enables educational research to impact upon classroom practice. The nature of the curriculum and the relationship between student and teacher is difficult to replicate between researcher and student. Where the fit is not acknowledged, the observed results gained can run against observations from authentic classroom practice (e.g. Karpicke and Blunt, 2011). The curriculum helps to provide this context, but in order for concept mapping to have a role in the students' learning, it must complement the way in which the curriculum is applied, and the assumptions that follow from that – in Wexler's terms, the '*who, what and why*' (Wexler, 2001). Piihl and Philipsen (2011) have used the conceptual lens provided by Gibbons *et al*. (1994) in their studies looking at the teaching of entrepreneurship. Piihl and Philipsen consider that the context-independent knowledge that students acquire in lectures (what they term the 'mode 1 curriculum') can be viewed as different from the context-dependent knowledge created through the solving of practical problems ('mode 2 curriculum') in terms of the 'theory-of-application' employed by each. By this they mean that in mode 1 the teacher acts as expert, based on the premise that they hold the appropriate knowledge to be taught. However, in mode 2, the teacher needs to be able to construct the knowledge that is necessary for a given situation and should be seen more as a change agent.

Moving from mode 1 to mode 2 is analogous to the description of 'crossing the threshold from discipline expert to discipline practitioner', as described by Behari-Leak and Williams (2011).

It would seem that the mode 1 curriculum would be representative of the decontextualized research environment in which the students are encouraged to produce concept maps that are static representations of acquired knowledge, whereas the mode 2 curriculum would be a more dynamic environment in which the maps are seen as tools to aid the construction of understanding. The latter would seem to fit best with the constructivist underpinnings of concept mapping (Novak and Cañas, 2007), where map morphology and linking phrase quality are key indicators of active learning (see Figure 1). The 'mode 2' curriculum mode aligns with Wexler's assertion that, "*knowledge maps must direct the search for information, not end it*" (Wexler 2001: 251).

Clariana (2010: 128) warns against '*training participants to create hierarchical concept maps, whether the domain organization is hierarchical or not*' as this will '*alter the obtained knowledge structure improperly towards hierarchical relationships*', and goes on to comment that this could '*devastate the relationship between the artefact obtained and the participant's actual knowledge structure'*. Whilst concept mapping rules offer helpful guidelines and help to maintain consistency of presentation to assist in analysis for research purposes, they should not be used to inhibit expression of understanding among learners or to create conflict with disciplinary ways of thinking. The structure of the discipline must be acknowledged when observing maps from various contexts. Indeed, where the learning context is 'interdisciplinary' in nature (such as in the clinical sciences) it should be anticipated that a possible duality of structures may co-exist (as seen in Figure 2A), and that this duality may actually define that particular area of study/practice (e.g. Anderson and Schönborn, 2008; McMillan, 2010) as theory and practice combine to form disciplinary expertise.

In their consideration of the complex processes involved in learning through problem-solving, Wu and Wang (2012) propose a dual mapping learning environment that may serve as a visual affordance for improving problem solving and the underlying knowledge construction process – as well as the transformation between the two. Whilst Wu and Wang (2012) consider complementing the concept mapping of knowledge structure with argument mapping to document problem-solving behaviour, the process of reciprocation between the processes is similar to the combination of problem-based learning (PBL) and concept mapping to relate the practice of physical education and the underlying concepts of physiology (reported by Baena-Extremera and Granero-Gallegos, 2012), and the chains of practice and networks of understanding produced by concept mapping that are described as components of professional expertise by Kinchin and Cabot (2010). The key point that is common to these studies is the structural transformation that links the two components (Kinchin and Miller, 2012), as predicted thirty years earlier by Novak and Symington (1982).

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Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

ISSN 1989 - 9572

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 15 de febrero de 2013

Fecha de revisión: 04 de marzo de 2013

Fecha de aceptación: 12 marzo de 2013

Mendonça, C. (2013). El uso de mapas conceptuales progresivos como estrategia de enseñanza y aprendizaje en la formación de profesores de Biología. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 107-121.

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Resumen
La investigación realizada con alumnos de la formación de profesores tuvo como objetivo comprender cómo el uso de los mapas conceptuales puede favorecer el aprendizaje significativo. Se parte del hecho de que los futuros profesores presentan dificultades en el aprendizaje de varios conceptos. Se considera que los mapas, como instrumento didáctico, es un valioso instrumento de diagnóstico y evaluación, favoreciendo el aprendizaje de conceptos. Durante la intervención pedagógica, se buscó evidenciar la evolución de los mapas hechos, antes, durante y después del estudio de un tema propuesto. El análisis de los mapas se centró en los procesos de enseñanza, aprendizaje y evaluación y tuvo un enfoque cualitativo. En este momento, el objetivo fue verificar si los alumnos consiguieron relacionar los conceptos estudiados, según los principios de la diferenciación progresiva y de la reconciliación integradora, investigando indicios de aprendizaje significativo. La intervención tuvo una duración de 45 horas, estudiando un tópico de la Zoología, cuyo concepto fue Elefantes, en una Universidad Pública de Brasil. El análisis cualitativo de los mapas manifestó, en el 58% de los casos observados, que los mejores resultados fueron en los mapas finales, demostrando una evolución del conocimiento sobre el tema. Los resultados indican que los mapas tienen un potencial de acción funcional y eficaz, contribuyendo a la mejora del perfil profesional que se desea formar.

Abstract
This paper presents a study carried out with Biology teachers under training, and aimed at investigating how concept maps enabled meaningful learning. The work was motivated by the fact that future teachers presented difficulties learning various concepts. In this light, maps can be a valuable instrument for the diagnosis and assessment of learning, enabling better concept learning. Thus, during our pedagogical intervention, we have strived to identify the conceptual evolution of students, through the construction of concept maps before, during and after the study of a proposed theme. The qualitative analysis of the produced maps focused on the processes of teaching, learning and assessment. At this point, the goal was to investigate whether or not students were able to relate the concepts under study, according to the principles of progressive differentiation and integrative reconcilitation. This was done while searching for evidences of meaningful learning.The pedagogical intervention lasted for 45 hours (8 meetings), during which a Zoology topic, concept *Elephants* was studied at a State university of Brazil. The qualitative analysis of the maps created by the learners has shown, in 58% of the cases, that there was an evolution of the learners' knowledge of the theme. Obtained results suggest that maps have an efficient functional action and help improve the professional profile under formation.

Palabras clave
Mapas conceptuales, formación de profesores, enseñanza y aprendizaje.

Keywords
Concept maps, teacher formation, teaching and learning.

1. Introducción

Los cursos de Licenciatura en Ciencias Biológicas, en Brasil, son una carrera universitaria de cuatro años, destinada exclusivamente a la formación de profesores para la Educación Básica (Lemos, 2008). El profesor de Biología, legalmente reconocido como biólogo por la Ley nº 6.684/79, tiene su identidad diferenciada por tener, además de la formación específica de biólogo, un conjunto de disciplinas de carácter pedagógico que lo habilitan a enseñar Ciencias Naturales y Biología en la Educación Básica (SEF, 1998).

De acuerdo con el parecer CNE/CES 1.301/2001, que trata de las Directrices Curriculares Nacionales, 2001, el profesor habilitado en Ciencias Biológicas debe poseer el entendimiento del proceso histórico de construcción del conocimiento en el área biológica, en lo que se refiere a conceptos, principios y teorías, así como la comprensión del significado de las Ciencias Biológicas para la sociedad.

Asumir un nuevo modelo de enseñanza y aprendizaje con calidad implica renovar la forma de enseñar con base en los principios ausubelianos de la diferenciación progresiva y de la reconciliación integradora.

En la diferenciación progresiva, se programan los asuntos de acuerdo con las ideas más generales y más inclusivas de la disciplina, que se presentan en primer lugar. De ese modo, se diferencian en detalles y especificidades (Ausubel, Novak y Hanesian, 1980), cuando los seres humanos son espontáneamente expuestos a un campo completamente desconocido del conocimiento o a un ramo desconocido de un cuerpo de conocimiento familiar.

La reconciliación integradora tiene lugar durante el aprendizaje significativo, en el que hay una delineación explícita de las semejanzas o diferencias entre los conceptos relacionados (Ausubel *et al*., 1980; Mintzes, Wandersee y Novak, 2000). Se refiere, por ejemplo, a los alumnos que aprenden los principios de la clasificación biológica y acaban por comprender las diferencias y semejanzas entre los protistas y los moneras: ambos son formas unicelulares o coloniales, pero unos son compuestos por células procarióticas y los otros por células eucarióticas.

En este caso la comprensión del conocimiento biológico y pedagógico de los futuros profesores de Biología aún no es satisfactoria para poder impartir clases potencialmente significativas. Ante esta realidad, se procuró estudiar y aplicar estrategias poco o nada practicadas en el día a día de las clases, que podrían, de algún modo, facilitar las operaciones cognitivas favorecedoras del aprendizaje significativo (Ausubel, 2002). En este sentido, las dificultades presentadas por los futuros profesores deben ser investigadas tomando como base los principios de la diferenciación progresiva y reconciliación integradora (Moreira, 2006).

De acuerdo con Novak (2000) y Moreira (2008), el Mapa Conceptual (MC), que de modo general, refleja la organización conceptual de una disciplina o parte de ésta, puede ser un buen recurso para esta forma de enseñar y aprender. Por tanto, al asumir el compromiso de enseñar conceptos sobre el tema *Elefantes* e investigar su evolución, se optó por el uso de mapas, como un instrumento de enseñanza y de evaluación del aprendizaje.

El tema desarrollado se inserta en los contenidos curriculares y básicos de la diversidad biológica de los seres vivos. La familia *Elephantidae*, en líneas generales, es un grupo de Seres Vivos, que cuenta con organización celular, que necesita alimentos para obtener la energía necesaria para el ciclo vital nacer, crecer, desarrollar y morir. Integrante del Reino Animal (pluricelulares heterotróficos), perteneciente al Filo Cordata, Clase *Mammalia*, cuyas Especies *Elephas maximus* y *Loxodonta africana* son las especies estudiadas.

La herramienta de enseñanza escogida fue el MC, por ser un instrumento que profundiza las reflexiones sobre el proceso de aprender y enseñar. En esta perspectiva, desarrollar saberes conceptuales sobre *Elefantes* demanda construir significados cada vez más elaborados y atribuirles sentido para que generen nuevos aprendizajes (Novak y Gowin, 1999). En este contexto, se espera una enseñanza que garantice la calidad del aprendizaje conceptual en el sentido de obtener evidencias de aprendizaje significativo.

El análisis cualitativo de los MC elaborados por los alumnos antes, durante y después de la intervención pedagógica es realizado con el objetivo de buscar evidencias de aprendizaje significativo. Este artículo pretende analizar, en momentos distintos, la evolución del aprendizaje de los futuros profesores al elaborar sus MC sobre el tema propuesto.

2. Marco Teórico

Así como Ausubel (2002), Novak (1985) también cree que hay un gran potencial de aprendizaje en los seres humanos. Sin embargo, este autor observa que éste potencial no se desarrolla y muchas prácticas educativas, en lugar de facilitar, acaban dificultando su expresión. De hecho, Novak llega a afirmar que el modelo de instrucción y evaluación más frecuente en escuelas y universidades justifica y recompensa el aprendizaje memorístico repetitivo y con frecuencia penaliza el aprendizaje significativo (Moreira, 2008).

Creados por Novak en la década de 1970, los MCs fueron desarrollados para analizar transcripciones de entrevistas clínicas que pretendían identificar los conocimientos de los alumnos (Novak, 1997). Fundamentados en la teoría de Ausubel *et al.* (1980), los MCs son vistos como instrumento didáctico facilitador del aprendizaje significativo y permiten evidenciar conceptos subsunsores presentes en la estructura cognitiva del alumno.

Los primeros trabajos con MC se realizaron en la Universidad de Cornell. Ejemplos de estos trabajos incluyen Bogden (1977), Moreira (1977) con estudiantes universitarios; más recientemente, con estudiantes de los primeros años de la enseñanza primaria, Kinigstein (1981); en la Enseñanza secundaria Novak, Gowin y Johansen (1983). Los MCs han sido testados con éxito durante años de investigación en centros educativos de enseñanza primaria, secundaria y superior, de acuerdo con lo relatado por Novak y Gowin (1999), Moreira (2010).

La elaboración de MC ayuda a evitar un tipo de enseñanza que lleva a un aprendizaje no sustantivo, arbitrario y memorístico por repetición mecánica. De esta forma, Moreira (2006), Nesbit y Adesope (2006), Novak y Cañas (2010) muestran la necesidad de ampliar su uso en la educación, utilizado como instrumento de enseñanza y en investigaciones que muestre su potencial como facilitador de la enseñanza y del aprendizaje.

3. Metodología

Se realizó un estudio exploratorio en clase, con 36 alumnos, (sexos: 13 masculino, 23 femenino) de la formación de profesores en Biología, participantes del *Segundo Curso de Extensión Universitaria sobre Aprendizaje Significativo y Mapas Conceptuales*. La intervención abordó contenidos específicos de Zoología sobre la familia *Elephantidae*, cuyo concepto principal fue *Elefantes.* Las clases tuvieron lugar durante los finales de semana, en los períodos diurno y vespertino, con un total de ocho encuentros y 45 horas de clase. Los encuentros se desarrollaron de la siguiente forma: los tres primeros encuentros fueron en días consecutivos; veinte días después fue el cuarto y el quinto encuentro; también en días consecutivos; y una semana después, tuvieron lugar los tres últimos encuentros.

Se recogieron los datos por medio de pretest, postest, MC, evaluación final del tema, cuestionario evaluativo sobre el MC y entrevistas semiestructuradas. A pesar de la diversidad de instrumentos utilizados, el propósito de este artículo es presentar sólo el análisis cualitativo de los MC progresivos, confeccionados por los estudiantes, antes, durante y después del estudio, identificados respectivamente como MCI, MCII y MCIII. La elaboración de los mapas fue de la siguiente forma: en el 1er encuentro se realizó el MCI, con el objetivo de evaluar los conocimientos previos de los alumnos; en el 3er encuentro se realizó el MCII y en el 5^{o} encuentro, el MCIII.

La intervención pedagógica se realizó de modo a investigar y a ofrecer recursos para el análisis de la evolución de los MCs elaborados en los tres momentos distintos, buscando evidencias de aprendizaje significativo. Éste será el principal instrumento de nuestra pesquisa. Los MCs investigados se evaluaron con base en el mapa modelo que sirvió de referencia, figura 1, organizado para el tema *Elefantes,* de acuerdo con lo establecido en las DCNs y, por consiguiente, con la planificación del profesor. La creación de ese mapa modelo indica si los futuros profesores están distantes o no del tema propuesto.

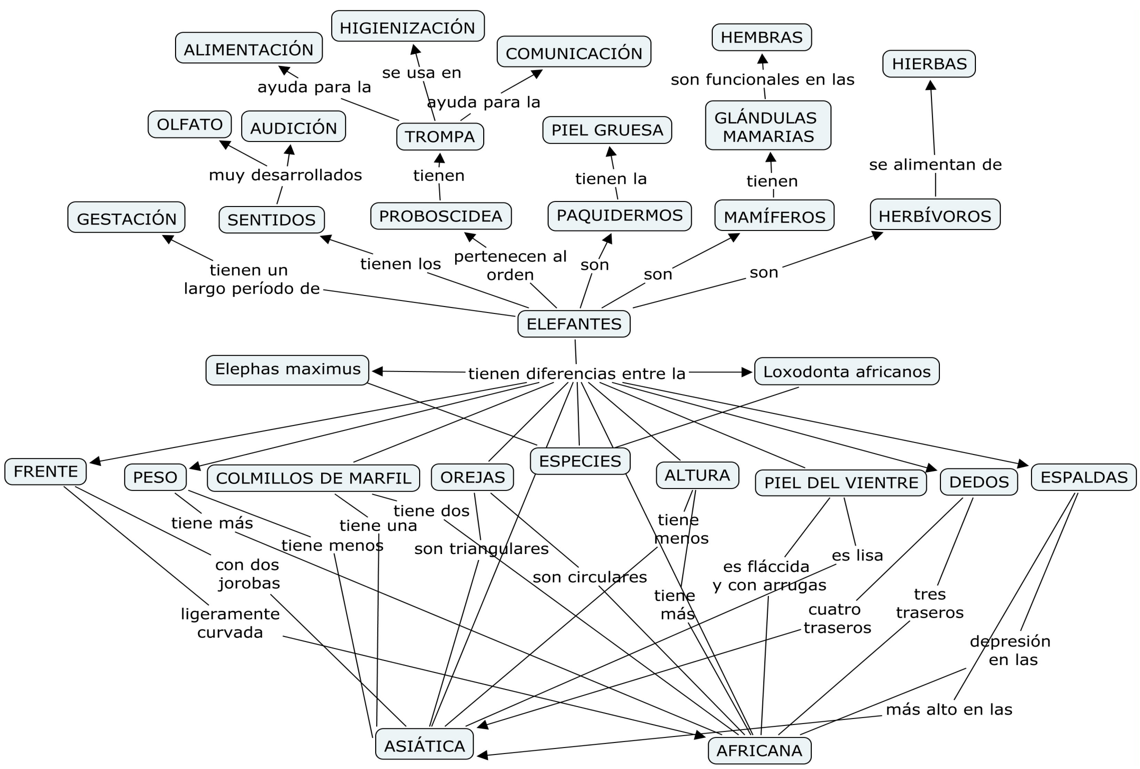

Figura 1: Un mapa conceptual de la pesquisidora sobre el tema Elefantes

Se agruparon en categorías los MCs elaborados en los tres momentos del estudio y fueron analizados conforme a las características e informaciones descritas en el cuadro 1. En este cuadro se presentan las categorías adoptadas en la evaluación de la calidad de los mapas conceptuales presentes en la tabla 1, presentada en los resultados y discusión. En esta tabla se presenta el porcentaje para cada conjunto de mapas realizados en los tres momentos con base en las categorías descritas en el cuadro 1. Los criterios de análisis adoptados se basan en las estrategias para evaluación de MCs, propuestas por Novak (2000). Esta investigación se apoya en el mapa para el contenido, elaborado por el investigador y en los principios de la diferenciación progresiva y reconciliación integradora de Ausubel (2002). En la tabla 2 se presenta la evolución cuantitativa de los conceptos presentes en los tres mapas elaborados por los profesores en formación en los tres distintos momentos.

El análisis cualitativo comparativo de los MCI, MCII y MCIII elaborados se realizó con base en su clasificación en tres categorías: MB, MR y MD, cuadro 1. Con el objetivo de identificar evidencias de aprendizaje significativo en los mapas de los alumnos, se consideraron los siguientes aspectos: el número de conceptos válidos y su relevancia (énfasis en los principales conceptos) con relación al tema; el número de enlaces correctos (simples y cruzados); la adecuación de las palabras de enlace; la validez y relevancia de las proposiciones formuladas; la indicación de ejemplos válidos; la existencia de diferenciación progresiva y de reconciliación integradora. De este estudio se escogieron tres casos como ejemplos para el análisis cualitativo descriptivo.

Cuadro 1: Categorías de análisis de la calidad del mapa conceptual

Categorías	Características	Informaciones importantes

MC Bueno (MB) Indica mayor compre-nsión del tema.	Contiene informaciones conceptuales relevantes; está bien jerarquizado, con el concepto inclusor en la parte superior, después los intermediarios y por último los más específicos.	Palabras de enlace adecuadas, con relaciones cruzadas, proposiciones correctas.
MC Regular (MR) Indica poca compre-nsión del tema.	Presenta algunos conceptos centrales del tema, pero con una jerarquía apreciable.	Las palabras de enlace y los con-ceptos no están claros. Puede realizar enlaces cruzados o no. Muchas informaciones con detalles y repeticiones de conceptos.
MC Deficiente (MD) Indica ausencia de comprensión del tema.	No presenta los conceptos centrales del tema; muy pobre en conceptos sobre el contenido trabajado.	Jerarquía básica, demostrando secuencias lineales y conocimien-tos muy simples.

Resultados y Discusión

En la tabla 1, que describe los mapas elaborados antes de la intervención, se puede observar que sólo 9 alumnos (25%) consiguieron elaborar MB. Los otros 27 profesores en formación (75%) demostraron que tenían algunos conocimientos básicos sobre la materia, que pudieron servir de ancla para nuevos conocimientos, sus mapas se encuadran en la categoría MR. Si ese conocimiento previo se modifica en función de ese anclaje, formará un subsunsor bien elaborado, teniendo como resultado un aprendizaje significativo (Ausubel, 2002).

Tabla 1: **Distribución de los alumnos con relación a las categorías.**

(n=36)	1er momento (antes)			2º momento (durante)			3º momento (después)		
	MB	MR	MD	MB	MR	MD	MB	MR	MD
Total de alumnos	9	27	0	10	26	0	21	15	0
% TOTAL	25	75	0	28	72	0	58	42	0

En los mapas elaborados durante la intervención, se observó un pequeño aumento en el número de mapas en la categoría MB, que pasó para 10 alumnos (28%). En cuanto a los mapas elaborados después de la intervención, indica que hubo un notable avance en el número de MB, que representó 58% del total (21 alumnos). La situación presentada muestra un avance en el aprendizaje conceptual y una respuesta positiva al MC utilizado. El hecho de que haya respuesta positiva a determinado material de aprendizaje demuestra su potencial significativo, condición que hace que se pueda relacionar con la estructura cognitiva del alumno. Además, si hay subsunsores disponibles, favorece el aprendizaje significativo (Moreira, 2008, 2010).

De los 26 alumnos con MR en el 2º momento, 17 consiguieron progresar en la elaboración de sus mapas. Sin embargo, 6 alumnos que habían hecho MB en el 2º momento retrocedieron para MR en los mapas del 3er momento. Eso puede indicar conocimientos previos con poco significado para los alumnos (Ausubel, 2002). El análisis revela que hubo evolución conceptual en el conjunto de los alumnos, apuntando indicios de un proceso de aprendizaje significativo en lo que se refiere al tema *Elefantes*.

El análisis cualitativo de los mapas progresivos muestra las relaciones conceptuales practicadas por cada alumno, o sea, las diagramadas en el MC, de acuerdo con su comprensión. Se verifica una serie de evidencias en cuanto a las representaciones externas de los significados atribuidos sobre el tema *Elefantes*. Como ejemplo, se presentan 3 conjuntos de mapas construidos individualmente, por 3 alumnos durante la investigación, tomados como ejemplos de la evolución del significado del concepto *Elefantes.*

3.1. Análisis Cualitativo de los Mapas Conceptuales

Caso 1 - alumno E3 - MCI

El MCI, figura 2, presenta el concepto general e inclusor *Elefantes*. Enseguida, en el 1er nivel de la jerarquía horizontal, los conceptos: *trompa*, *animales* y *piel gruesa*, que son conceptos relevantes y aceptados, pero no son los centrales. Dos de ellos, *piel gruesa* y *trompa*, son conceptos intermediarios que podrían estar relacionados a los conceptos subordinados *paquidermos* y *proboscídeos*. Este mapa propone una jerarquía vertical, indicando pocas relaciones de subordinación entre los conceptos iniciales. Clasificado como MR, algunos conceptos son relevantes, indicando que el alumno posee en su estructura cognitiva subsunsores que podrán sufrir cambios a lo largo de la enseñanza, dando lugar a nuevos conceptos, más científicos, evolucionados y mejor elaborados.

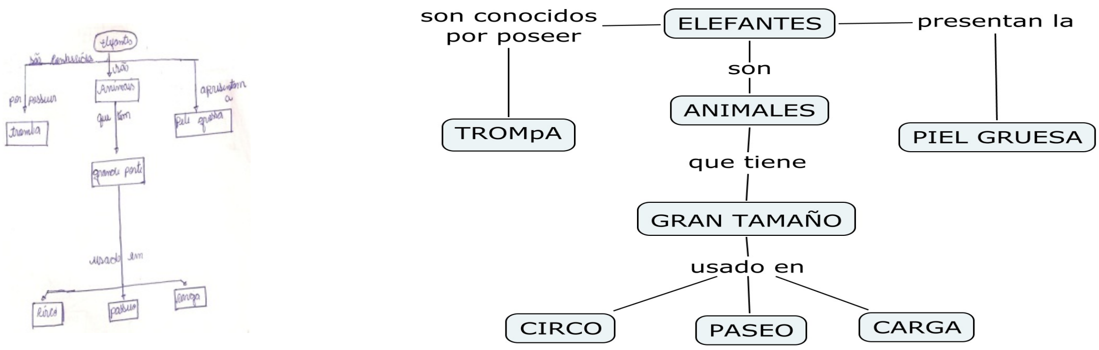

Figura 2: Mapa Conceptual I (E3) - Mapa Regular

Caso 1 – alumno E3 – MCII

El MCII, figura 3, presenta el concepto general e inclusor *Elefantes* y enseguida trae en el 1er nivel de la jerarquía horizontal los conceptos *proboscídeos* y *paquidermos*, que son relevantes. Dos de ellos, *piel gruesa* y *trompa*, son conceptos intermediarios que aparecen en el 2^{o} nivel de la jerarquía horizontal. En el 3er nivel se sitúan los conceptos: *alimentación*, *comunicación*, *higienización*, *protección térmica* y *mamíferos*, siendo este último un concepto central, que debería estar en el 1er nivel.

El MCI tenía los conceptos: *trompa* y *piel gruesa*, que no son centrales para el tema, sin embargo, en este 2^{o} mapa, el alumno cita *proboscídeos* y *paquidermos*, que son conceptos subordinados y centrales. Con relación al MCI, este alumno presenta 10 conceptos nuevos, que priorizan los aspectos relacionados a las características generales de los elefantes. La diferenciación progresiva y la reconciliación integradora están presentes en el mapa al explicar lo que son proboscídeos y cuáles las funciones ejercidas por la trompa. El MCII fue considerado MR, por no haber presentado ninguna relación cruzada entre los conceptos y por no traer ninguno de los conceptos específicos referentes a cada especie, presentando sólo conceptos generales.

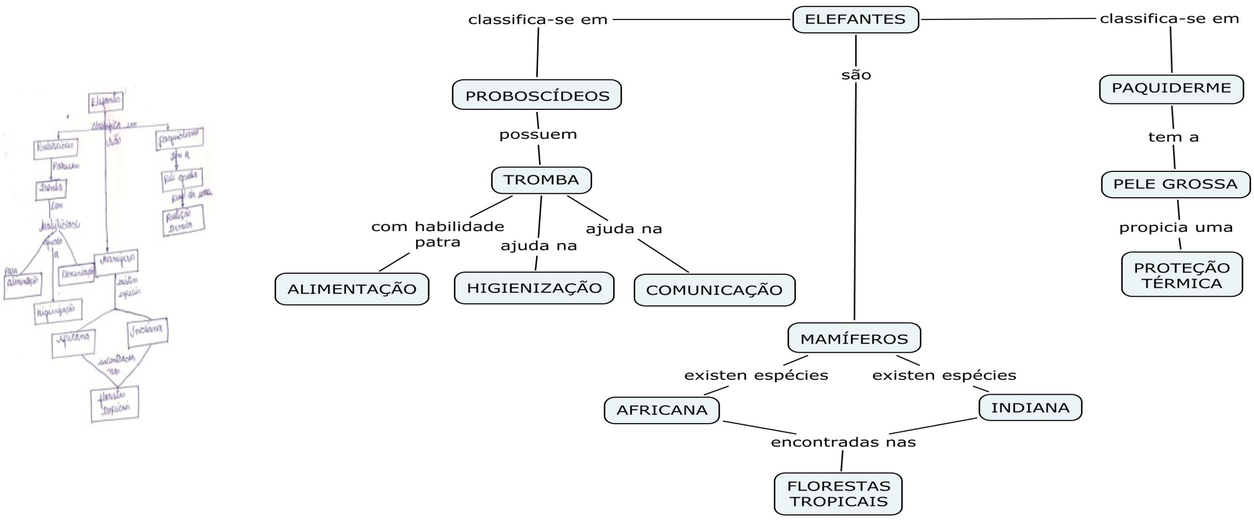

Figura 3: Mapa Conceptual II (E3) - Mapa Regular

Caso 1 – alumno E3 – MCIII

El MCIII, figura 4, presenta el concepto general e inclusor *Elefantes* en la parte superior y en el 1er nivel de la jerarquía horizontal trae los conceptos generales de las especies *africanos* y *asiáticos*. Surgen 2 nuevos conceptos relativos a las características generales de los elefantes: *herbívoro* y *gestación*. Con relación al MCI, hay 10 conceptos nuevos. Comparando el mapa con el MCII, se observa la utilización de conceptos relacionados no sólo a las características generales, sino también a las características específicas de las especies. Durante la presentación de este mapa se observó cómo estructuró, jerarquizó, relacionó, discriminó, diferenció e integró los conceptos del tema estudiado (Moreira, 2006).

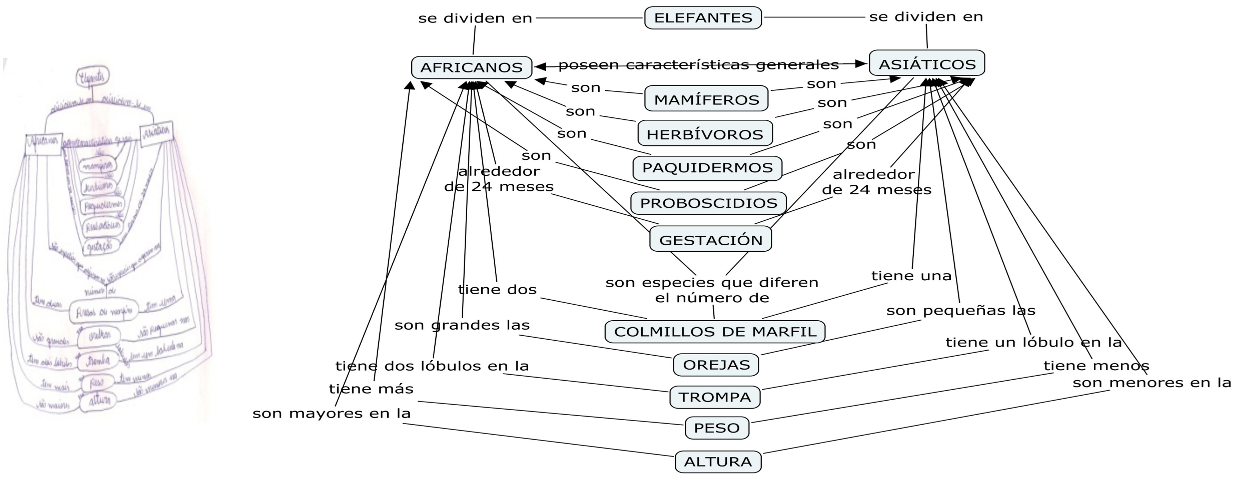

Figura 4: Mapa Conceptual III (E3) - Mapa Bom

Caso 2: alumno E27 – MCI

El MCI, figura 5, presenta como concepto general e inclusor *Elefante*, en la parte superior de la jerarquía vertical. Después, trae el 1er y único nivel de la jerarquía horizontal, los conceptos: *dientes incisivos*, *piel gruesa*, *orejas anchas*, *cuello corto*, *hocico prolongado* y *piernas*. El alumno usa conceptos/ideas de su conocimiento previo, demostrando que posee algunos subsunsores que podrán facilitar el estudio. Por presentar una estructura muy simple, fue clasificado como un MR.

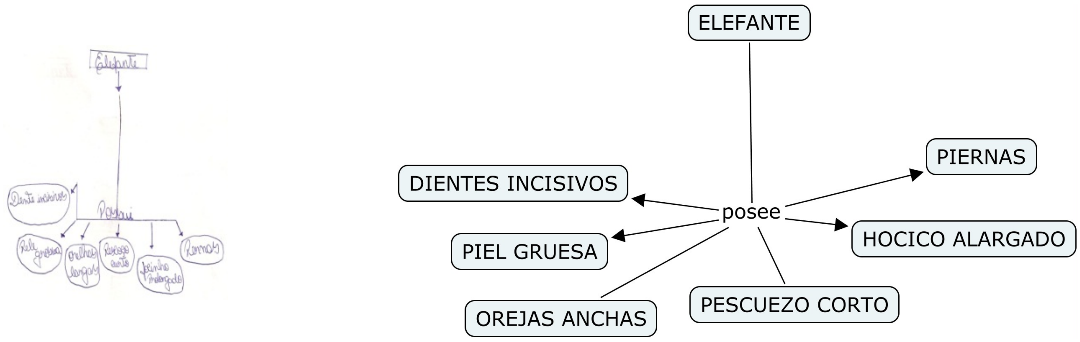

Figura 5: Mapa Conceptual I (E27) - Mapa Regular

Caso 2: alumno E27 – MCII

El MCII, figura 6, presenta el concepto general e inclusor *Elefante* en la parte superior. Enseguida trae en el 1er nivel de la jerarquía horizontal los conceptos *florestas tropicales*, *mamíferos* y *paquidermos*, que se ramifica en tres conceptos: *orejas anchas*, *piel gruesa*, y *cuello corto*. Éstos son relevantes y aceptados en la materia de enseñanza. En el 2º nivel de la jerarquía horizontal aparecen los conceptos *herbívoros* y *proboscídeos*. Este 2º concepto da origen a un 3er nivel, en el cual se citan los conceptos *trompa*, *piernas* y *dientes de marfil*. En el 4º nivel se especifica la función de la *trompa* y los *lóbulos*, así como el formato de las piernas. Los conceptos *herbívoros* y *proboscídeos*, colocados en el 2º nivel de la jerarquía horizontal, son generales, pues valen para todas las especies de elefantes, y por eso deberían estar subordinados al concepto principal. El mapa fue considerado como un MR, pues no establece relaciones cruzadas.

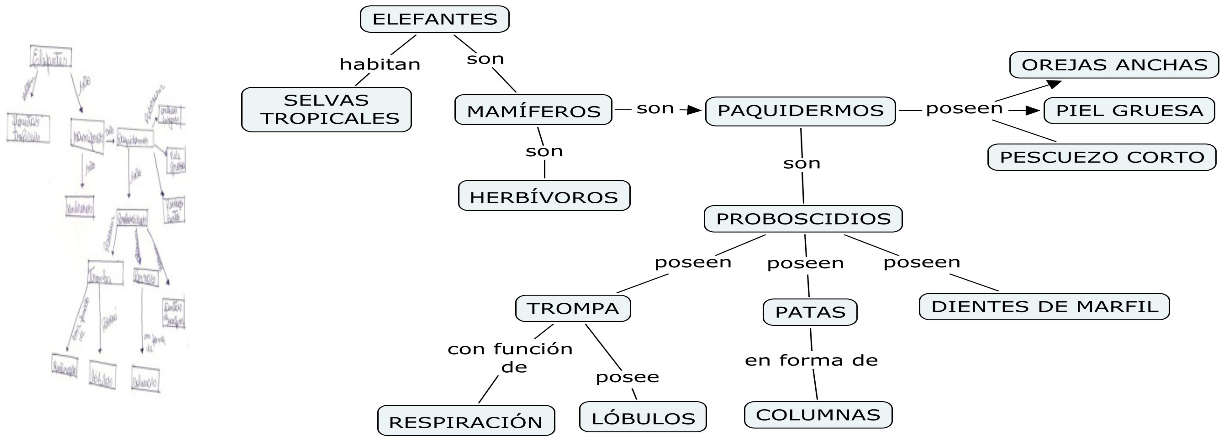

Figura 6: Mapa Conceptual II (E27) - Mapa Regular

Caso 2: alumno E27 – MCIII

El MCIII, figura 7, también presenta como concepto general e inclusor *Elefantes*, en la parte superior de la jerarquía vertical. En ese mismo nivel, en sentidos opuestos, el mapa cita las especies *africana* y *asiática*, y a partir de ahí, los conceptos *herbívoros*, *mamíferos*, *paquidermos* y *proboscídeos*, que son las características generales mostradas en el mapa como los aspectos comunes a las dos especies. En el 4º nivel aparecen los conceptos relativos a los dos tipos de orejas: *circulares* y *triangulares*.

Se observa la evolución del concepto *orejas*, que en el mapa anterior apareció solamente como oreja ancha y ahora es un elemento diferenciador de las dos especies de elefantes, distinguiéndose dos tipos: *orejas circulares* y *orejas triangulares*. Lo mismo ocurrió con el concepto *dientes de marfil* presente en el mapa intermediario, que evolucionó para el concepto *colmillos*. El mapa engloba los aspectos relacionados tanto con las características generales como con las características específicas de los elefantes y demuestra una evolución conceptual. Se consideró un mapa "bueno" porque, de acuerdo con el cuadro 1, cumple todos los requisitos.

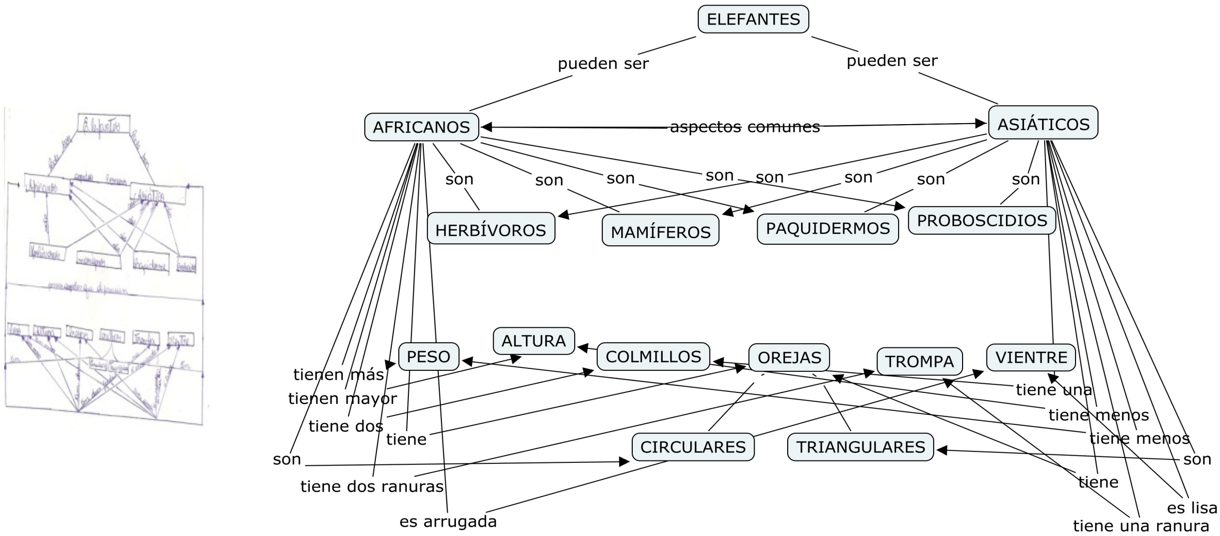

Figura 7: **Mapa conceptual III (E27) - Mapa Bom**

Caso 3 – alumno E8 – MCI

El MCI, figura 8, presenta el concepto general e inclusor *Elefantes* en el centro. En el 1[er] nivel de la jerarquía horizontal está el concepto *dientes* y por encima de éste, en el 2º nivel, la explicación sobre de qué están formados esos dientes. En ese mismo nivel hay una característica específica de la especie, que es la *piel gruesa*. Al lado izquierdo del concepto general está el concepto *sabana,* que es una de las características generales de la especie. En el 3[er] nivel, se especifican las especies *asiáticas* y *africanas* y en el 4º el concepto *vegetales* está caracterizando el modo de alimentación de las dos especies. Fue evaluado como MB, pues presentó conceptos científicos del tema que se iba a estudiar como *colmillos de marfil*, *sabana*, *vegetales*.

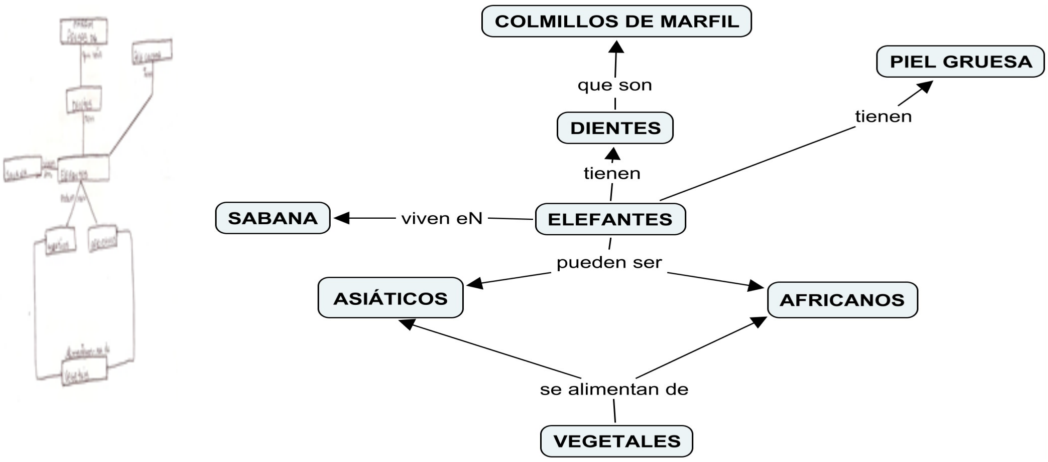

Figura 8: **Mapa Conceptual I (E8) - Mapa Bom**

Caso 3 – alumno E8 – MCII

El MCII, figura 9, presenta el concepto general e inclusor *Elefantes* en la parte superior de la jerarquía vertical. En el 1[er] nivel de la jerarquía horizontal presenta conceptos centrales como: *mamíferos*, *proboscídeos* y *paquidermos*. Presenta en el 4º nivel características específicas con relación a las orejas de cada especie. En la presentación oral de ese mapa, el alumno dio ésa y otras explicaciones. En el 5º nivel, está el hábitat *florestas tropicales* de ambas especies. En el 6º nivel el alumno cita algunos ejemplos de alimentos utilizados por las dos especies y en el 7º nivel, un único concepto, *evolución,* presenta en el mapa la diferenciación progresiva y la reconciliación integradora. El concepto *piel gruesa,* que aparece en el MCI, figura 8, evolucionó para *paquidermo* en el mapa intermedio, figura 9, así como hay nuevos conceptos con relación al MCI. Fue considerado un MB. Ese mapa puede indicar que el alumno posee en su estructura cognitiva subsunsores que pasaron por cambios positivos a lo largo de la enseñanza.

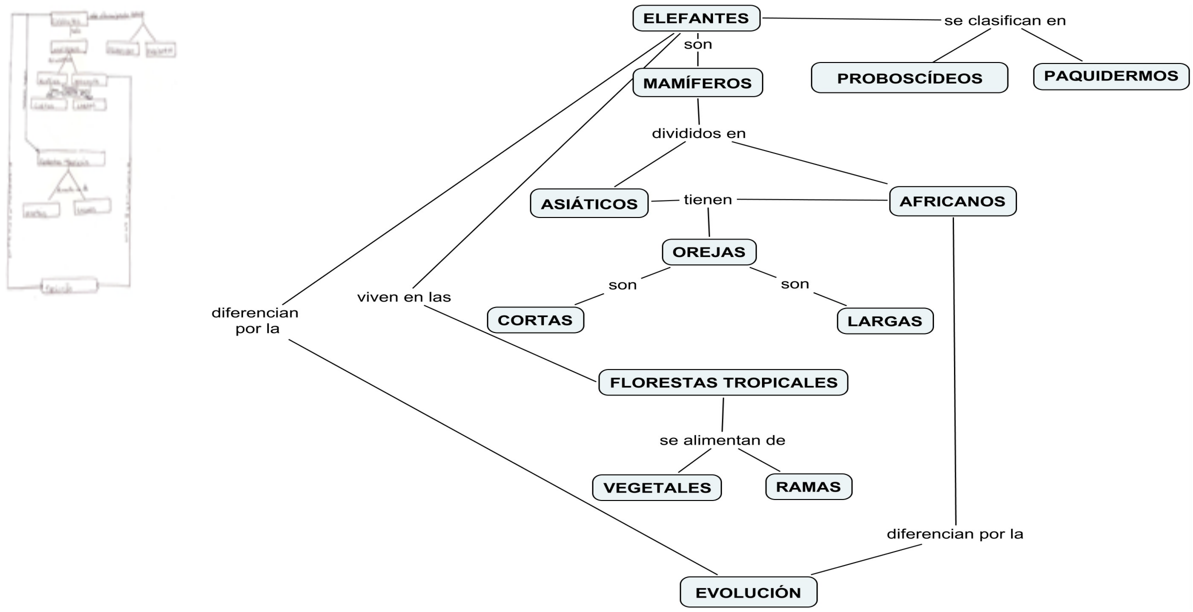

Figura 9: **Mapa Conceptual II (E8) - Mapa Bom**

Caso 3 – alumno E8 – MCIII

El MCIII, figura 10, presenta el concepto general e inclusor *Elefantes* en el centro y a la derecha de éste una de las características generales, que es uno de los conceptos centrales, seguida de explicación, y a la izquierda, el nombre del orden, al que pertenecen los elefantes. Encima del concepto general, en el 1er nivel de la jerarquía horizontal hay dos conceptos centrales, *herbívoros* y *mamíferos*. Fue considerado como un MB porque usó palabras de enlace adecuadas, con relaciones cruzadas, ausencia de repetición de conceptos.

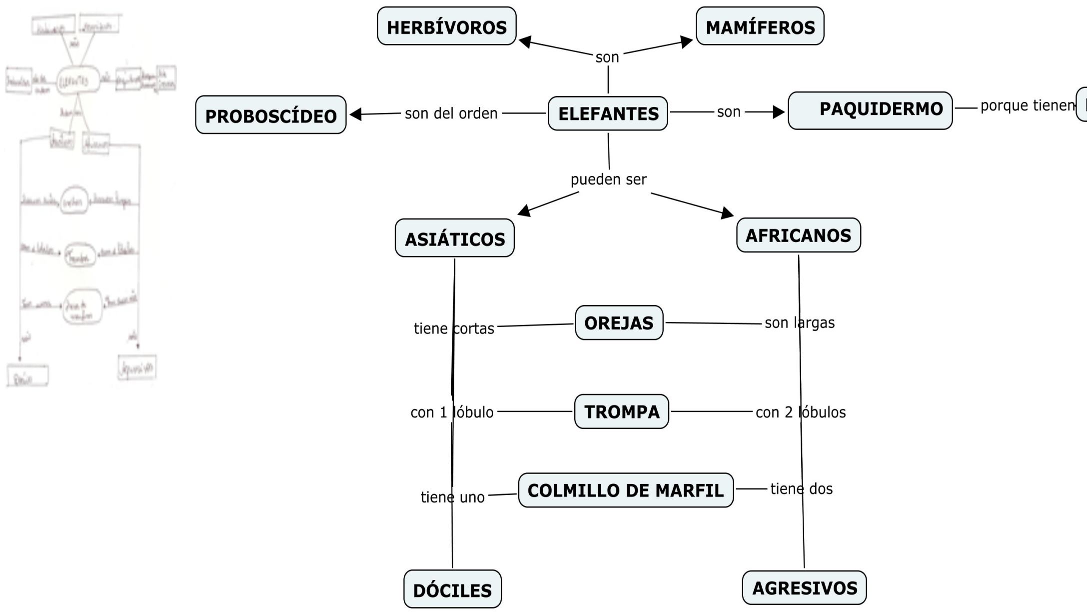

Figura 10: **Mapa Conceptual III (E8) - Mapa Bom**

A continuación, como ejemplo, se describe la presentación del alumno E8 (MCII), incluyendo las intervenciones realizadas por los demás estudiantes. Este alumno demostró gran preocupación en ofrecer explicaciones además de los conceptos que había incluido en su mapa, porque creía que estaba muy resumido con relación a los mapas de los compañeros. Presentó diversos conceptos relevantes y en varios momentos aplicó los principios ausubelianos de la diferenciación progresiva y de la reconciliación integradora, aunque algunas de esas explicaciones no estén presentes en su mapa.

> *"Mi mapa, profesora, está muy resumido, pero yo voy a complementarlo con mi explicación. Los elefantes se clasifican en proboscídeos porque tienen trompa, que sirve para oler, coger la comida, echar agua en el cuerpo. Son clasificados también como paquidermos, porque tienen la piel grosera y arrugada. Los elefantes pertenecen a la clase Mammalia, luego, son mamíferos y las hembras tienen glándulas mamarias, que producen leche para amamantar a sus crías. Esos mamíferos se dividen en dos grupos: elefantes asiáticos y elefantes africanos. Una diferencia importante entre esas dos especies son las orejas. En la especie asiática, son cortas y en la especie africana son largas y anchas. La importancia de las orejas está en que refrescan la temperatura del cuerpo de esos animales. Los elefantes en general viven en las florestas tropicales, son herbívoros y se alimentan de hierbas, vegetales, ramas de árboles. Los elefantes de las dos especies se diferencian por su evolución, o sea, evolucionaron conforme el clima y las condiciones de los lugares donde viven".*

Intervenciones de los futuros profesores en la presentación de E8:

"*No estoy de acuerdo con esas dos líneas que salen de mamíferos, que tienen como conectores divididos en asiáticos y africanos, porque no todos los mamíferos son asiáticos o africanos, pueden ser también de América del Sur o de Europa, en todas las partes del mundo hay mamíferos. Creo que la línea debería salir del concepto elefantes".* (E6)

"La única sugerencia que yo tengo es sobre la línea que sale de elefantes para florestas tropicales, creo que debía salir esa línea de asiáticos para florestas tropicales". (E25)

"Me ha gustado la presentación de E8, ha dicho cosas que nadie había dicho todavía en las presentaciones, como la importancia de las orejas. Yo hasta ahora sólo había oído la explicación de los otros diciendo que las orejas eran grandes o pequeñas, de abanico o cortas, etc... Muy buena la presentación" (E5).

El mapa debe ser visto como un instrumento para compartir significados, de manera que facilite el aprendizaje significativo (Moreira, 2006). Es un diagrama que va cambiando en la medida en que tiene lugar el aprendizaje. No son definitivos. Un ejemplo de eso fue la secuencia presentada por el alumno E8, que representa cómo ve él la estructura conceptual de un cuerpo organizado de conocimiento. La práctica de presentación del mapa conceptual les enseña a los alumnos a cooperar con el alumno E8. Con la participación de los compañeros, el presentador del mapa puede aceptar o no la contribución de los demás.

3.2. Evolución de los conceptos en los tres mapas

La evolución de los conceptos construidos en los tres conjuntos de MC, en los diferentes momentos, muestra que los conceptos presentes en los mapas MCII y MCIII fueron analizados comparándolos a los citados en los MCI, tomados como representativos de los conocimientos previos de los profesores en formación.

Estos dato, presentados en la tabla 2, permiten observar que la variedad de conceptos presentes aumentó a lo largo de la enseñanza. Hay que analizar la calidad de la diferencia de los conceptos y sus respectivas relaciones, lo que permitirá decir si la inserción de esa herramienta mejoró la enseñanza del concepto *Elefantes*.

Un aspecto importante considerado en el análisis fue la evolución de los conceptos en los 3 mapas progresivos. Se analizaron los conceptos presentes en los MCII y MCIII con relación a los utilizados en el 1er conjunto de mapas, tomados como representativos de los conocimientos previos, tabla 2. Si los conceptos nuevos incluidos en los MCII y MCIII corresponden a los aspectos más centrales y generales del tema, eso es un indicador de éxito del proceso de enseñanza/aprendizaje. Lo mismo ocurre si los conceptos presentes sólo en el MCI corresponden a características puntuales. Por otro lado, si los *mejores* conceptos están presentes en los 3 mapas, eso revela que la influencia de la enseñanza en el conocimiento de los alumnos fue insignificante.

Tabla 2: Evolución cuantitativa de los conceptos en los mapas de los profesores en formación

Profesores en Formación	Conceptos							
	MCI	MCII			MCIII			
	Total	MCI	Nuevos[a]	Total	MCI	MCII	Nuevos[b]	Total
n = 36	**23**	21	18	**39**	14	16	18	**48**

[a] Con relación al mapa MCI [b] Con relación a los mapas MCI y MCII

En los MCIII se encontraron 48 diferentes conceptos, de los cuales 34 son nuevos con relación a los mapas iniciales. De éstos, 18 son exclusivos y 16 ya habían surgido en los MCII. Se pueden observar 11 conceptos coincidentes en los MCI, MCII y MCIII, que representan conocimientos previos de los alumnos y son también conceptos relevantes para el tema, relacionados con la enseñanza desarrollada: *piel gruesa*, *colmillos de marfil*, *cabeza grande*, *porte aventajado*, *asiáticos*, *africanos*, *florestas tropicales*, *sabanas*; *trompa*, *alimentación* y *oreja*. En los MCII y MCIII, estos conceptos estuvieron asociados a los más generales e inclusivos, por ejemplo, *piel gruesa* y *trompa* estaban respectivamente conectados a conceptos como *paquidermos* y *proboscídeos*.

Los 16 conceptos exclusivos de los MCII y MCIII del estudio, cuyo origen está relacionado con la enseñanza desarrollada, se citan aquí en el orden en el que aparecen en los MC de los alumnos, con los respectivos números de citaciones en los MCII y MCIII: especies (2, 2); *gestación larga* (4, 7); *mamíferos* (31, 24); *paquidermos* (27, 29); *proboscídeos* (27, 29); *manadas*, *bandos*, *grupos* (3, 2); *herbívoros* (16, 26); *audición* (2, 8), *olfato* (2, 8); *comunicación* (2, 3); *defensa* (4, 1); *lóbulos* (2, 3); *dedos* (1, 2); *respiración* (15, 5); *peso* (3, 11); *altura* (1, 15).

Los 18 conceptos presentes sólo en los MCIII fueron: familia *Elephantidae* (4 alumnos); *Elephas maximus* (12); *Loxodonta africana* (12); *pastos* (2); *dóciles* (7); *agresivos* (5); *desarrollados* (3); *dos lóbulos* (6); *un lóbulo* (8); *resfriador natural* (3); *triangulares* (3); *circulares* (3); *piel del vientre* (5); *frente* (6); *curvada* (3); *espalda* (5); *depresión* (3); *pies traseros* (3).

El análisis comparativo de los mapas reveló que los conceptos presentes en los MCII son cualitativamente mejores que los conceptos presentes en los MCI, eso es una evidencia de que la enseñanza fue potencialmente significativa y, por tanto, favoreció la captación de significados. En esta misma línea, los conceptos presentes sólo en los MCI corresponden a características puntuales de los Elefantes, lo que representa un indicador más de éxito del evento. Por otro lado, los *mejores* conceptos están presentes en los MCII y MCIII, demostrando que la enseñanza modificó el conocimiento previo de los futuros profesores. Entonces, la calidad de los conceptos y sus respectivas relaciones permitió decir que la inserción de esa herramienta favoreció el aprendizaje de los futuros profesores de Biología.

4. Consideraciones Finales

Se considera que el uso de MCs contribuyó para mejorar el nivel de aprendizaje de los conceptos necesarios para la comprensión del tema *Elefantes*. Por tal razón, estos recursos muestran un poder de acción funcional competente. En cuanto a su utilización en las clases, se verifica que revelan diversas posibilidades, o sea, diferentes caminos para el aprendizaje de los contenidos, construyendo subsunsores integradores de los conceptos específicos de la materia de enseñanza, favoreciendo el aprendizaje significativo. El análisis de los mapas elaborados por los alumnos permite percibir la evolución de los significados atribuidos a los conceptos estudiados, así como de las relaciones conceptuales establecidas. Cuando los mapas se realizan de forma progresiva, pueden evidenciar la evolución del aprendizaje y mostrar en qué momento de la intervención son más eficientes. De esta forma el mapa demostró que es eficiente después del proceso de intervención, apuntando la necesidad de uso efectivo. Los resultados obtenidos en esta investigación permiten deducir que en la práctica es posible mejorar el aprendizaje, con el uso de referentes sólidos, como el que ofrece la Teoría del Aprendizaje Significativo. Se espera con este trabajo no sólo ampliar la divulgación de los estudios sobre mapas conceptuales en la formación de profesores, sino también incentivar el desarrollo de nuevas investigaciones en esa área, ofreciendo mayor contribución para los docentes de Ciencias Naturales.

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Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

ISSN 1989 - 9572

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 21 de diciembre de 2012

Fecha de revisión: 20 de enero de 2013

Fecha de aceptación: 07 de febrero de 2013

Molina-Azcárate, L. (2013). Los mapas conceptuales como herramientas de diagnóstico y tratamiento de errores conceptuales. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 122 – 131.

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The use of concept maps to detect and correct concept errors (mistakes)

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Resumen
Este trabajo propone abordar y tratar los errores conceptuales (EECC) para lograr un Aprendizaje Significativo (AS). El modelo conductista no responde a las demandas de un aprendizaje significativo en integrar el pensamiento, el sentimiento y la acción conduciendo a la capacitación humana para el compromiso y responsabilidad. Responder a los desafíos de la Sociedad del Conocimiento y la Información requiere cambiar la forma de enseñar (Modelo Conductista al Constructivista) y aprender, en este contexto aprender significativamente y crear conocimiento son claves para el desarrollo del pensamiento divergente, creativo y crítico. Los EECC suponen barreras, para ello, esta investigación trata de eliminar y/o paliar este problema. Son requisitos claves para conseguir el AS elaborar un material curricular e instruccional, el Módulo Instruccional (MI); el tratamiento de los EECC y un docente responsable que cambie su dinámica de trabajo áulico. Se diagnosticaron EECC y con ellos se realizó el MI implementado en escuelas secundarias de Argentina en las provincias de Tucumán y Jujuy a un grupo de clase (6º grado o 1º año). Se evalúa las actividades, dinámica propuesta y resultados de la implementación del MI con un mapa conceptual evaluador. Los resultados obtenidos evidencian cambios en los grupos experimentales en actitudes y rendimiento académico. En el pensamiento divergente se manifiesta el aprendizaje significativo, al aparecer en los trabajos de los alumnos la creatividad en expresiones, producciones, y aplicaciones a la vida real.

Abstract
This work proposes to detect and correct concept errors (EECC) to obtain Meaningful Learning (AS). The Conductive Model does not respond to the demand of meaningful learning that implies gathering thought, feeling and action to lead students up to both compromise and responsibility. In order to respond to the society competition about knowledge and information it is necessary to change the way of teaching and learning (from conductive model to constructive model). In this context it is important not only to learn meaningfully but also to create knowledge so as to developed dissertive, creative and critical thought, and the EECC are and obstacle to cope with this. This study tries to get ride of EECC in order to get meaningful learning. For this, it is essential to elaborate a Teaching Module (MI). This teaching Module implies the treatment of concept errors by a teacher able to change the dynamic of the group in the classroom. This M.I. was used among sixth grade primary school and first grade secondary school in some state-assisted schools in the North of Argentina (Tucumán and Jujuy). After evaluation, the results showed great and positive changes among the experimental groups taking into account the attitude and the academic results. Meaningful Learning was shown through pupil's creativity, expressions and also their ability of putting this into practice into everyday life.

Palabras clave
Aprendizaje significativo, errores conceptuales, mapas conceptuales, módulo instruccional

keywords
Concept error, meaningful learning, teaching module, concept maps

1. Introducción

Las razones para innovar en educación son las exigencias de la sociedad del conocimiento y de la información, así como la necesidad de nuevas competencias cognitivas y una personalidad equilibrada emocionalmente. Para esto es fundamental un aprendizaje significativo frente al memorístico, reconocer los errores conceptuales y alcanzar una inteligencia emocional necesaria para el metaprendizaje. En general los sistemas educativos no cubren estas demandas ya que los planes de estudio apenas contemplan esta situación (González García, 2008).

En el aprendizaje significativo los errores conceptuales son un obstáculo y el docente debe ser consciente de los mismos y hacerlos conscientes a sus alumnos para avanzar en el aprendizaje. El alumno es un receptor activo, utiliza los conceptos y significados que ya internalizó para captar los nuevos e incluirlos en su estructura cognitiva (esquema conceptual). Si existen errores conceptuales (EECC) se dificulta la reorganización de su propio conocimiento, no elabora nuevas proposiciones ni logra su integración a la estructura cognitiva. El aprendizaje no es progresivo, los significados no son captados e internalizados, aprende de memoria (memoria a corto plazo) los EECC no se reconocen y no generan inconvenientes.

El aprendizaje significativo permite "SABER" ser, hacer, y sentir, lo que implica aprender a aprender. Al saber hacer se resuelven las situaciones problemáticas manejando el conocimiento para accionar en el mundo con creatividad. El "ser" ayuda a vivir rodeado de personas diferentes, actuar en una interacción social, y el "sentir" es ser plenamente responsable de uno mismo, actuando con voluntad y esfuerzo para el bien personal y colectivo. La complejidad de la vida cotidiana necesita del aprendizaje significativo, para Moreira (2000) debe ser crítico y subversivo. El pensamiento subversivo es poder cuestionarse, al plantear diferentes líneas de razonamiento y generar discursos distintos (es poder desestructurar su razonamiento y el de otros). El cambio conceptual tan necesario para lograr el aprendizaje significativo llevó a transformar los enfoques y las concepciones del aprendizaje de la ciencia. Los epistemólogos hablan de conceptos erróneos, concepciones alternativas, nociones ingenuas, nociones pre científicas pero Novak propuso adoptar la sigla *LIPH* (Limited or Inappropriate Proposicional Hierarchies) como la más apropiada para esas concepciones erróneas. (Novak, 1983 y 1993).

En el aprendizaje significativo el alumno se involucra, establece relaciones significativas y no arbitrarias. La incapacidad de trasladar ideas y el uso de conocimientos adquiridos en contextos diferentes, generan dificultades propias del aprendizaje, necesitando el cambio conceptual (González García, 2001). En general en las clases no se trabaja para lograr el aprendizaje reflexivo ni la argumentación, es necesario enseñar a pensar. El docente debe trabajar con las inteligencias múltiples (Gardner, 1995) desarrollando en sus alumnos la capacidad de resolver problemas o elaborar productos que puedan ser valorados dentro de su cultura. Las inteligencias múltiples generan en el aula nuevas oportunidades de actuar (desde las diferentes disciplinas) potenciando la autoestima y autovaloración, brindando la libertad de pensamiento, acción, creación y autogestión Para lograr este cambio es necesario considerar estas variables en un constructo (MI, módulo Instruccional) o recurso didáctico que permita su implementación. Como antecedentes sobre la aplicación de un módulo instruccional (*MI*) para lograr el aprendizaje significativo al detectar y corregir errores conceptuales se pueden citar el Proyecto Gonca (2003), Albisu y cols (2006) y González García (2008). Los objetivos de este trabajo fueron: 1) Aplicar nuevos criterios en el desarrollo y evaluación del AS, mediante el uso de los EECC. 2) Organizar la planificación en un marco general con los criterios propuestos para el MI. 3) Emplear las nuevas tecnologías para ayudar al alumno en el aprendizaje, 4) Planificar las actividades y recursos para aprender a aprender.

2. Metodología

La hipótesis asume que es posible encontrar diferencias en el rendimiento académico final (hay AS) entre los estudiantes que utilizan MMCC, trabajan con EECC y *MI* como estrategia de enseñanza con los que no lo hacen. La variable independiente es la metodología utilizada con sus dos niveles, en un curso utilizar errores conceptuales y en el otro no. La muestra estuvo integrada por alumnos de 6º grado o 1º año (12 a14 años de edad) de escuelas públicas, tres de la provincia de Tucumán (de zonas diferentes)y una de la provincia de Jujuy (escuela en zona muy pobre). Para la recolección de datos se utiliza un diseño cuasi experimental, con pretest y postest, y dos grupos de experimentación no aleatorizados.

Provincia	Muestra		Establecimiento	Curso	Tipo	Nº alumnos
Tucumán	A	1	Esc. Com. Nº 3	7º 3	Experim	38
	B			7º 4	Testigo	38
Tucumán	C	2	Liceo Nacional	1º E	Experim	38
	D			1º A	Testigo	36
Tucumán	E	3	Esc. y Liceo V. Sarmiento	6º A	Experim	36
	F			6º B	Testigo	36
Jujuy	G	4	Escuela Nueva La Salle	7º1	Experim	32
	H			7º2	Testigo	31

Tabla 1: Características de la muestra.

El estudio se extendió durante cuatro meses (Período lectivo 2010) en sesiones de tres horas cátedras semanales (40 minutos cada una) en un módulo de 80 minutos y otro de 40 minutos. La muestra se dividió en el grupo testigo y el experimental, en espacio (aulas) distintos y con docentes diferentes. El curriculum de cada escuela está adaptado a los lineamientos del curriculum oficial. Este estudio se realizó en 4 etapas:

1º etapa. Diagnóstico y detección de EECC (mediante encuestas a docentes y alumnos) para elaborar el MI. Elaboración y aplicación del 1er mapa conceptual evaluador (MC evaluador 1º), elaborado por un docente y transmitido a los demás docentes de la experiencia. Consta de 25 conceptos inclusivos, necesarios para el trabajo del tema durante el año. Se incluyen conceptos que generalmente son erróneos. Se realiza en el período de diagnóstico durante 2 semanas. En el grupo experimental la organización de las actividades sigue lo propuesto en el MI utilizando el software específico cmaptools, y en el testigo la realiza el profesor siguiendo su criterio.

2º etapa. Elaboración y aplicación del MI para la detección y corrección de errores durante la aplicación del mismo. Este permite organizar de manera diferente los contenidos para el logro del AS y por otro ayudar a cambiar el esquema mental del alumno, corregir sus errores conceptuales o por lo menos aprender a pensar en ellos. Permitió al docente actuar en la zona de desarrollo próximo (González García, 2008), se enfatizan los procesos cognitivos, el desarrollo de habilidades metacognitivas, y afectivas del alumno. En el MI se organizan actividades y será a través de ellas y como ellas son asimiladas por cada uno de los estudiantes donde se puede analizar el concepto de tarea la que comprende variables fundamentales que permiten el logro de habilidades cognitivas. Los contenidos a trabajar en el MI se organizan en una serie de actividades relacionadas, en una secuencia temporal y de complejidad creciente considerando los errores detectados. Los diferentes temas se organizan en introducción, focalización y resumen, adaptado de Project LEAP (Learning about Ecology, Animals and Plants, Cornell University, 1995). El MI está inserto en un marco general que presenta siete ejes verticales (sicológico, didáctico, epistemológico, procedimental, social, comunicacional y conceptual) y un eje transversal que integra y relaciona los anteriores) la evolución del pensamiento del alumno manifestado en el AS. Los ejes verticales surgen en la complejidad del aula e intervienen la experiencia del docente y las características del grupo de alumnos

Para el diseño y aplicación del MI se tiene en cuenta los siguientes criterios: Manejar el conflicto cognitivo para generar cambio conceptual, aprender a aprender, considerar las inteligencias múltiples, trabajar la comunicación biunívoca, el docente como mediador en la zona de desarrollo próximo, actitud positiva del alumno y del docente, vigilancia epistemológica del docente, trabajar con TIC (Nuevas Tecnologías de la información y de la comunicación), hipertexto como creación, el docente confía y valora el trabajo individual y grupal del alumno, los contenidos curriculares se trabajan como vehículo de las estrategias cognitivas, trabaja con herramientas heurísticas, mapas conceptuales, V de Gowin, valorar positivamente el error conceptual por permitir el cambio de la estructura cognitiva, valorar lo que el alumno sabe, las ideas previas, errores conceptuales, concepciones alternativas, fomentar el diálogo intrapersonal e interpersonal para conocer las estructuras cognitivas propias y las de los otros. Estos criterios, aunque no son trabajados todos a la vez, deben ser considerados durante el trabajo en clase ya que permiten de alguna forma asegurar el logro del AS.

Es fundamental en el desarrollo de este proceso enseñar la argumentación que favorece el dialogo interpersonal e intrapersonal tan necesario para el logro del AS. Con el diálogo o comunicación en el aula se puede acceder a las estructuras mentales propias y ajenas y lograr generar la circulación de información tan necesaria para romper las barreras de la timidez, desconfianza u otras. Estas pueden impedir que afloren los errores conceptuales que obstaculizan la restructuración de los esquemas mentales. La autodisciplina y el trabajo consciente de ellas permiten ejercitar el autocontrol y el autoaprendizaje para llegar a aprender a aprender.

Otros aspectos de la tarea en el aula considerados importantes de observar y analizar son: el afectivo (como actitudes, las características propias de la personalidad, la actitud, motivación, o interés) y la evolución cognitiva continua (proceso profundo, invisible que aparece en la mente de los alumnos al responder, reaccionar o realizar las tareas en el aula o en la casa) y controlada. Es importante crear un clima de trabajo, de confianza y seguridad, donde los errores no son descalificados, sino reconocidos y reelaborados. Todo esto relacionado con el grado de dificultad que la tarea exige, y en un feedback adecuado entre la calidad de realización, permite oportunidades para lograr el final de un producto exitoso.

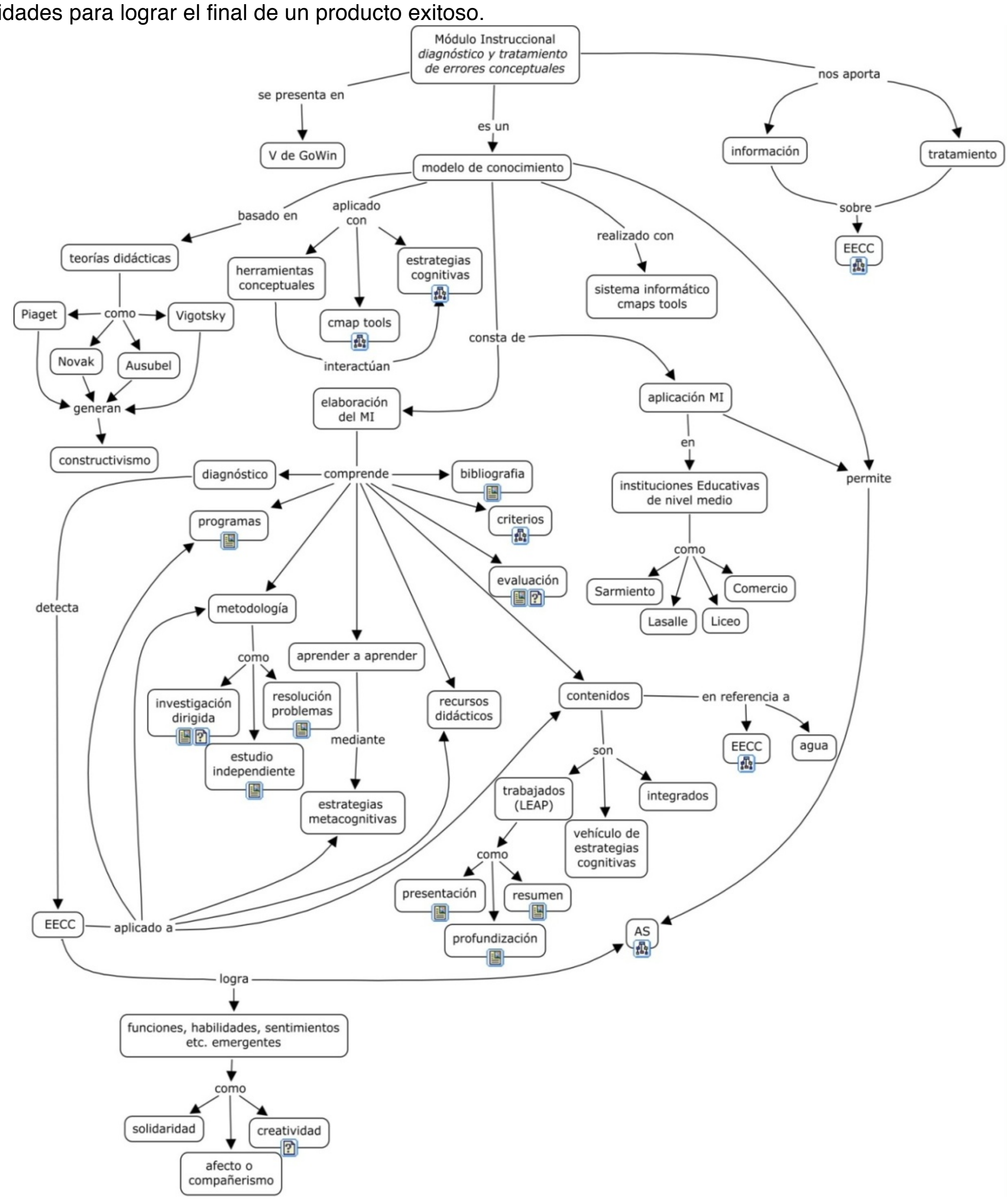

Figura 1. Mapa conceptual que describe el MI

Se pone énfasis en los errores detectados por los propios alumnos y se trabaja con la argumentación en el aula. En esta etapa la evaluación del alumno se hace en forma permanente, analizando su evolución cognitiva.

3º etapa. Aplicación del 2º mapa evaluador (MC evaluador 2º), el alumno debe repetir el mapa evaluador de referencia.

4º etapa. Análisis comparativo MC evaluador 1º y 2º. La Valoración de Mapas y Errores Conceptuales en el grupo experimental y testigo se realiza mediante un análisis cualitativo (desde la topografía y la semántica) y cuantitativo, para lo cual se realizó el seguimiento del rendimiento académico de los alumnos, previo, durante y posterior a la aplicación del *MI.* Se aplicaron pruebas multivariadas a los indicadores de Bartels (*issuu.com/abocc/docs/evaluarmapasconceptuales)*, Novak (1988), y a un nuevo índice propuesto que incluye los índices anteriores y agrega la presencia y número de los EECC. Para determinar si se da el AS se utilizaron por un lado los índices de González García y Guruzega (2004) y por otro lado se realizó la comparación del promedio de notas obtenidas durante la aplicación del MI con el obtenido en los dos cursos anteriores (4º y 5º grados).

Los datos obtenidos mediante la aplicación de los índices, fueron analizados utilizando un análisis de varianza longitudinal multivariado para comparar el rendimiento de los grupos control y experimental. El método multivariado permite estudiar simultáneamente varias respuestas. Este tipo de modelo permite cuantificar la evolución del aprendizaje de los alumnos expresado como la diferencia de los puntajes obtenidos en los MMCC inicial y final, de cada uno. A partir de los promedios de las diferencias individuales dentro de cada curso, se puede comparar el comportamiento promedio del grupo control y el experimental y establecer si existen diferencias significativas entre ellos. El test de Tukey fue utilizado cuando se obtuvieron diferencias significativas en el ANOVA.

3. **Resultados**

La encuesta para conocer los EECC se realizó a docentes (30 entre expertos y noveles) la que curiosamente no se devuelve quedando solamente por informar los resultados de la encuesta a los alumnos.

De las Instituciones Educativas en las que se realizó la experiencia solo en una de ellas (Escuela y Liceo Vocacional Sarmiento) se logran datos estadísticamente significativos. En las otras instituciones debido a situaciones de huelgas, ausencia y renuncia de profesores entre otros motivos se producen irregularidades que afectaron el normal desempeño del dictado de clases, pero si se pudieron obtener datos cualitativos. En todas las instituciones y en todos los grupos experimentales se aprecian cambios actitudinales como ser: clima afectivo positivo, mayor contención de alumnos problemáticos, mejora en las relaciones interpersonales, el trabajo con cmaptools en el laboratorio de informática permite la integración de los alumnos avanzados al colaborar con los menos diestros, además mejoran las relaciones interpersonales, y el tratamiento óptimo de alumnos con dificultades cognitivas manifiestas (Jujuy, Síndrome de Sutton).

Cuando se comparan los resultados en la Escuela 3, entre el 1º periodo (MC 1) y 2º Periodo (MC2) se observa que hay diferencia significativa entre medias solamente en el grupo experimental (indicado por letras diferentes) ($p< 0,05$), cuando se aplica el índice de Bartels.

Escuela 3	Experimental		Testigo	
	Mc 1	Mc 2	Mc 1	Mc 2
Bartels A	1.30^{a}	2.00^{b}	1.21^{a}	1.13^{a}
Bartels B	1.25^{a}	1.86^{b}	0.70^{a}	0.92^{a}
Bartels C	1.05^{a}	1.61^{b}	0.59^{a}	0.75^{a}

Tabla 2. Promedios de cada ítem del índice de Bartels, dentro de los grupos experimental y testigo. Superíndices diferentes, en cada fila, indican diferencias significativas entre medias ($p<0.05$) obtenidas con test Tukey

Categoría A) Conceptos y terminología; B) Conocimiento de las relaciones entre conceptos; C) Habilidad para comunicar conceptos a través del mapa conceptual.

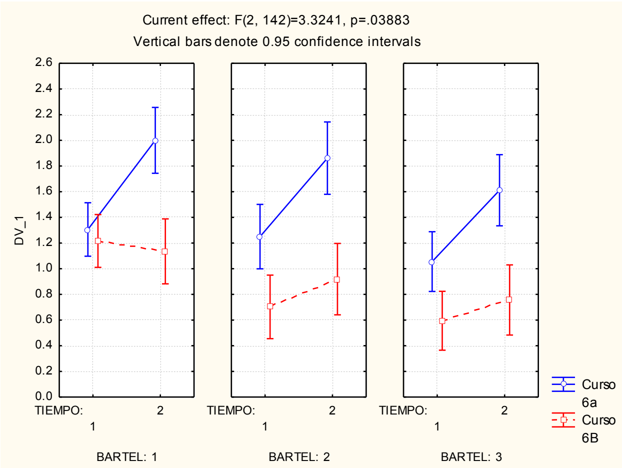

Figura 2. Gráfico de los resultados indicados en la tabla 1. Grupo experimental en azul (línea continua) (6a) y en rojo (línea de puntos) el grupo testigo (6B)

Resultados de aplicación del índice de Novak.
En la siguiente tabla nº 3:

Escuela 3	Experimental		Testigo	
	Mc 1	Mc 2	Mc 1	Mc 2
Jerarquía	**0.6a**	**1.2b**	0.5a	0.6a
Relaciones	0.3a	0.7b	0.2a	0.4b

Tabla 3. Promedios de dos ítems del índice de Novak

Al comparar los resultados obtenidos para la categoría "Jerarquías", entre el 1º y 2º Periodo hay diferencia significativa entre medias solamente en el grupo experimental (indicado por letras diferentes) (p< 0,05). En cambio, en "Relaciones" se observa diferencias significativas en los dos grupos. Se consideran los puntajes obtenidos en las jerarquías y relaciones ya que prácticamente no existen relaciones cruzadas y ejemplos.

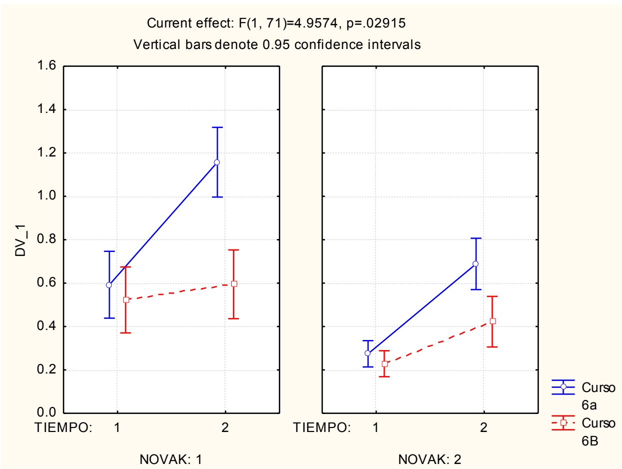

Figura 3. Gráfico de los resultados indicados en la tabla 2.

Los resultados obtenidos con el análisis de los índices de Bartels, Novak y el nuevo índice midiendo los EECC coinciden en sus resultados.

A continuación se muestran dos figuras de mapas conceptuales evaluadores (escaneados) realizados por una alumna antes (figura 4) y después de la aplicación del MI (figura 5). En la figura 4 se aprecia la falta de conectores y jerarquías, no usó todos los conceptos y las proposiciones son incorrectas. En la figura 5 se aprecia el uso correcto de conectores, de diferentes jerarquías, usa todos los conceptos y las proposiciones son correctas.

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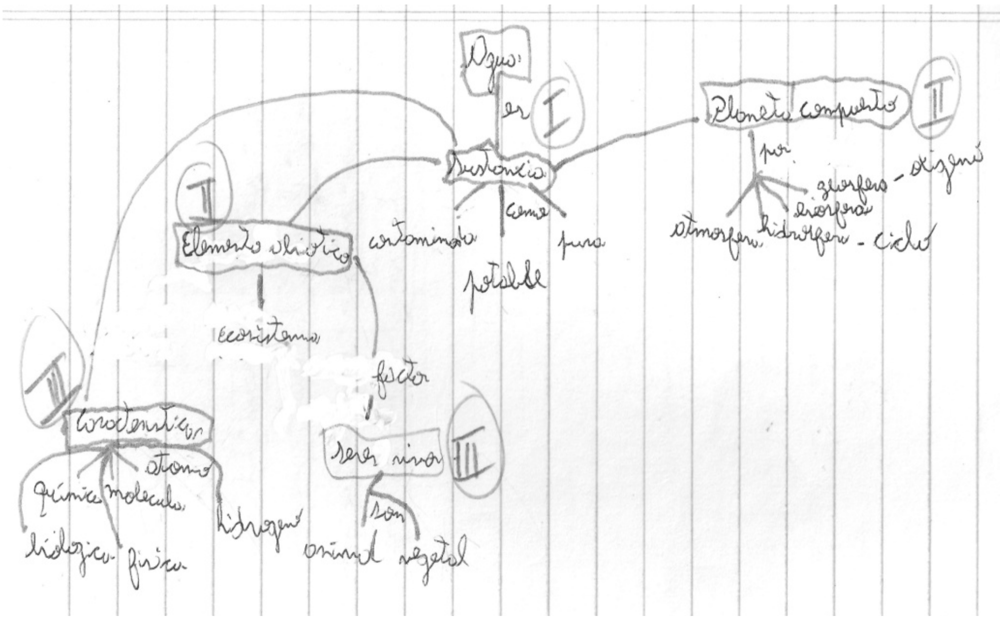

Figura 4 . Mapa conceptual evaluador 1 (previo a la aplicación MI)

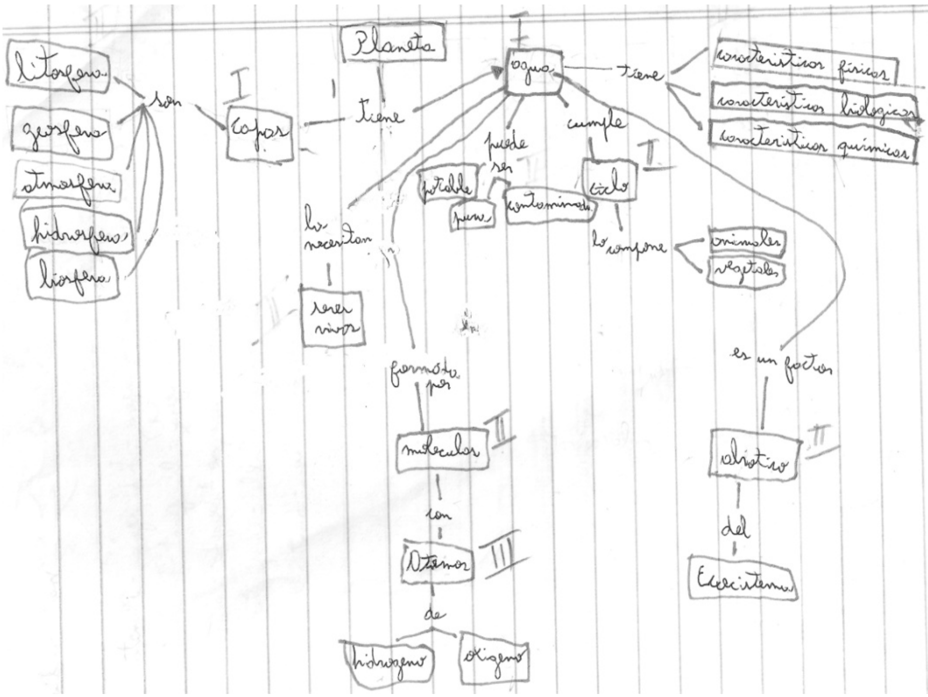

Figura 5 . Mapa conceptual evaluador 2 (posterior a la aplicación MI)

Los resultados de comparar las calificaciones finales de dos curso previos y las calificaciones trimestrales del curso correspondiente al período de aplicación del *MI* se observa en la figura 6. En la misma se grafica los resultados de la comparación de los grupos experimental y testigo donde se observa una marcada diferencia a partir del 1º trimestre (diferencia significativa). Cabe recordar que se inicia la aplicación del *MI* al comenzar el período lectivo y el dato del 1º trimestre corresponde a las primeras pruebas evaluadoras del año.

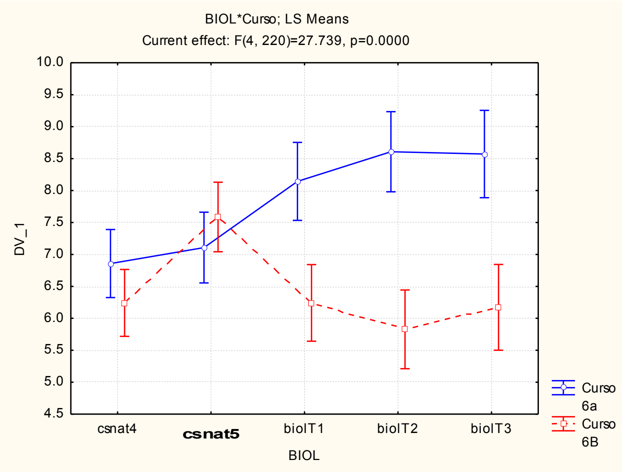

Figura 6. Resultados de la comparación de las calificaciones finales (asignatura biología).

Los alumnos del grupo experimental valoraron positivamente sus resultados y resolvieron aplicarlos voluntariamente en asignatura Historia. En la figura 7 se grafica los resultados de esta experiencia donde se observa una tendencia a la mejora en el grupo experimental hacia el 3º trimestre.

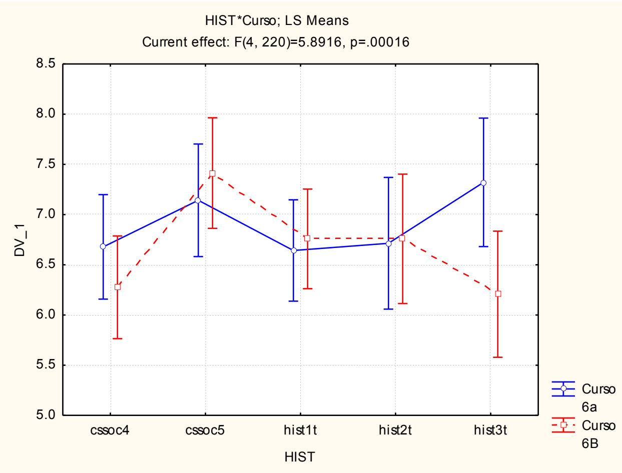

Figura 7. Resultados de la comparación de las calificaciones finales (asignatura historia).

Cuando se evaluó el Aprendizaje Significativo utilizando los indicadores descriptos por González García F Mª y Guruceaga A. Se puede decir que en ambos grupos se logra el mismo pero de manera diferente.

4. Conclusiones

Las notas registradas en la escuela Nº 3 en 4º y 5º grado en ambos grupos al ser comparadas con los resultados de 6º, muestra que si se da una mejora en el grupo experimental. La mejora puede ser explicada por causas que tienen que ver con la organización institucional, por ejemplo: las alumnas empiezan su escolaridad en esta institución, lo que permite el logro de una gran pertenencia y les da seguridad emocional (se sienten seguras); se promueve la autodisciplina; la autogestión de actividades extra programáticas por las alumnas; un sistema de evaluación continua (exámenes parciales y finales en todas las asignatura y todos los curso); se procura la inclusión de todas las aspirantes a jardín (1º año inicial de escolaridad) y se favorece la recuperación (la no expulsión) de las alumnas con problemas de aprendizaje. Esto permite disminuir las diferencias sociales con las que ingresan las alumnas. Pudo detectarse en todo momento en el grupo experimental muy buen estado de ánimo, disposición para el trabajo y colaboración.

Este tipo de metodología permite un trabajo integrado e interdisciplinario con otros espacios curriculares y los alumnos entusiasmados con el trabajo con mapas y por sus resultados positivos utilizaron voluntariamente los mapas conceptuales en la asignatura de ciencias sociales.

La construcción de significados es un hecho individual, solo el estudiante puede decidir hacer el esfuerzo, así el debe empeñarse en modificar y reestructurar consciente y deliberadamente sus esquemas mentales. Los maestros deberían ayudar a sus alumnos a que realicen y reconstruyan sus esquemas personales en el plano conceptual, de manera que formen su competencia cognoscitiva.

Los criterios seleccionados y empleados para diseñar el *MI* se consideran adecuados y en cierta forma novedosos por su interrelación. Estos mismos criterios pueden aplicarse perfectamente en otras disciplinas en el trabajo del aula.

Se pudo organizar la planificación en un marco general que abarque los criterios propuestos para el *MI*, con diferentes núcleos temáticos fundamentales y criterios para el AS mediante el tratamiento de los EECC. Esto fue aplicado por las docentes involucradas en la experiencia. Tanto los alumnos como los docentes implicados en la experiencia reconocen la existencia y persistencia de los errores conceptuales.

La aplicación del *MI* facilita detectar y trabajar los EECC, permite la autocorrección por parte de las alumnas, que aprendan a aprender, tendiendo al aprendizaje significativo. Se detectan cambios actitudinales en la tarea en el aula, mejor rendimiento general, mayor creatividad en las producciones, más participación en el aula con mejor nivel de argumentación.

Se aplicó el software específico para el trabajo con mapas conceptuales (cmaptools) cumpliendo así el objetivo de emplear las nuevas tecnologías para ayudar al alumno en el aprendizaje.

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Journal for Educators, Teachers and Trainers
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ISSN 1989 - 9572

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 29 de diciembre de 2012

Fecha de revisión: 15 de enero de 2013

Fecha de aceptación: 2 de febrero de 2013

Prieto, A.B. y Chrobak, R. (2013). Integración de TICs, investigación y herramientas metacognitivas en la educación de ciencias y ambiental. Estudio de caso: disponibilidad de agua de las cuencas del noroeste de Patagonia y su relación con la actividad solar. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 132 – 141.

Journal for Educators, Teachers and Trainers
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Resumen

Este trabajo muestra una innovación educativa desarrollada en una escuela agrotécnica que participa en redes colaborativas internacionales de educación ambiental como The GLOBE Program y Environment On-Line que se basan en la realización de mediciones ambientales, investigación y comunicación utilizando las TIC. Para el análisis de la información, el procesamiento, el diseño y ejecución de la investigación los alumnos utilizaron herramientas metacognitivas (mapas conceptuales y la UVE de Gowin). Luego elaboraron una presentación multimedia para difundir su investigación. Se realiza una encuesta sobre la metodología de trabajo empleada y se analizan los resultados obtenidos en cuanto a habilidades y conocimientos adquiridos en el trabajo de investigación.

Abstract

This work shows an educational innovation developed in an agrotechnical school, involved collaborative international networks, of environmental education, as The GLOBE Program and Environment On-Line which are based on the realization of environmental measurements, research and communication using ICT. For data analysis, processing, design and execution of research, students used metacognitive tools (concept maps and Gowin's Vee). After, they developed a multimedia presentation to disseminate their research. We performed a survey on the methodology employed and analyzed the results in terms of skills and gained knowledge during the research work.

Palabras clave

Herramientas metacognitivas. Mapas conceptuales. UVE de Gowin. Educación ambiental. Investigación.

Keywords

Metacognitive tolos, concept maps, Gowin's Vee, environmental education, research

1. Introducción

Las publicaciones en aprendizajes de ciencias consideran que el alumno construye sus propios conocimientos en interacción con su entorno físico y social. Ésta construcción depende de la interacción entre la estructura interna de sus conocimientos y la situación problema que se le propone. La incorporación de herramientas informáticas en los procesos de enseñanza y aprendizaje enriquece la interacción individual y la colectiva al trabajar en espacios colaborativos. Tanto las TIC como las redes colaborativas de trabajo han impactado en los modos de concebir y reelaborar los conocimientos.

Las TIC pueden potenciarse si le incorporan herramientas metacognitivas como el diagrama UVE desarrollado por Gowin (diagrama en forma de ve corta que ayuda a diseñar y desarrollar una investigación a partir de una pregunta foco interactuando entre el área conceptual y metodológica) para diseñar y desarrollar una investigación y los mapas conceptuales para procesar la información. Ambas herramientas favorecen el aprendizaje significativo debido a que propician interacción entre el viejo y nuevo conocimiento. (Moreira, 2010; Mintzes et al., 2001; Novak & Gowin, 1985). Actualmente se cuenta con el software CmapTools (Cañas et al., 2005) que facilita la construcción de mapas conceptuales individuales o colaborativos, pudiendo reunir todos los recursos ya sean imágenes, links externos de internet, videos, animaciones, etc. Estas imágenes pueden estar incrustadas en el mapa conceptual o vinculado, desplegándose al hacer clic sobre ellas.

2. El referencial teórico que guía esta investigación

En lo que sigue, se presentarán muy brevemente, los fundamentos teóricos de la teoría A-N-G, pionera en la introducción de los conceptos centrales de lo que se ha dado en denominar aprendizaje significativo, entendiéndose por tal el proceso de incorporación no arbitraria, sustantiva y no literal de nuevos conocimientos en la estructura cognitiva del individuo. Este tipo de aprendizaje se diferencia del que se conoce como aprendizaje mecánico, en el cual las nuevas ideas se relacionan en forma arbitraria y no sustancial con lo que el estudiante ya sabe. Diremos, además, que el significado a que se refiere este análisis debe ser "construido" por el alumno o aprendiz, o sea que, es el ser humano en cuestión, quien debe poner de manifiesto en qué forma interaccionan los elementos involucrados en el proceso de formación de significados.

Al desarrollar los conceptos centrales de la teoría, se deben considerar las siguientes premisas de la psicología educativa: (Ausubel, D., et. al., 1978)

1) la naturaleza del aprendizaje en el salón de clases y sus variables pueden ser identificadas con seguridad
2) el conocimiento obtenido como resultado de esta premisa puede ser:
   a) Sistematizado
   b) Dado a conocer a los docentes

La teoría de Ausubel-Novak-Gowin ha sido desarrollada pensando especialmente en aquéllos que opinan que la educación puede y debe ser significativamente mejorada, que están desalentados por ver que tantas innovaciones hechas hasta ahora han logrado tan poco.

En el marco de la teoría ANG, consideraremos a la educación como: “toda experiencia que contribuye al potenciamiento de una persona para desenvolverse en la vida diaria”.

Una experiencia educativa positiva acrecentará la capacidad de una persona para pensar, sentir y actuar.

Los seres humanos son únicos en su habilidad para percibir regularidades en objetos y eventos. Además pueden codificar estas regularidades simbólicamente. Esos símbolos son por lo general palabras o signos (+, =, $, %, etc.) y todos ellos representan conceptos que se definen como "regularidades percibidas en objetos o eventos", o también el registro de eventos u objetos.

Los Principios: Llamamos principios a los enunciados que describen relaciones significativas entre distintos conceptos. Ejemplo: en Física el principio de masa describe la relación entre los conceptos de masa, fuerza y aceleración. En educación, sabemos que el aprendizaje está relacionado con el tiempo de estudio, pero esta relación es compleja y no la podemos describir en forma de principio o mediante una expresión matemática. Veremos más adelante que los mapas conceptuales son una excelente herramienta para representar gráficamente este tipo de relaciones significativas.

En 1956, George Miller publicó un artículo titulado "El mágico número 7 más o menos 2" donde presenta datos que muestran que nuestra memoria de corto plazo puede operar solamente alrededor de siete "porciones" de información por vez. Las porciones pueden ser números, letras o palabras, dependiendo también del grado de familiaridad que se tenga con ellas; por ejemplo, si son frases muy familiares, una porción de información, puede ser toda una oración, como por ejemplo en el siguiente caso: 1) Mario y Emilce subieron la colina 2) Ser o no ser, esa es la pregunta 3) Pi es igual a la longitud de la circunferencia dividida por el diámetro 4) La ganancia es igual al precio de venta menos el costo.

Por lo tanto, aun con un gran deseo de aprender por parte del estudiante, existen limitaciones en cuanto al grado de significación que se puede alcanzar. La dependencia del aprendizaje significativo con respecto al conocimiento previo tiene ventajas y desventajas: la posesión de conocimientos previos relevantes y bien organizados en un campo determinado hace mucho más fácil la adquisición y uso de nuevos conocimientos en ese campo.

Considerando este concepto es posible entender que las prácticas tan comunes en que los instructores actúan como "proveedores" de información y los alumnos son meros "adivinadores" de las respuestas que sus profesores consideran aceptables, no colaboran para cambiar el significado de la experiencia del estudiante.

En base a la cosmovisión aquí planteada y a los elementos provistos por la psicología educativa y la pedagogía, se pueden llegar a desarrollar los principios didácticos que forman parte de la teoría de la enseñanza y aprendizaje de la ciencia. Esta teoría seguramente propondrá una revisión de los métodos utilizados tradicionalmente (como por ejemplo la memorización exacta de hechos, fórmulas y definiciones; el "recitado" del contenido de los textos; la resolución mecánica de problemas, etc.) para llegar a una formulación general de los modernos principios, aplicables a los procedimientos instruccionales que deben conducirse a diario en las aulas.

El proceso fundamental del aprendizaje significativo es la incorporación de nuevos conceptos y proposiciones a una estructura cognoscitiva que, por naturaleza, está organizada jerárquicamente. Ausubel denominó a este proceso "subsumption" ("inclusión" en las traducciones al español) y a los conceptos preexistentes los llamó "subsumers" (conceptos inclusores o ideas de anclaje).

Evidentemente este tipo de aprendizaje requiere del esfuerzo intencionado del que aprende para relacionar lo nuevo con lo que ya conoce como condición indispensable para su concreción. Este esfuerzo, en palabras de Ausubel, conlleva un alto nivel de eficacia, atribuible a que, una vez que las ideas nuevas se establecen adecuadamente en la estructura cognoscitiva,

A medida que el proceso de aprendizaje significativo avanza, las ideas pertinentes, claras y estables, (que aquí llamamos inclusores) van sufriendo modificaciones, a veces sustanciales, que le permiten adquirir diferenciación. Esta diferenciación progresiva también se produce cuando se establecen nuevas relaciones entre conceptos.

El proceso de subsumsión adecuadamente generado por el docente e intencionalmente buscado por el alumno, constituye la base de compartir significados con que Gowin define la tarea educativa.

Durante el transcurso del aprendizaje significativo tienen lugar dos importantes procesos relacionados entre sí. A medida que la información nueva es subsumida bajo un determinado concepto o proposición más general, la nueva información es adquirida y el subsumsor modificado. Este proceso ocurre una o varias veces, conduciendo a la diferenciación progresiva del subsumsor. Por ejemplo, los nuevos significados que se van adquiriendo a lo largo del tiempo sobre proposiciones o conceptos como democracia o evolución, representan el principio de la diferenciación progresiva.

Durante el aprendizaje supraordinado o combinatorio, ideas establecidas en la estructura cognitiva, pueden ser reconocidas como relacionadas entre sí en el transcurso del nuevo aprendizaje; de esta manera, se va adquiriendo nueva información y las ideas existentes pueden adquirir nuevas organizaciones y nuevos significados. Esta recombinación de elementos existentes en la estructura cognoscitiva, se denomina reconciliación integradora. Por ejemplo, los estudiantes pueden conocer que las paltas o tomates son vegetales, pero los mismos se clasifican como frutos en Biología. La confusión inicial del estudiante se resuelve cuando adquiere nuevos significados combinatorios y reconoce que la clasificación nutricional de los alimentos no es la misma que la clasificación botánica.

La reconciliación integradora se favorece cuando las posibles fuentes de confusión son aclaradas por el profesor o el material instruccional. Es decir, los estudiantes deben recibir ayuda para resolver las aparentes inconsistencias o conflictos entre conceptos o proposiciones.

Todo aprendizaje que resulta en reconciliación integradora, también resultará en una posterior diferenciación de los conceptos o proposiciones existentes.

Una característica de los profesores destacados es que tienen suficiente amplitud de conocimientos y experiencia en su campo que les permiten ayudar a los estudiantes explícitamente para que puedan realizar su reconciliación integradora individual. Cuando los estudiantes reconocen un curso o libro como bien organizado, es porque:

- hay claridad en la presentación del significado de los nuevos conceptos o proposiciones,
- están aclarados los posibles conflictos en significado
- se facilitan nuevas reconciliaciones integradoras.

En este punto cabe acotar que resulta evidente que la elaboración de mapas conceptuales nos ayuda a construir nuevos significados, porque sirven para organizar los conocimientos que situamos en la memoria de largo plazo y pueden funcionar como "andamiaje" (en términos de Bruner) mental para ensamblar los fragmentos de conocimiento en la memoria de trabajo.

3. Las herramientas metacognitivas

Las herramientas metacognitivas que consideraremos son: el mapa conceptual, la Uve heurística, y la entrevista clínica.

Para Gowin (1981), heurístico es algo que se utiliza como ayuda para resolver un problema o entender un procedimiento.

El uso de estas estrategias tiene como intención dotar al estudiante de un método alternativo de estudio y demostrarle que es más eficaz estudiar de esa manera que memorizando.

Puede afirmarse que los "mapas conceptuales", introducidos por Novak, constituyen una ayuda para que el estudiante y el profesor vean más claramente el significado del material a estudiar.

Los "diagramas heurísticos o de conocimientos" UVE introducidos por Gowin, facilitan profundizar la estructura y el significado del conocimiento que se pretende comprender y, por otro lado, guían el proceso de producción de nuevos conocimientos. También estos diagramas permiten a docentes y alumnos desentrañar la naturaleza de la construcción del conocimiento.

Asimismo la entrevista clínica ha mostrado ser una herramienta poderosa a la hora de determinar el conocimiento previo de los alumnos o de verificar los resultados de nuestra instrucción.

4. El estudio de caso: caudales y manchas solares

Los problemas ambientales han generado la necesidad de educar a las nuevas generaciones con el objetivo que tomen conciencia y adopten un estilo de vida y de desarrollo sustentable. Hoy se considera que la educación para el desarrollo sustentable, es una parte esencial del desarrollo humano. Existen varias definiciones de desarrollo sustentable, aunque la más conocida es la del Informe Brundtland (WCED, 1987), que dice que el desarrollo sustentable es el desarrollo que satisface las necesidades de las generaciones presentes y futuras. Desde el punto de vista biológico todos los organismos tienen necesidades reales. Cuando estas necesidades están satisfechas los organismos pueden prosperar, tener un buen ambiente y una buena vida. Es decir que han alcanzado su satisfacción óptima que es el núcleo del desarrollo sustentable. (Kaivola & Ahlberg, 2007) La UNESCO reconoce cuatro dimensiones interdependientes del desarrollo sustentable: social, económica, ecológica y política que dan lugar a los principios: a) paz, igualdad y los derechos humanos, b) desarrollo apropiado, c) conservación y d) democracia. (UNESCO, 2005, 2012). Por lo tanto la educación para el desarrollo sustentable implica educar en los valores.

Los programas de educación ambiental colaborativos internacionales ayudan a los alumnos a ampliar su visión del mundo, a tolerar a otras personas, a valorar la diversidad, entre otros. También le ayudan a entender la similitud de los problemas ambientales alrededor del mundo, a poner en escala los problemas ambientales de su región y a detectar causas y predecir consecuencias. Al realizar mediciones ambientales, los alumnos visualizan por ellos mismos las variaciones en su lugar, y las comparan con otros sitios para extraer conclusiones.

Desde el año 2001 la escuela comenzó a trabajar con el programa internacional GLOBE (Howland & Becker, 2005) realizando mediciones ambientales utilizando los protocolos de hidrología, suelos, atmósfera y fenología. Estos datos se comparten en internet para que cualquier escuela pueda acceder y realizar investigaciones usando sus propios datos o los de otros alumnos. (EOP, 2010)

Dado la receptividad de los alumnos al monitoreo ambiental y a su preocupación por el ambiente, en el año 2004 se incorporó el programa ENO (Environment On-Line) (Vanhanen, 2003) como complemento de GLOBE ya que estudia el impacto social de los cambios ambientales. Cada escuela realiza una investigación y discute los resultados mediante videoconferencias, otras herramientas de la web 2. Esto ha fortalecido el trabajo colaborativo entre compañeros y fuera del aula. (Mayadas et al., 2009)

5. Metodología

Se realizó el trabajo de investigación en el último curso de la curso de la escuela agrotécnica CEI "San Ignacio", de Junín de los Andes, Provincia de Neuquén, Argentina. Todo el curso estaba formado por 12 alumnos. Las asignaturas donde se desarrolló el trabajo fueron biología y físico-química.

A partir de la proyección de un video de la BBC denominado "Maravillas del sistema solar: El imperio del Sol" donde se planteaba la posible influencia del sol en el cambio climático actual e incluso mostraba datos de correlación con el río Paraná en Argentina, los alumnos comenzaron a preguntarse si a nosotros nos estaría afectando también. Para realizar ésta investigación elaboraron las siguientes preguntas: ¿Cómo varían los caudales de los ríos en el Noroeste de la Patagonia? ¿Los caudales son afectados por la actividad solar?

El trabajo comenzó con la búsqueda de información sobre la influencia del sol en los caudales de los ríos y cómo éstos caudales podrían cambiar interanualmente. La búsqueda de información específica del lugar solo se encuentra en publicaciones técnicas que en su mayoría están en inglés. Por éste motivo utilizaron el traductor on line de Google para facilitar la tarea. Los trabajos de investigación realizados por otros fueron analizados utilizando el diagrama UVE, también denominado diagrama V (Moreira, 2010). Los alumnos, divididos en grupos de a dos, fueron haciendo mapas conceptuales de cada investigación realizada por otros que leían. Luego reunieron la información en un mapa conceptual que a su vez fueron resumiendo. El mapa conceptual general fue vinculado a los distintos recursos (imágenes satelitales, gráficos, animaciones, videos, links, etc) para facilitar su consulta durante la redacción del trabajo de investigación. Más información sobre cómo realizar éstos vínculos puede encontrarse en Cañas & Novak, 2008.

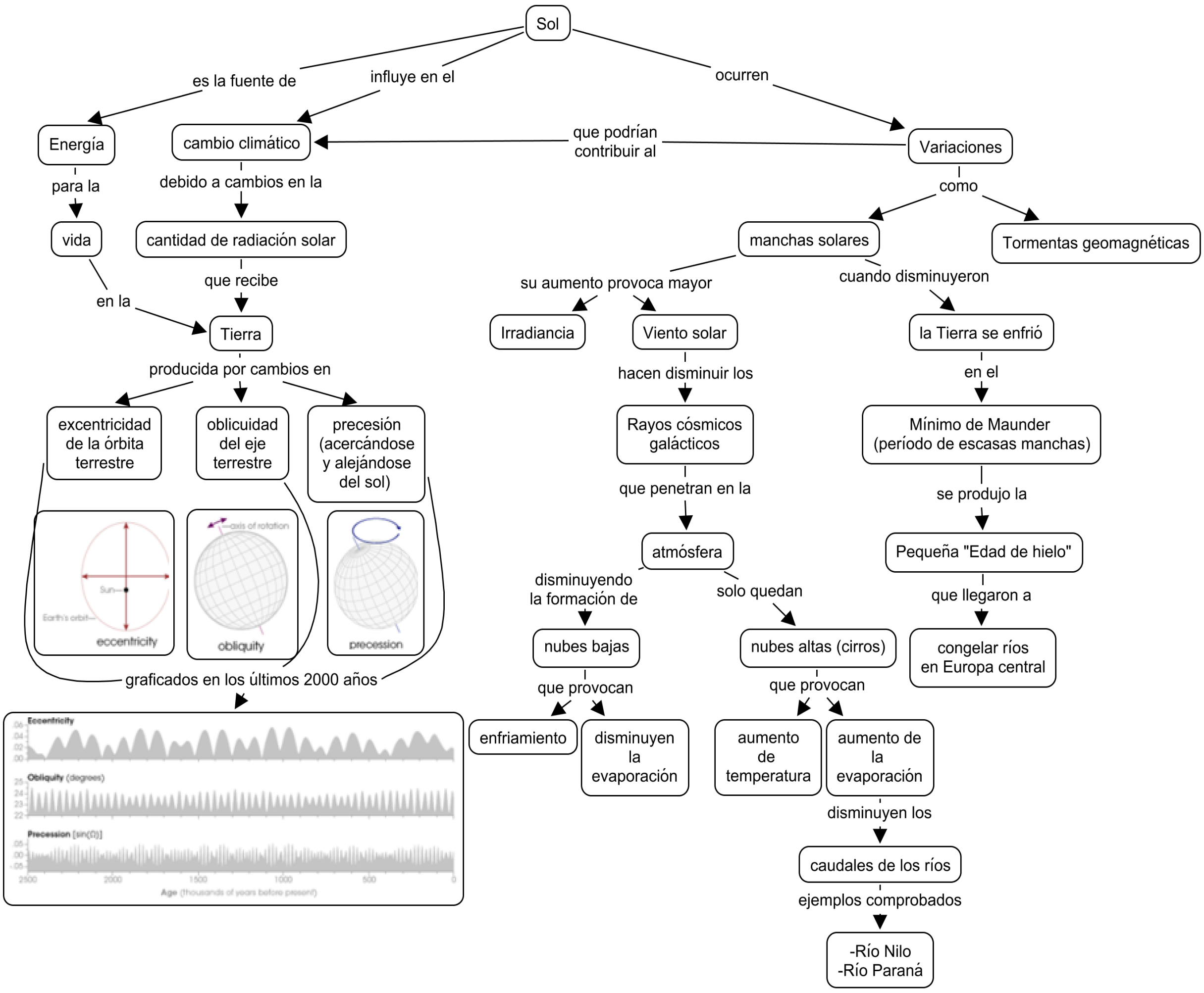

Figura 1. Mapa conceptual la posible influencia del sol en el cambio climático.
(Para facilitar la visualización en ésta publicación se omitieron los links)

Luego, tomaron sus preguntas como pregunta foco y diseñaron la investigación utilizando el diagrama UVE. Dado que era muy complejo para los alumnos realizar un análisis tan detallado del dominio conceptual, éste fue reemplazado por un mapa conceptual como se muestra en la figura 2.

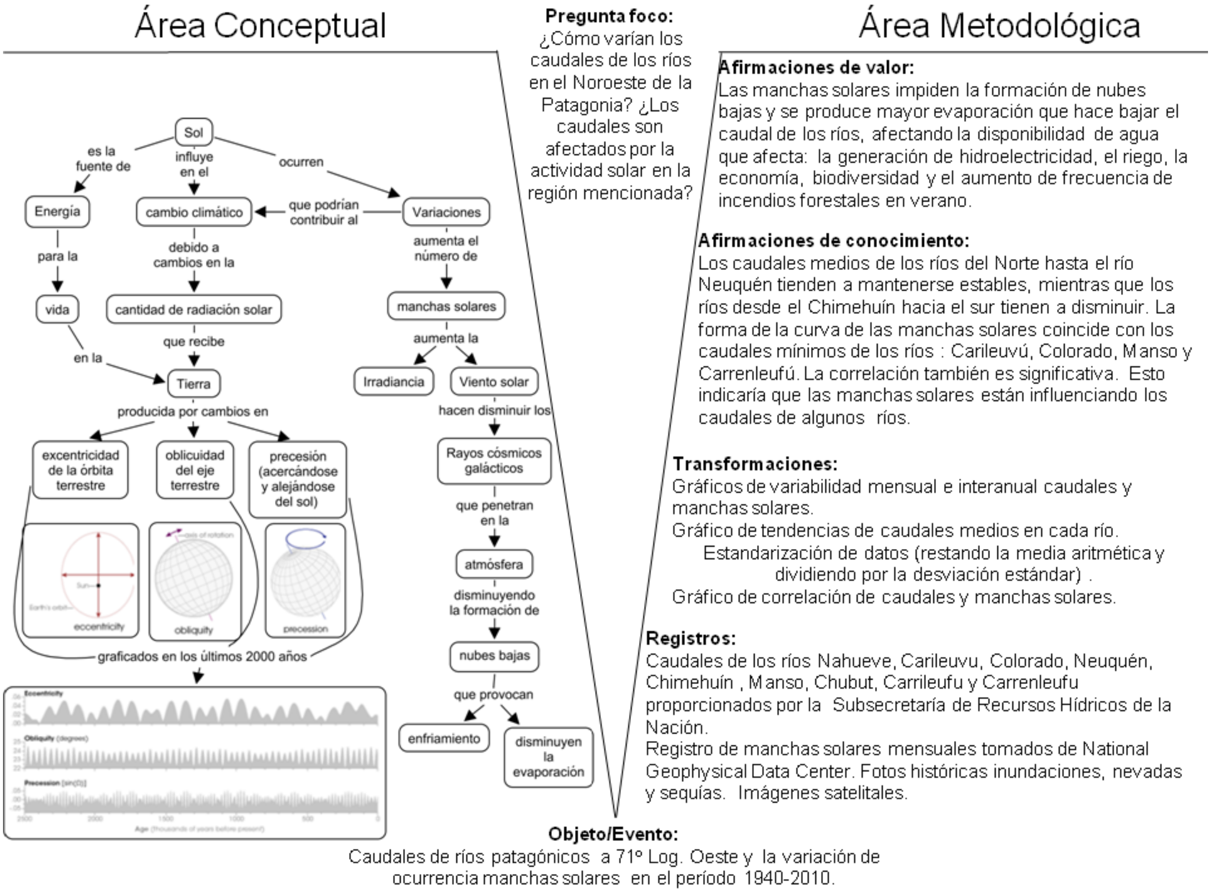

Figura 2. Diagrama UVE de Gowin con los resultados de la investigación realizada por los alumnos.

Tomaron los datos de caudales de los ríos patagónicos en estaciones hidro-meteorológicas localizadas aproximadamente a los 71° de longitud Oeste, casi en las nacientes de los ríos del Norte de la región de Patagonia, en Argentina, proporcionados por la Subsecretaría de Recursos Hídricos de la Nación[1]. Estos datos abarcan generalmente de la década del cincuenta, aunque algunos son anteriores a ésta, hasta el año 2004.

Los datos de las manchas solares fueron descargados del sitio web de la National Geophysical Data Center[2]

Para el procesamiento de datos se utilizaron los softwares Excel y Statistica.

Posteriormente, utilizando una wiki en forma colaborativa redactaron el informe de investigación y diseñaron una presentación multimedia para difundir los resultados y generar conciencia en la escuela y en la comunidad. Dado que los ríos patagónicos nacen en zonas húmedas pero luego atraviesan áreas áridas donde son la principal fuente de agua, los alumnos realizaron recomendaciones en cuanto al uso de agua en el verano (que coinciden con los períodos de sequía más críticos) y la prevención de incendios (forestales y de pastizales) debido a la susceptibilidad de la región.

La evaluación consistió en la presentación de la investigación en forma grupal y en una evaluación escrita individual sobre los contenidos desarrollados y las metodologías empleadas para desarrollar la investigación.

[1] http://www.hidricosargentina.gov.ar/InformacionHidrica.html
[2] http://www.ngdc.noaa.gov/nndc/struts/results?t=102827&s=5&d=8,430,9

6. Resultados

Por tratarse de una escuela agrotécnica la mayor parte de los contenidos enseñados tienen alguna relación con las variables ambientales y con el clima. El tema de los efectos del cambio climático en la agricultura y en la ganadería es mencionado frecuentemente en varias asignaturas. Muchos de los alumnos provienen de comunidades rurales pobres, que en su mayoría viven en ambientes de la estepa patagónica donde se está acentuando la sequía y la erosión. Según los pronósticos de cambio climático para la región del Nor-Oeste de Patagonia, en Argentina, las temperaturas tienen tendencia a aumentar y las precipitaciones a disminuir. (Srur et al., 2008). Este contexto genera mayor interés por parte del alumnado en el tema y en la investigación realizada, ya que se trata de una problemática global que los afecta localmente.

Los mapas conceptuales fueron muy útiles a la hora de recopilar la información. La posibilidad de asociar recursos que ofrece el software CmapTools facilitó la tarea de interpretación y de consulta de la información al momento de redactar el informe de investigación. Esta facilidad fue señalada por el total de los alumnos. La UVE les fue muy útil para diseñar y desarrollar la investigación (Novo et al., 2010). El uso de la estadística les permitió visualizar la fortaleza de algunos datos como la debilidad de otros y discernir sobre el tipo de conclusiones que pueden surgir del tratamiento estadístico. Los resultados dudosos o débiles los hacían pensar en que quizás estaba influyendo más de una variable además del sol.

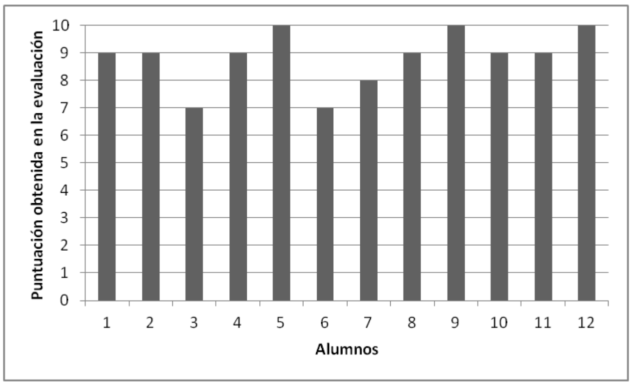

Figura 3. Puntuación obtenida por los alumnos en la evaluación final.

El aprendizaje se reflejó en sus notas individuales. La totalidad de los alumnos aprobaron (el 77% aprobó con 8, 9 y 10, el 23% aprobó con 7 y nadie desaprobó). En la entrevista realizada todos expresaron que las mediciones ambientales los hicieron tomar conciencia sobre la influencia ambiental de sus estilos de vida y sobre cada una de las prácticas productivas que realizan. (Novo et al., 2010; Grumbine, 2010) El trabajo colaborativo los ayuda a analizar el mismo problema en diferentes sitios y también señalaron la importancia de aprender diferentes formas de resolverlos. El 40% de éstos alumnos ha participado presentando proyectos en convocatorias ambientales.

El trabajo colaborativo es considerado por la totalidad de los alumnos como muy positivo, pero el 80% señalan que el uso de la wiki para redactar el informe de investigación les resultó muy dificultoso ya que era la primera vez que trabajaban en una wiki. Les resultó difícil modificar lo redactado por otros compañeros.

Esta investigación fue presentada en la escuela, invitando a diferentes actores del ámbito local relacionados con la problemática. También fue expuesta en las III Jornadas Interdisciplinarias de Cambio Climático de la Universidad de Buenos Aires (PIUBACC) - 10 y 11 de noviembre de 2011 en la Universidad de Buenos Aires. También obtuvo la 2º mención del concurso de AIC 2011 “El agua en la región del Comahue” y el 3º Premio en el concurso de AIDIS Argentina 2012 “Premio Argentino Juniors del Agua.

7. Conclusiones

Los programas colaborativos internacionales brindan un buen marco para la investigación, además de generar interés en los alumnos por la problemática ambiental a partir del monitoreo. Si además de realizar mediciones los alumnos logran realizar una investigación ya sea con sus propios datos o con datos de otros, enriquece aún más los aprendizajes a la vez que desmitifica la labor de la ciencia como algo inalcanzable. La investigación también les permite contextualizar los datos obtenidos, cotejarlos con otros y comprobar la fortaleza de los mismos a la hora de extraer conclusiones.

Tanto las herramientas metacognitivas y como las TIC ayudan mucho a la comprensión de los conceptos, son fáciles de manejar por los alumnos y muy útiles para procesar la información, diseñar y realizar una investigación. Trabajar colaborativamente los ayuda a consensuar ideas y a trabajar en equipo. La presentación en público genera mayor compromiso con el ambiente a la vez que aprenden a expresarse técnicamente.

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Agradecimientos: Los autores agradecen a la escuela por permitir realizar una innovación en la enseñanza, a los alumnos y a los colegas que realizan monitoreos ambientales. Además agradecen a María Marta Daneri, Albert Ortiz y Teresa Kennedy del Programa GLOBE y a Mika Vanhanen del Programa ENO (Environment On Line).

Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

ISSN 1989 - 9572

Large scale studies with concept mapping

Estudios a gran escala con mapas conceptuales

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 18 de febrero de 2013

Fecha de revisión: 4 de marzo de 2013

Fecha de aceptación: 12 de marzo de 2013

Reiska, P. (2013). Large scale studies with concept mapping. *Journal for Educators, Teachers and Trainers*, Vol. 4 (1), pp. 142 – 153.

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Abstract
Concept mapping is a method for determining the achievement of knowledge. Concepts are linked with labelled lines to proposition and so the concepts create a graphical structured meaningful relationship. There are many ways to use concept mapping in research as data collecting and assessment instrument. Changing the conditions (like focus question about the concept map, lists of concepts, given structure of concept map etc.) also change the results. For a valid research is necessary to analyse the study and define the aims before collecting the data. Probably the most comfortable concept mapping constructing opportunity is to use special Internet based environment and analysing program – that makes data collection easier and more objective. This article brings out, what kind of problems may occur, when concept mapping method is used as a research instrument in a large scale study and it also tries to define how to select the a valid instrument for a study. Researchers want to analyse students' knowledge, but instead sometimes they can only control whether they were able to create concept maps. The study brought out, that the quality of concept maps does not depend on concept maps creating frequency and computer handling skills.

Resumen
Los mapas conceptuales son un método para determinar los logros de aprendizaje. Los conceptos se unen mediante líneas etiquetadas y, de esta forma, los conceptos crean una relación significativa estructurada gráficamente. Existen muchas vías para usar mapas conceptuales en investigación como instrumento de recogida de datos y cómo instrumento de evaluación. Cambiando las condiciones (como la pregunta de enfoque, la lista de conceptos, una estructura dada del mapa conceptual, etc.) también cambian los resultados. Probablemente la forma más cómoda de construir mapas conceptuales sea usar un programa de análisis basado en un entorno de Internet, que hace la toma de datos más fácil y objetiva. Este artículo resalta los distintos problemas que pueden aparecer cuando los mapas conceptuales son usados como instrumento de investigación en un estudio a gran escala e intenta definir también cómo seleccionar un instrumento válido para un estudio. Los investigadores desean analizar el conocimiento de los estudiantes, pero en muchos casos sólo controlan si fueron capaces de crear mapas conceptuales. El estudio hizo evidente que la calidad de los mapas conceptuales no depende de la frecuencia de realización de mapas conceptuales ni de las habilidades para el manejo del ordenador.

Keywords
Concept mapping, assessment, validity, large scale study

Palabras clave
Mapas conceptuales, evaluación, validez, estudio a gran escala

1. Introduction and theoretical background

This article aims to find out what are the main problems which may occur when concept mapping method is used as a research instrument for large scale studies. In this article all of the concept maps and analyses of results are made using a computer programme. It is explained why it is comfortable and objective. This article describes how to control researching instruments' validity.

Concept mapping method

Concept mapping method is developed by Joseph Novak and his research team in early 1970s (Novak, 2010). The method is based on the theory of Ausubel (1968). This is also called meaningful learning and it assumes that learners construct their knowledge while they are already influenced from the previous knowledge. Concept maps could be created in different ways – on computer, by pen and paper, with labels etc. (Reiska et al., 2008; Ruiz-Primoet al., 1997; Novak, 2010). Concept map is a collection of propositions which is constructed in a certain way; it expresses graphically structured meaningful relationships which exist between different concepts (Ruiz-Primo et al., 1997). Novak (2010) suggests connecting the concepts with lines in order to create a good concept map; and labelling the lines with one or a few linking words which define the relationship between the two concepts so, that one could read them as a statement or a proposition.

Concept maps are widely used at schools in learning process; the method helps to prevent rote learning, to summarize already studied knowledge or class discussions, to create presentations etc. (Novak, 2010). Educational mapping is seen as a tool, which supports activities of learning, teaching, researching etc. The main idea in all fields of concept mapping is to reflect the brain work. Educators are interested in connections of working and long-term memory.

The structure of the concept map depends on many different conditions. Before students are asked to create a map, it should be clarified what kind of knowledge the map should develop or assess. There are many different possibilities to instruct students. Concept maps could be created without conditions, with a focus question, with root concept, with a list of concepts, restricting list of concepts, expert skeleton concept maps etc. Each of the methods gives a different map, with various outlook and nature (Cañas et al., 2012). To use concept mapping for assessment should be clarified the validity of the concept mapping. It should be verified concept maps are checking the knowledge of students, not constructing ability, computer handling skills or something else. For example if to provide students only with a focus question, it cannot be checked how all the students use some concept, which is connected with the question.

Studies from science have proved the necessity of concept maps in assessing and have pointed out that concept mapping is a useful tool to portrait the process of knowledge transformation from novice to expert. At first, concept maps were created mainly by pen and paper and results were calculated manually. The whole process took quite long.

Although many researchers have reported that concept mapping is a useful tool for learning and instruction, scientists have found some disadvantages to constructing concept maps using pencil and paper:

a) It is inconvenient for a teacher to provide appropriate feedback to students during concept mapping.
b) The construction of a concept map is complex and difficult for students, especially novice students.
c) Concept maps constructed using pencil and paper are difficult to revise. The 'pencil-and-paper' concept map is not an efficient tool for evaluation. (Chang et al., 2005).

Nowadays it has become easier because of the computers. (Novak, 2010; Gouli et al., 2003).

Assessing with concept maps

Novak (2010) noticed that students had recognized the value of concept mapping as learning and assessing tool.

For evaluating concept maps, certain dimensions for measuring are needed. Miller, Cañas et al (2008) have developed a topological taxonomy for evaluating created concept maps. They considered five criteria, when topological levels were defined: 1) recognition and using concepts; 2) presence of linking phrases; 3) degree of ramification; 4) hierarchical depth and 5) presence of cross-links. The taxonomy consists of 7 levels: from 0 to 6. Maps, which are evaluated with 5 and 6, satisfied almost all of the criteria. There are several measures for analysing concept maps: number and quality of propositions, size and hierarchy of the concept map, clusters of maps (Reiska et al., 2008).

An analyzing program is created for a programme IHMCmaps (http://cmap.ihmc.us/)- *CmapAnalysis.* This program gives an opportunity to analyse various algorithms, rubrics and techniques of concept maps. Parameters could be defined by the researcher. Creators of the program propose that this software helps instructors, researchers and teachers to have routine analytical operations automatically (Cañas et al., 2010). This program is indispensable for assessing and analyzing concept maps of large scale studies.
Sometimes it is said that concept maps could be used for assessing only when they have also been used in the learning process. This argument, however, is debateable and therefore further analysed in the current study.

2. Research questions and methodology

The main task of the paper was to study the validity of using concept mapping for assessment. More specifically, to find out what are the issues assessed using concept mapping. For that, the following research questions were defined:

a) Why are concept maps marked with different taxonomy scores? Could the computer based analysing program help in understanding the map quality?
b) Does the concept mapping quality measure, like taxonomy score and number of propositions, depend on students knowledge or methodical skills (earlier experience uisng this method, easiness to use, etc)?

The data collection was carried out in 2012 and the stratified sample of the study included 1614 sixteen to seventeen-year old students from 46 Estonian high schools. Schools varied by location, number of students, results of the state exams. The aim of the study was to analyse natural science literacy skills among Estonian students. Data collection instruments were: PISA-like three dimensional scenario-based tasks from chemistry, physics, geography and biology; concept map from one of the subjects and questionnaires about previous use of concept mapping and students' computer skills. Some of the questions were open ended and some were with multiply choices.

This paper is focused on 377 students, who created a concept map in the field of chemistry. Students had a focus question and a list with 30 certain concepts, meaning they did not have much freedom. The maps and answers to the questionnaire were analysed for this paper.

Data collection was performed with different instructors who used the Internet version of programme *CmapTools* and the same instructions were given for the whole class. Students needed computers and Internet connection for the mapping. Each student had a personal password and code for the Internet based *CmapTools*.

Problems with large scale study data collection and analysis

The main problem with large scale study data collection and analysis is how to carry out concept mapping so that it would measure the knowledge, not the ability to create concept maps or to use the computer. The pilot study compared what kind of concept maps are created by the students, when: a) only a focus question and the solved scenario-based exercise are given to students; b) focus question and the list on concepts (defined by the scenario-based exercise) are given to students. The result was that highly taxonomy scored concept maps were built when students had a focus question and the list of concepts (Soika et. al., 2012). This pilot study showed that it is difficult to measure with concept mapping the same aspects (e.g. conceptual knowledge) if just one condition is different.

In current study the students had to solve the scenario-based exercise on the first day. Weeks later they had to create the concept map about the same topic. Some of the data was lost, because some students were absent. There was also some data lost because of the internet based concept mapping environment (all students could not save their work; school did not have the right hardware in all the computers; some computers broke suddenly; Wifi connection was not strong enough). In order to eliminate such problems to minimum, the schools were checked before. It would have been easier with less students and schools. Internet based environment was used instead of computer based program, because it was more comfortable and a special code was given to every student that did not strain schools servers. Nobody was therefore able to peek into others work.

The questionnaire was created in Google Docs environment; some students forgot to submit their answers. For eliminating such problem, students were asked several times to follow the instructions (instructions were in written form).

Students were asked to compose their maps individually and different topics were distributed all over the classroom. Still students wanted to collaborate, to use help from the internet database or to connect concepts randomly without delving. Some of the students were a bit afraid of assessing and wanted to show that they are able to connect all of the concepts. Instructors had said that the aim of the work was not to connect the concepts randomly, but to create correct propositions. In order to eliminate such problems to minimum, all of the instructors had been instructed and used the same presentations. This also gave a possibility to get comparable concept maps and validity results for the research.

Some more problems arouse when analysing concept maps with the programme due to the peculiarities of the Estonian language - some special letters (õ, ö, ä, ü) are not accepted by the analysing programme. Therefore some words from fails had to be rewritten. Due to the large number of concept maps, this process was quite long-lasting.

Whether it is possible to compare the current study with other similar concept maps based studies is questionable. As the conditions for compiling the concept maps are not always known, the results cannot be compared. But there is always a possibility to glean some important facts to the instruments and studies from other interesting concept mapping based studies. In large scale studies with concept maps which have many different instructors have to be very careful with establishing the same conditions every time, otherwise the results would not be comparable.

Conditions for the concept mapping task

The focus question of the concept map was: “Cold bag- is it only chemistry?”. The question was connected to previously solved exercise. Students received 30 different concepts, which were defined by experts. Concepts were in different abstract levels and from various subjects and topics of natural sciences. 10 concepts were from chemistry (water, solubility, exothermic reaction, endothermic reaction, speed of reaction, equilibrium of chemical reaction, mole, pH, temperature of freezing, water, salt), 6 from physics (energy transfer, energy, pressure, melting, friction, absorption), 6 from biology (capillary, nerve impulse, lymphatic drainage, blood circulation, edema, dislocation) and 8 were social concepts (cold bag, tumour, risk, safety, pain, ethics, treatment, first aid). Time for creating a concept map was not limited.

3. Results of the study

Why are concept maps marked with different taxonomy scores? Could the computer based analysing program help us in understanding the map quality?

The average taxonomy score for all concept maps in the study was 2,5. There were two certain types of concept maps used and others were unclassifiable.

Cold bag- is it only a chemistry?

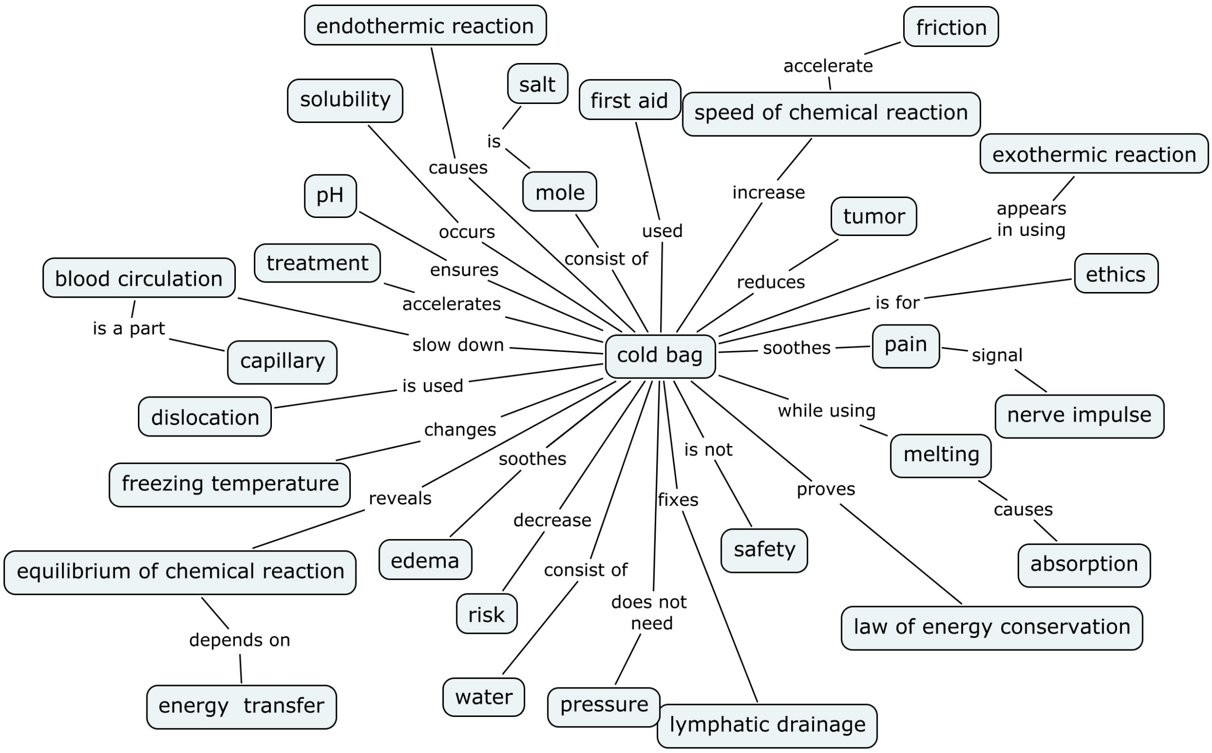

Figure 1. "Star"-shape concept map, which taxonomy score was 2 and average proposition per concept was 1, there was no orphan count, but the proposition count for concept cold bag was 24.

The concept map of 2% of the students who created 23-15 propositions with the concept cold bag was mainly with a shape of a "huge star". Concept "cold bag" was in the middle and all of the other concepts were connected mainly wit the central concept. Average taxonomy score for such maps was 2,25, that is lower than the average taxonomy score. In Figure 1 the map is not with high taxonomy scored, because students did not find connections with concepts to each other (for example in the concept map of Figure 1 the student could make a proposition "tumour could be pain"). So the score of taxonomy score does not depend only from the number of average proposition count, but it also depends on the structure of the whole map. Higher taxonomy scores for the maps groups appeared, when fewer concepts were connected with the central concept. These maps where only some propositions existed were marked with 1 or 0.

Table 1

Average proposition count per concept for the group	Average taxo-nomy score for the group	Number of proposition with the concept **cold bag**	% of students	Average proposition count per concept for the group	Average taxo-nomy score for the group	Number of proposition with the concept **cold bag**	% of students
0,77	2,25	17,9 *	2,1	0,78	2,76	6	9,5
0,73	2,36	14,7 **	2,9	0,69	2,54	5	9,3
0,93	3,14	10	3,7	0,61	2,71	4	13
0,88	3,09	9	2,9	0,57	2,55	3	15
0,72	2,67	8	4,8	0,56	2,56	2	16
0,78	2,56	7	4,8	0,44	1,78	1	9,8
				0,49	1,89	0	4,8

*- the concept "cold bag" was connected with 23-15 propositions- the number is average of the proposition count
**- the concept "cold bag" was connected with 14-11 propositions- the number is average of the proposition count

Cold bag- is it only a chemistry?

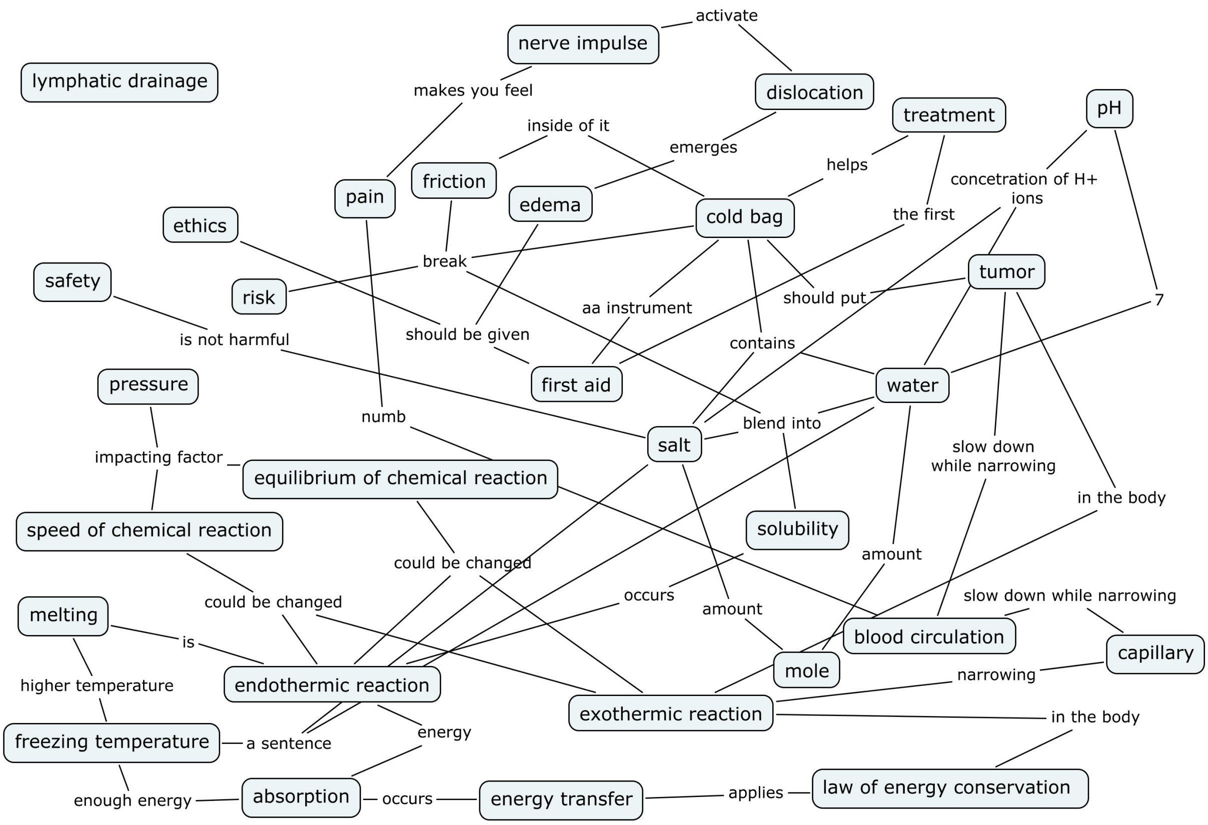

Figure 2. The taxonomy score of the map was 4 and the average proposition count was 1,5; there was 1 orphan count and the number of proposition for the concept cold bag was 10

Thanks to the computers and analysing programme, it is possible to imagine the shape of the map, when seeing only the scores of different indicators (as taxonomy score, central concept, orphan count etc.). That analysing method makes it easier to generalize the data. It is very hard to handle and analyse large scale studies of concept maps without the special program. At first, collecting the data would be hard and secondly, the analysis would take much time. The program enables higher level of objectivity, because the matrix measures the same values.

Does the concept mapping quality measure, like taxonomy score and number of propositions, depend on students knowledge or methodical skills (earlier experience uisng this method, easiness to use, etc)?

If the taxonomy scores depended on the program handling skills or the frequency of creating concept maps, the instrument of the study would not be validated, because the knowledge from the topic of students would not be checked. To exclude such possibilities, the questionnaire with multiply choices was used. The questionnaire included questions like how many times students had created concept maps before; how many times they had used computers for creating the maps; if they enjoyed creating concept maps and if they had some problems with creating the concept map during the study.

Analysis of the data revealed that there is no correlation between taxonomy score level, frequency of creating concept maps, program handling skills, pleasantness, school type or the number of classmates.

As table 2 shows, most of students from the sample had made concept maps before.

Table 2

How many times have you create concept maps?	More than 10	6-10	2-5	1	I have never made any map
% of students	30 %	17 %	38 %	3,7%	11%

A question arose whether the quality of concept map depends on the frequency of creating concept maps. This analyse bases on the average taxonomy scores.

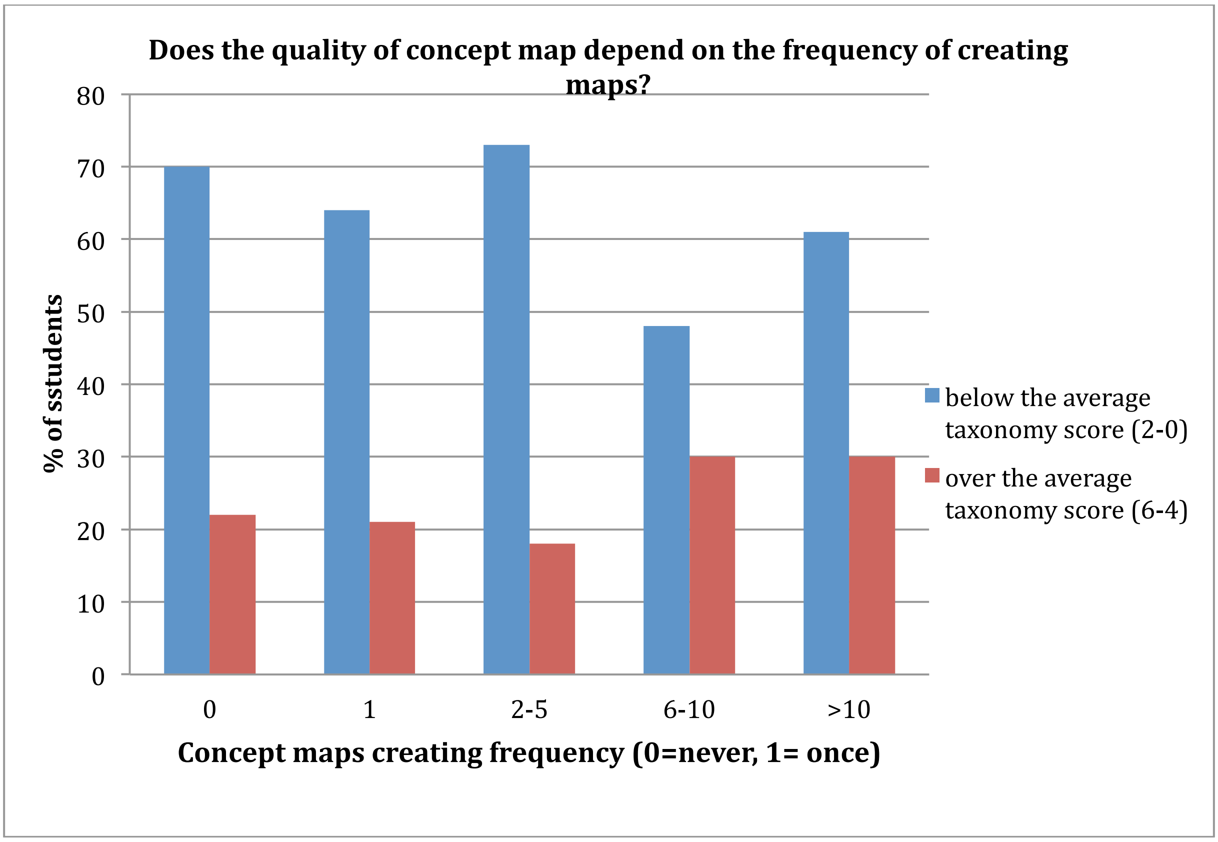

Figure 3. How does the quality of concept maps depend on the frequency of creating maps-comparing taxonomy score and concept maps creating frequency?

Figure 3 shows that the lowest taxonomy scores got maps that were created by students who had made concept maps 2-5 times. Students, who had never created concept maps before built more maps that scored 5 than students, who had made maps 6 to 10 times and they had more over the average taxonomy scored maps, than students, who had built maps 2 to 5 times.
It is also interesting whether the average proposition count depended on the concept maps creating frequency.

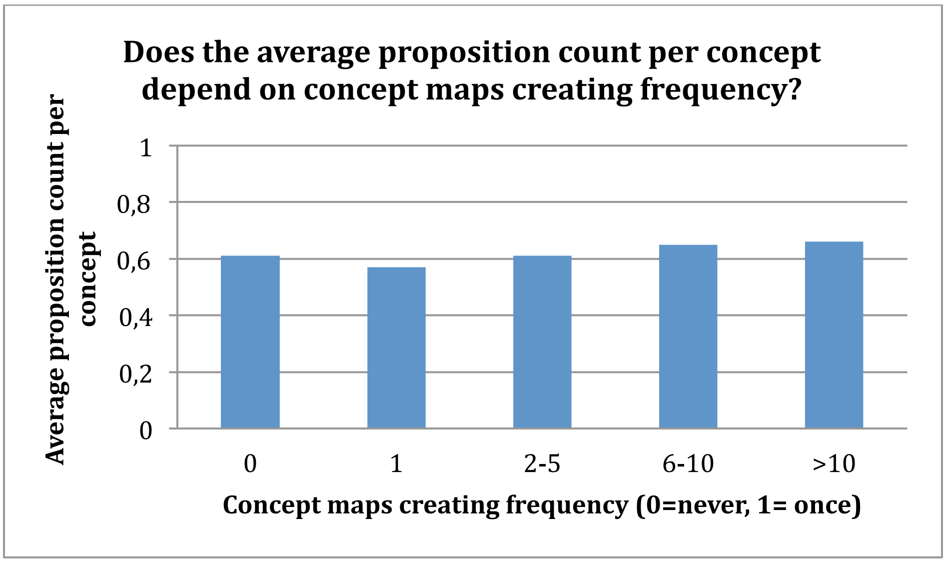

Figure 4. How does the quality of concept maps depend on the frequency of creating maps- comparing average proposition count and concept maps creating frequency?

Figure 4 reveales, that there is no huge difference in the number of average proposition count per concepts, when comparing the frequency of creating concept maps. Students, who had never made any concept maps, had as many propositions per concepts as students, who had created maps 2 to 5 times.

In the instrument, there were 9 abstract chemistry and physics-based concepts. Testing whether these concepts were used more by students, who had created more concept maps before, was carried out. An assumption was that probably students, who had created more concept maps before, have more time and skills to use abstract concepts in the propositions.

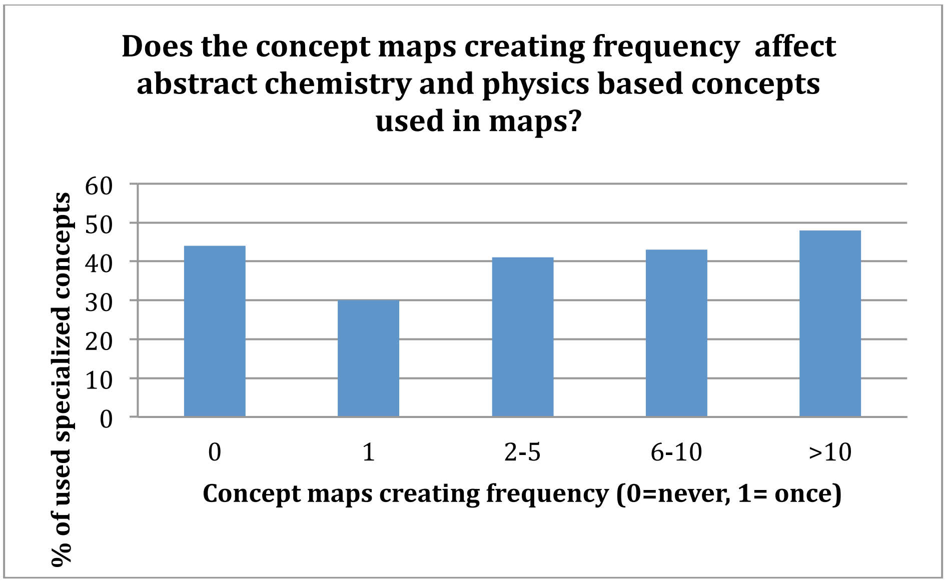

Figure 5. Do experienced concept mappers use more chemistry and physics based concepts than beginners?

Figure 5 shows that there is no differences between novices and expert students in using abstract subject based concepts. For the analysis, nine low centrality abstract concepts from the given concepts list were chosen. As seen from Figure 5, 44% of students, who had never created concept map, used all of the abstract concepts in their concept maps. 48% of the students, who had created concept map more than 10 times, also used all of the concepts.

So based on this study, it can be concluded, that the quality of the concept map does not depend on the concept map creating frequency and it was valid to use concept map in our study. Maybe the computer-based program used in the study was not valid, because the computer handling skills were not measured. While analysing the data, a question arose: were the program handling skills measured? Figure 6 illustrates this question.

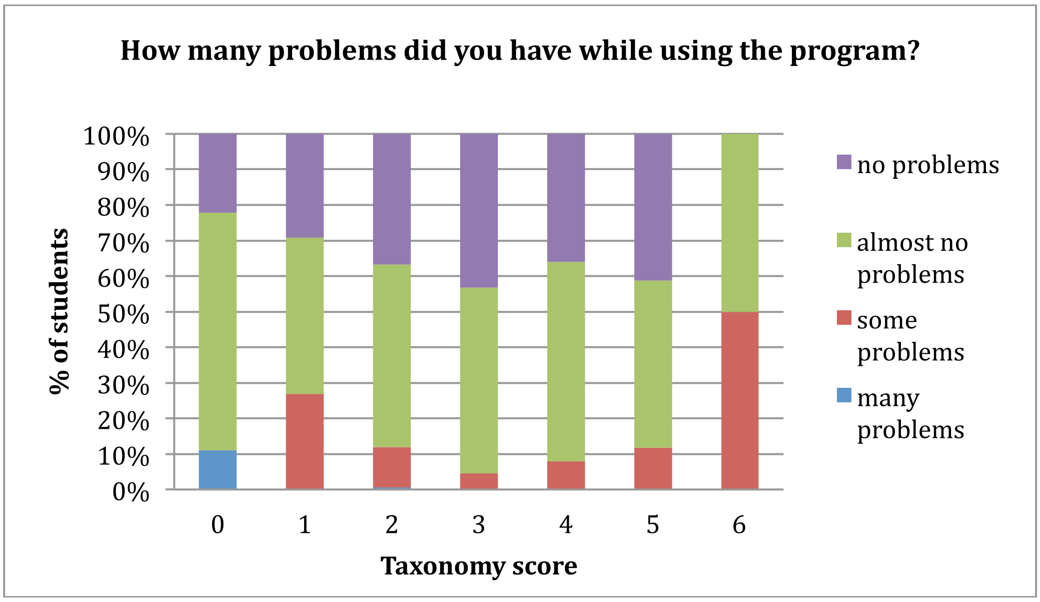

Figure 6. Does the taxonomy score of concept maps depend on problem appearance frequency?

As we seen from the Figure 6, most of the students said that they had almost no problems while they created their concept map in the computer. It is surprising, that students, whose concept maps got taxonomy score 6, found that they had some problems or almost no problems during the process. Therefore, students, whose map was evaluated with low level taxonomy score, got the mark due to their knowledge, not because of the occurred problems with program. Only 11% of students, who got taxonomy score 0, admitted that they had technical problems with the program (some of them had added, that they could not save or did not have the opportunity to concentrate, because the computer or the problematic Wifi connection). Therefore the program using skills were not measured and the instrument was valid.

It was also the interest of the researchers to find out who had more problems with the concept maps creating program- those, who had made concept maps often or those, who had not made concept maps.

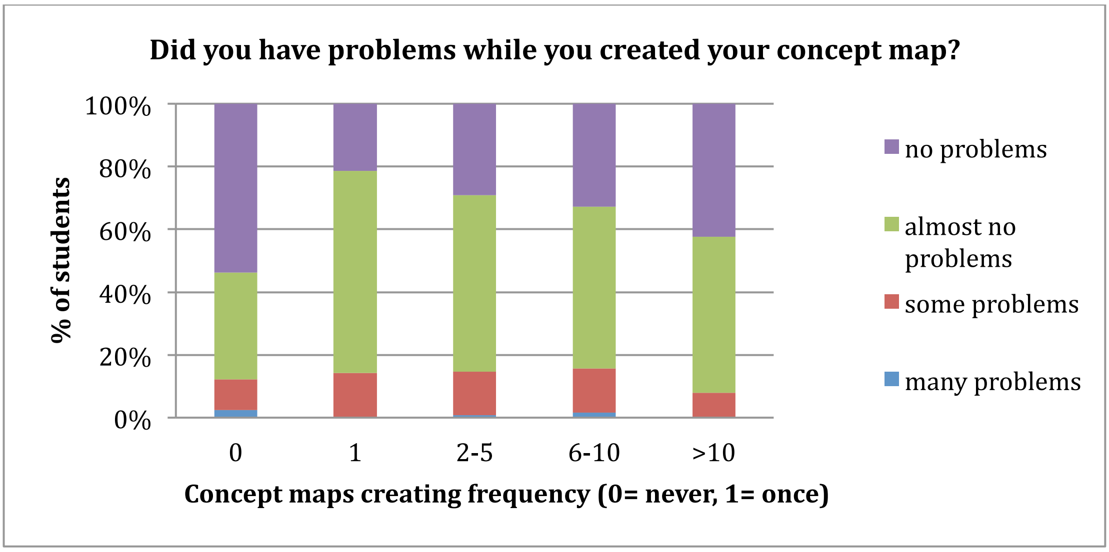

Figure 7. Does the problem appearance frequency depend on the concept maps creating frequency?

Figure 7 pointed out, that problems of the concept map building did not depend on the frequency of creating maps. Students, who had not created concept maps, did not have more problems with the program. Sometimes it is questioned whether it is correct to compare maps of students who are novices and experts in building concept maps. The current study revealed that in the internet-based environment, there was no difference. It means that the instructors had explained the topic clearly and so the students felt that they were able to fulfil this exercise- they were able to create a concept map with the focus question and the list of concepts. Therefore it could be concluded that the study was valid and the difference of computer handling or instructors competences was not measured.

Because of the comprehensive sample, the researchers decided to find out if the result of the concept map depended on the school feature. No correlation was found between schools based on its peculiarity (number of students, location, results of the state exams or directions) and taxonomy score results. During this study, the best concept maps were not created in bigger schools in (with more than 100 students in one grade level), but in the average and smaller ones.

4. Discussion

It is always hard to carry out a large-scale study. Probably it is especially hard with a concept mapping instrument. Usually the main problem is how to create equal (even the same) conditions to the whole group of participants. Without the same conditions, the results could not be compared and the study would not be valid. Instructors should give the same advice and actually they should even use the same words and examples, because concept map is a projection from ones knowledge. The knowledge depends on the memory- how many facts one remembers about different concepts, what kind of feelings one has. Even different words from various instructors may affect students' consciousness diversely. Using computers makes data collection and analysis easier. It also means that one could be more objective in interpreting the results and data collection conditions are similar. It should be remembered that slightly different studies could not be compared, if all of the conditions are not known.

In this article, the validity of the study and concept mapping instrument was analysed. Emphasis was put on what was actually studied. Due to the questionnaire and focus question-based and concepts given concept maps, the analysis brought out, that the quality of concept maps does not depend on concept maps creating frequency and computer handling skills. The conclusion is that the concept mapping instrument was valid for this study.

To go further with this large-scale study, it would be interesting to compare the results with the scenario-based three-dimensional PISA-liked knowledge test and the results on the concept mapping part. It would give another unique possibility to interpret the results of this large-scale concept mapping research.

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Acknowledgements
This study has been supported by European Social Fund program “Eduko” grant “LoTeGüm”.

Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

ISSN 1989 - 9572

Integrating collaborative concept mapping in case based learning

Estudio de caso y mapeo conceptual, un proceso colaborativo integrado

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 16 de febrero de 2013

Fecha de revisión: 5 de marzo de 2013

Fecha de aceptación: 12 de marzo de 2013

Tifi, A. (2013). Integrating collaborative concept mapping in case based learning. *Journal for Educators, Teachers and Trainers*, Vol. 4, pp. 154 – 163.

Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

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Abstract

Different significance of collaborative concept mapping and collaborative argumentation in Case Based Learning are discussed and compared in the different perspectives of answering focus questions, of fostering reflective thinking skills and in managing uncertainty in problem solving in a scaffolded environment. Marked differences are pointed out between the way concepts are used in constructing concept maps and the way meanings are adopted in case-based learning through guided argumentation activities. Shared concept maps should be given different scopes, as for example *a)* as an advance organizer in preparing a background system of concepts that will undergo transformation while accompanying the inquiry activities on case studies or problems; *b)* together with narratives, to enhance awareness of the situated epistemologies that are being entailed in choosing certain concepts during more complex case studies, and *c)* after-learning construction of a holistic vision of the whole domain by means of the most inclusive concepts, while scaffolded-collaborative writing of narratives and arguments in describing-treating cases could better serve as a source of situated-inspired tools to create-refine meanings for particular concepts.

Resumen

El mapeo conceptual y la argumentación colaborativa son utilizados en la estrategia de estudios de caso con la ayuda de andamiajes conceptuales. Se discute y comparan las respuestas que los estudiantes dan a las preguntas de enfoque, prestando atención a las habilidades de pensamiento reflexivo y el manejo de lo incierto en la resolución de problemas. Se observan marcadas diferencias entre la manera en que los conceptos son utilizados en la construcción de mapas conceptuales, y la manera en que los significados son apropiados durante la resolución de problemas mediante actividades guiadas de argumentación. Los mapas conceptuales compartidos pueden tener diferentes perspectivas, por ejemplo: a) como organizadores previos, que sirven de soporte, mediante el uso de un sistema de conceptos, para acompañar las actividades de indagación en la solución de problemas: b) junto a narrativas, permiten ampliar la toma de conciencia de la relación entre los conceptos utilizados, y las posiciones epistemológicas asumidas en la resolución de problemas y casos complejos, y c) para después de la experiencia de aprendizaje, como una visión holística del dominio (de conocimiento) completo, integran los conceptos más inclusivos, mientras se ayuda a la escritura en colaboración de narrativas y argumentos que describen y discuten los casos estudiados, este enfoque puede servir como una fuente de herramientas situadas de inspiración para desarrollar y refinar los significados de conceptos específicos.

Keywords

Generalized Concept Mapping, bottom-up concept mapping, case-based learning (CBL), pre-*concept, Scientific concept*

Palabras clave

1. Introduction

The purpose of this paper is to lay down the foundation for a combination of strategies to enhance reflective thinking, to drive high school learners toward intellectual modes [Donaldson 1992] and to enhance their processes and social skills, in a three-year longitudinal experiment that is aimed to cognitively and affectively empower the students[1].

The main strategy is based on the proposal of inquiry activities (problems, case study) through collaborative writing of online argumentation with the new feature of Google Apps Comments (asynchronous) and instant messaging (synchronous discussion), both supported on Google Drive documents and mediated by teachers' feedback. The idea is that through this prolonged activity, a reflective aptitude towards knowledge construction will be slowly regenerated, after years of "intake" of knowledge through repetition and mechanical application of rules.

2. Concept mapping vs inquiry based learning

Provided that meanings and concepts arise in problem solving for the sake of arguing or representing cases in situated contexts through narrative or argumentation, the aforesaid activity is excellent to tease out new meanings and to familiarize students with newly introduced concepts (respectively: bottom-up and top-down processes), but it is not the best way to organize a conceptual domain in a hierarchical system, for which concept mapping can be proficiently adopted.
In every case we want to avoid learning by rote, as seen in the intake of "pre-packaged" information, definitions and notions that won't be challenged in any way.

There are indeed important differences in the de-construction and re-construction involved in concept mapping (even if there is a focus question to answer) and in inquiry-based learning. In the former it is more likely that the student will resort to accepted rules and definitions, no matter if s/he does or does not know the anchorage of those rules to concrete mechanisms or instances. This leads to static meanings controlled by symbolic, iconic or logical functions in a formal system rather than to awareness of their effectiveness to represent concrete situations, to serve a precise role in solving a given problem or a controversy.

Yet, as we will see in more detail in the "eight concepts" paragraph, students are used to constructing concept maps that follow associative paths starting from particular views and going towards multiple differentiations, while leaving the "high-rank structure" of the most inclusive level of the cmaps poorly organized and with frequent indications of misconceptions or omissions of the most inclusive concepts.

On the other side, from the first monitored cases we also see that, in discussions stimulated by close-guided inquiry-based learning through focused questions, arguments undergo radical movements, shifting from one domain to another that carries completely new embedded meanings. So, provided that we want to minimize learning based on acceptation and promote the most inquisitive learning, concept maps will be made by the students after they will have tackled real cases, examples and problems, where arguments are put forward spontaneously and actions are accomplished for a precise purpose, even if students don't master formal-systematic definitions for the implied concepts. We want to recover the positive pedagogical function of errors (which are so frequent in inquiry-based learning) and of social negotiation, debates and argumentation in making inter-subjective meanings that can be gradually and consciously fitted to match with formal-academic meanings.

Reflecting during concept mapping is typically directed to find a better and simpler organization of concepts or to find more suitable and precise linking words or qualifiers for relations and concepts that are already placed in a learner's working memory. Rarely, a student bases himself or herself on the associative network of concepts to create some higher rank of generalization. S/he needs scaffolding from the teacher even to "feel" the necessity of some inclusive concepts and/or general setting to organize the whole layout (see an example in Fig. 1).

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[1] Collaboration includes 27 students of classes 3CH of the author of this paper, and 3L of Silvia Recchia from Istituto Galileo Ferraris of Verona.

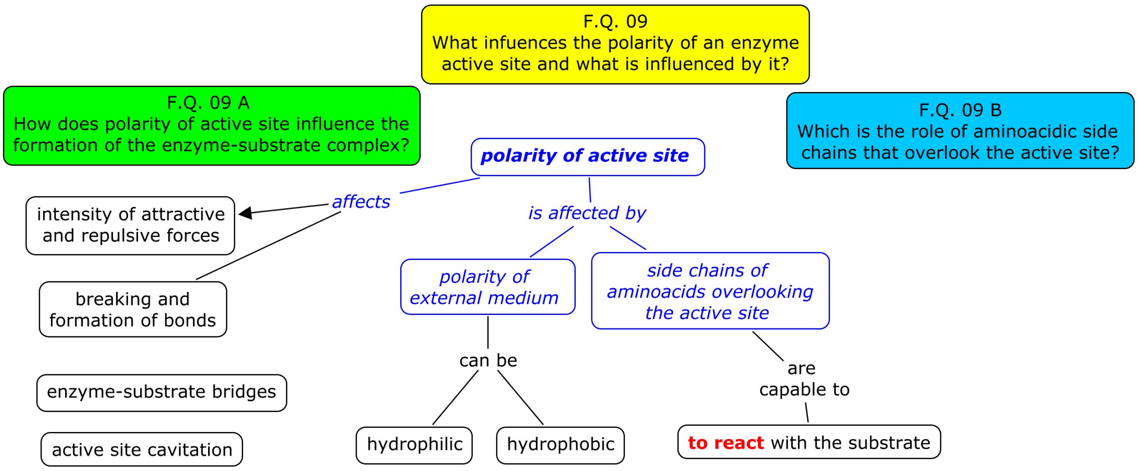


Figure 1. The original-complex focus question about enzymes (not shown) was divided into a simpler and more general question (central-top box) and into two sub-questions, F.Q. 09 A and F.Q. 09 B (colored left and right top boxes), after the students of the team started to connect concepts directly from the second level (black). The need of more inclusive framework (blue-italics first level) was obtained by persuading them in a few minutes. The left side of the progressing cmap shows two other concepts that remained parked for future development.

In inquiry-based learning reflection typically consists of re-reading and re-writing the terms of the problem, re-reading others' statements, suspending or redirecting concentration to read another source, being receptive to any clue that could help to discover or to challenge illicit assumptions (if the process is stagnant) or to find out some starting idea (if the process haven't started yet). In reflecting for inquiry, learner's working memory is often occupied by an overload of irrelevant information and preconceptions, which block the process; while in concept mapping the process flows more regularly, especially if it is helped by concepts pre-collected in a "parking-lot".

On the other hand, scientific inquiry, as problem solving, has just to do with a "what to do when all the paths of thought seem to be barred" kind of situation and there is just one way to learn the necessary ability to overcome that condition: to *get into* that situation (that is intentionally avoided by traditional instruction) *repeatedly*, to come back to the subject after some time, and then attempt to solve it, thanks to both one's own resources and collaboration from other people in the learning community. This is in conflict with the tendency of most students to prefer "only one access to knowledge", that determines the well-known negative chain: dependence on the teacher → vanishing of critical skills → inclination to a-priori giving up any challenge.

3. Eight concepts

As described in the previous paragraph, analysis, start and development of case-based inquiry learning is a matter of continuous realization of the usefulness of concepts and meanings as applied in situated contexts. There are no repeated applications of algorithmic procedures, and all cases are qualitatively different, but there are several recurrent concepts that learners become more and more confident with, in bottom-up processes that are activated by this case study.

This is indeed a good approach for familiarizing with single concepts or certain clusters of concepts, but not as effective in constructing a holistic model of a certain knowledge domain. We believe that the degree of confidence with "top rank" concepts is strictly related to the capability to find, understand and face the problem in case study. In other words, familiarity with the most inclusive concepts corresponds to the above stated individual resources that help to both initiate and engage in the inquiry process.

Therefore, we have devised a novel strategy to stimulate the revision of meanings about the most general structures and assumptions of a knowledge domain.

1. A general focus question – with some restrictions and frame requirements – is posed by the teacher and answered in text-form with as much breadth and detail as possible by students, autonomously. The same focus question, without specifications, has

served to introduce the general theme of case studies at the beginning of the module, and to progressively developing a complex concept map of related details to scaffold integration of the newly incoming concepts.

2. From the text-form answer, each student selects or elicits her/his *eight most general concepts*, and "parks" them in a Cmap that is shared with other buddies in a team.
3. The team buddies read the other's answers, criticize them, propose changes and propose-elaborate a "best" single text-form answer that is shared by all.
4. From that best answer, *ten* most general concepts are extracted and parked in a cmap.
5. A cmap is collaboratively made of just a maximum of ten concepts to answer the same focus question.
6. The cmaps of all teams are discussed in the class to enlighten differences in choices and, possibly, disagreements between teams, revealing any residue misconceptions.

While writing this paper we are at the end of the first module about *chemical reactions from the point of view of initial and final substances (reactants and products)* and at the first two steps of this experimental route to help learners mind in "mapping the fundamental (most general) concepts". We aim to help learners to reach a firm general conception of chemical transformation, which is based on the fundamental concepts of *Chemical System*, *Energy,* conciliating *Structure* and *Substance* levels of representation. It is widely documented that students can apply themselves with a high degree of competence in describing reaction mechanisms and doing stoichiometric calculations while lacking a general and correct representation of what is really going inside the chemical system and of how everything "collapses" in the synthetic balanced equations and energy exchange values [Osborne and Freyberg (1985), Nurrenbern and Pickering (1987-1990), Nakhleh (1993), Nakhleh and Mitchell (1993)]. The overwhelming reduction of chemistry to "managing of symbols" also makes vague and undefined the differences in meaning between entities as stable substance and molecular species that are often unstable. Without these distinct concepts in mind, any direct exposition and observation of chemical phenomena, as could derive from laboratory activities, would never be able to stimulate any learner's conceptual change, which should be the goal of all education.

We started from the beginner's course of Organic Chemistry to set such basis of General Chemistry, so the examples of cases in the case-based learning activities are taken from Organic chemistry, but the outcomes we wanted are absolutely general. Everything is new for both the teachers involved in the task and their third grade (age 16) students, so we are proceeding through cautious steps to optimize the process. Student were so used to preparing "top-down" concept maps about past topics that several of them started to answer the focus question by direct-normal (top-down) concept mapping (e.g. connecting the concepts to the focus question's square) or answering in text-form in a superficial way, while putting concepts in the cmap that were significantly different from the answered text. As a lesson for the future, for the next subtopic (that is already running) we will use Google docs and collaborative writing for the second and third steps and only then we will pass to concept mapping in the proper - dedicated environment (Umaps – CmapTools), separating the bottom-up reflection on the fundamental concepts from the reproduction of the elaborated and negotiated system of concepts in a concept map.

The first answers from the learners, reported in the following examples, demonstrated that an apparently simple task, such as explaining what happens in a chemical reaction, received inadequate answers from a conceptual point of view, notwithstanding the fact that a lot of sophisticated concepts and differentiations were used competently by the learners during the main activity of case study. So, as an example, many students ascribed a high rank to the *classification* of chemical transformations in Exothermic and Endothermic; they were classifying everything: Chemical Bonds, Reactants etc., but forgetting to talk of the Chemical System, the "stage" in which everything happens. That once more showed us the tendency of students to articulate concept maps as outlines of increasing completeness of details, but with scarce integration in a wide-range generalization, that would entail a higher level of awareness of inclusive concepts' meanings. The following table summarizes the concepts that were elicited by the answer to the focus question "*What does occur to a chemical system that undergoes a chemical reaction, considering the energetic and structural point of view of reactants and products only?",* sorted for number of occurrences.

Students:	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	**total occurrences**
CONCEPTS	12	9	12	8	7	8	9	8	7	9	5	8	6	
reactants/products	5		5		1	2		1	1	3	1		5	24
reaction (chemical)	6	2	4	1		4	2			4	1			24
chemical system		3	8		1	1	1		1	1	1	1	3	21
endothermic/exothermic	5		3			2	2			2			2	16
chemical bond energy	1	1	4			1	1	1	1	2		1		13
molecular skeleton		3	2						1	1		5	1	13
chemical bond: covalent	3				1	2	4	1						11
energy/enthalpy of formation	2	1	2	1	1				1	2				10
heat (absorbed/released)	4		4											8
chemical bond: single/multiple							3	1				3		7
connectivity change		1							1	2		1	2	7
Molecules			1			2	2	1					1	7
chemical bond								1	1	3	1			6
substance(s)						2	2	1			1			6
chemical bond cleavage	1	1	2											4
chemical bond formation		3												3
chemical bond: ionic	3													3
configuration change		1										2		3
atoms tied together by their bonds												2		2
electron shared	2													2
Reaction: Carbon hydrogenation												2		2
Reaction: hydrogenation					1		1							2
aggregates: covalent-continuous solids				1										1
aggregates: ionic solids				1										1
atomic electron exchange	1													1
atomic energy levels					1									1
atomic orbitals					1									1
chemical bond dissociation energy			1											1
element(s) (given)				1										1
energy/enthalpy level				1										1
heat of combustion								1						1
intermediate state			1											1
mass conservation (law)	1													1
structure				1										1
transformation				1										1

Table 1. Collected "eight concepts" from the first individual concept lists

Students that exceeded 8 concepts were constructing the concept map before or simultaneously to the text-form answer to the focus question. Their occurrence numbers for each concept indicate the number of propositions showing the concept at a node (isolated concepts should get a zero rank, but they were rated with "1" for coherence with simple concept lists). Cases with less than 8 concepts, were due to the students' choice to differentiating between multiple concepts that were counted as single concept in the table (e.g. exothermic/endothermic; reactants/products; etc.) The total occurrence numbers permit to have a first impact of the most rated concepts, that could be compared, for example, to an hypothetical answer and rated list from a teacher: "A *chemical system* which undergoes a *chemical reaction* changes its state due to a *rearrangement of its atoms* that leads to different final-*stable species* from the starting molecular species. These species correspond to observable *reactant and product substances* that are characterized by different structures and have different stabilities which depend on their *intra-intermolecular bonds* and are measured by their *enthalpy of formation*. These *structural changes* cause the final and initial states of the system having *different energy or enthalpy levels,* difference that is exchanged by the system with its environment and appears as *absorbed or released heat*." These concepts can be partially retained/modified in constructing a cmap (Fig. 2)

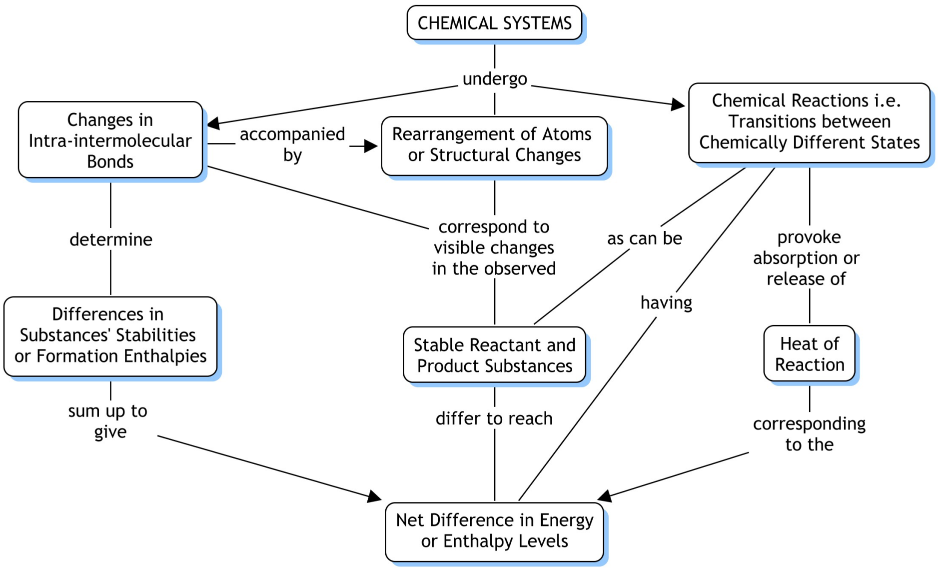
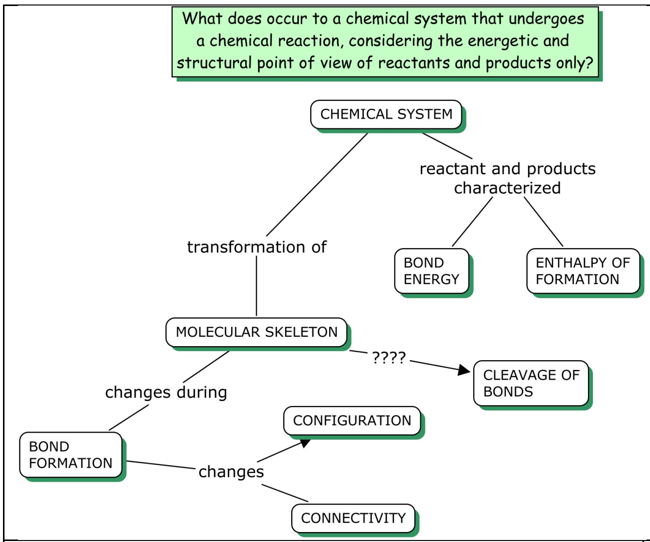


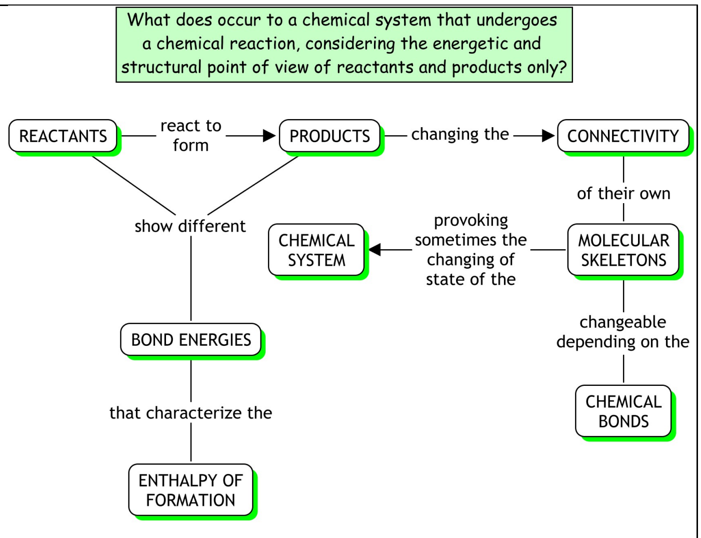
Figure. 2 A possible teacher's cmap based on the text-form answer to the focus question.

The occurrence-number table of this cmap is as follows:

- changes in intra-intermolecular bonds	4
- chemical reactions i.e. transitions between chemically different states	4
- net difference in energy or enthalpy levels	4
- rearrangement of atoms or structural changes	4
- stable reactant and product substances	4
- chemical systems	3
- differences in substances' stabilities or formation enthalpies	2
- heat of reaction	2

"Teacher concepts" are more often expressing relations (e.g. changes, differences in something, transitions between states) or result completed with qualifying attributes (net, inter-intramolecular, stable), and have more interconnections (linking phrases) if compared to students' concepts. The following cmaps are from students S2 and S9.





In a reaction there is a passage from reactants to products in which we have a transformation of the molecular skeleton that change in the formation of (single, double, multiple) bonds that are different from the products' bonds, while the system shifts from a state to another. Reactants and products are characterized from different enthalpies of formation and different bonding energies; the formation of new chemical bonds will cause	During a reaction there's a shift from reactants to products that happens when a change in the structure of molecular skeletons occurs that depends on the chemical bonds that are going to form. Consequently the products' bonds will be different from the reactants' bonds. Reactants and products have also different enthalpy of formation and different bonding energies, and with the formation of new bonds the connectivity will change too, while

a change in connectivity and also the configuration of the aggregates.	the chemical system will change its state.
TEAM_A: *A chemical reaction means a transformation of structure (of connectivity and configuration of molecular skeletons) consisting in a rearrangement of atoms. This takes place with a formation or breaking of (single or multiple) bonds, causing formation of substances (products) which are different from the reactant substances, that equates to the shift of the chemical system from a state to another. The reactant and product substances are characterized by different enthalpies of formation and by different bond energies. Taking the difference of formation enthalpies of products minus the reactant (all stable substances) we get the overall energy variation of the system.*	

Figure 3. Two typical "eight concepts" cmaps that were constructed from students S2 (left) and S9 (right) contextually to the text-form answer to the focus question. The individual answers were in the cmap layout in the original cmaps, but here they have been reported below for better readability. The answer below (italics) is the first coming from a collaborative adaptation within S2's team_A.

As in the two examples in Figure 3, the first text-form students' answers were often better descriptors of the correspondent cmaps that were made prematurely (instructions prescribed team collaborative cmaps only, at step six). Student S2 influenced a lot the final text-form answer of his team, subordinating, as an example, the concept of change in molecular 'connectivity' and 'configuration' as particular cases of 'structural change', an important inclusive concept that was adopted from individual answers of the other two team members. Team_A's answer shows many of the inclusive concepts appearing also in the "Teacher" answer (that was made only for the purpose of this article).

These observations support our conviction that text-form type of bottom-up generalization-reflection learning is more effective that than direct concept mapping in rising up the accuracy of learners' conceptions towards the academic ones.

4. Conclusions

We are not sure of the final form of this kind of concept mapping, of how it will be susceptible to adaptation in other future topics, but it will certainly be systematically structured to assure that enough time and energy will be devolved to that part of social construction that is needed to complete the meanings of those few general "words" that are taken for given and discounted in traditional - algorithmic - teaching, avoiding any flight towards lower-level empty words and particularizations. Students will learn that ascribing relevance to this imaginative undertaking, connecting the studied cases to general claims, is as important as solving the cases. We believe, in such way, to obtain a well integrated system to get a complete heuristics to facilitate up and down movement along the meridians of a conceptual system as described by Lev Vygotsky [1986]. This would facilitate those developmental changes in the structure of generalization that could be expected by sixteen-years-old students facing with the first very intellectual tasks. To define what we mean with these tasks we may quote in the second appendix some Vygotsky's [1986] and Donaldson's [1992] references, containing some relevant and partially superimposable passages that are guiding our research.

5. Appendix 2

> "The rise from preconcepts [...] to true concepts, such as the algebraic concepts of adolescents, is achieved by *generalizing the generalizations* [italics added] of the earlier level [...] The new, higher concepts, in turn, transform the meaning of the lower. The adolescent who has mastered algebraic concepts has gained a vantage point from which he sees concepts of arithmetic in a broader perspective. We saw this especially clearly in experimenting with shifts from the decimal to other numerical systems. As long as the child operates with the decimal system without having become conscious of it as such, he has not mastered the system, but is, on the contrary, bound to it. When he becomes able to view it as a particular instance of the wider concept of a scale of notation, he *can operate deliberately* [italics added] with this or any other numerical system. The *ability to shift at will from one system to another* [italics added] [...] is the criterion of this new level of consciousness, since it indicates the existence of a general concept of a system of numeration." Vygotsky [1986, p. 202-3]

Donaldson [1992] distinguishes two modes of intellectual functioning of the mind: 'construct' and 'transcendent', corresponding to different stages of development (the second not being always reached by all the individuals). In general terms:

> "Beyond the line mode the major step that is taken consists in *movements towards the impersonal* [italics added]. That is, the mind starts to be able to function in ways that achieve some *independence from personal goals* [italics added]. For instance*, it becomes possible to think about problems of some generality* [italics added] […] On the other hand, it is also possible for human beings *to think with the aim of understanding some aspect of the way things are* [italics added]. In this sense there is movement towards impersonality, though the movement may be powered by intense personal curiosity. […] The process of 'opening out' in those two directions is the one that I have previously called *disembedding.*" [Donaldson, (1992) from the introduction, p.16-17]

Later on, Donaldson defines the 'construct' variety of concern in intellectual modes:

> "What has to be achieved beyond this is the movement of the locus of concern away from particular happenings in time. Instead of here/now or there/then the mind will next begin to concern itself with a locus conceived as somewhere/sometime or anywhere/anytime. […] We start to be actively and consciously concerned about the general nature of things. […] The needed context is, by definition, no longer provided by the perception of specific events, by the memory of them or by the anticipation of them. So it has to be supplied by a *deliberate constructive act of imagination* [italics added]. For this reason […] it is called the construct mode." [ibid. p.80-81]

A similar example to Vygotsky's idea of movement towards generalization can be quoted, also to clarify Donaldson's meaning of 'embedded/disembedded': "What is involved in the mind's movement from 'seven fishes' to 'seven' is abstraction indeed, but it is more: it is a dramatic decontextualization. In the contexts of our ordinary life we have to deal with quantities of fishes, but we never encounter seven. […] A pure number resists embedding in any human context." [ibid. p. 90] .

The grasp of general concepts is a momentous development for the gained independence of thought, but the imaginative activity we call "making sense" becomes even more useful in the transcendent modes, described as the most advanced modes by Donaldson:

> "We move on now from the intellectual construct mode to a further mode that is also intellectual, yet radically different. I shall call it transcendent mode. […] I stress again that this does not mean they are unemotional. It means only certain kinds of emotion - the kinds liable to distort or bias thinking – are excluded by definition. For where potentially distracting emotions are present to any appreciable degree the mind has shifted gear and has slid back into one of the core modes – a shift that remains always easy and tempting. […] In the case of intellectual transcendent mode, [however,] the concern is no longer about something that could happen 'sometime, somewhere'; and the need for imagined setting has dropped away.[…] To speak paradoxically, we may say that the focus of concern is nowhere. […] The prototypical activities of the intellectual transcendent mode are logic and mathematics. But […] what […] are logics and mathematics *about*? […] The general answer has to be that logics and mathematics are about *relationships*: relationships of compatibility or incompatibility, of symmetry or asymmetry, of inclusion or exclusion, of equality or inequality, and so on. More than this: they entail the systematic study of *patterns* of relationships. […] A shift of concern from things-in-relation to *relations themselves* [italics added] is made easier if the dominance of 'things' can be diminished. But that dominance is powerful indeed, and hard for our minds to reduce. It is harder still to give up entirely the construct-mode habit of thinking about imaginable entities of some kind, even if their individuality is diminished to the limit. This means that the diminishing of individuality is not a sufficient condition for the shift to *concern about relations* [italics added], though I think it is a necessary one." [ibid. p. 125-126]

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Journal for Educators, Teachers and Trainers
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ISSN 1989 - 9572

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Los mapas conceptuales y el aprendizaje significativo de la ciencia

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Journal for Educators, Teachers and Trainers, Vol. 4

http://www.ugr.es/~jett/index.php

Fecha de recepción: 15 de enero de 2013

Fecha de revisión: 20 de febrero de 2013

Fecha de aceptación: 05 de marzo de 2013

Valadares, J. (2013). Concept maps and the meaningful learning of science. *Journal for Educators, Teachers and Trainers*, Vol. 4, pp. 164 – 179.

Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

Journal for Educators, Teachers and Trainers, Vol. 4 (1)

ISSN 1989 - 9572

http://www.ugr.es/~jett/index.php

Concept maps and the meaningful learning of science

Los mapas conceptuales y el aprendizaje significativo de la ciencia

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Abstract

The foundations of the *Meaningful Learning Theory* (MLT) were laid by David Ausubel. The MLT was highly valued by the contributions of Joseph Novak and D. B. Gowin. Unlike other learning theories, the MLT has an operational component, since there are some instruments based on it and with the meaningful learning facilitation as aim. These tools were designated *graphic organizers* by John Trowbridge and James Wandersee (2000, pp. 100-129). One of them is the *concept map* created by Novak to extract meanings from an amalgam of information, having currently many applications. The other one is the *Vee diagram* or *knowledge Vee*, also called *epistemological Vee* or *heuristic Vee*. It was created by Gowin, and is an excellent organizer, for example to unpack and make transparent the unclear information from an information source. Both instruments help us in processing and becoming conceptually transparent the information, to facilitate the cognitive process of new meanings construction. In this work, after a brief *introduction*, it will be developed the *epistemological* and *psychological grounds* of MLT, followed by a reference to *constructivist learning environments* facilitators of the meaningful learning, the characterization of *concept maps* and exemplification of its use in various applications that have proved to be very effective from the standpoint of meaningful learning.

Resumen

Los cimientos de la Teoría del Aprendizaje Significativo (TAS) fueron puestos por David Ausubel y fue valorado muy positivamente por las contribuciones de Joseph Novak y D.B.Gowin. A diferencia de otras teorías del aprendizaje, el TAS tiene un componente operativo, ya que en virtud del mismo, y teniendo como objetivo facilitar el aprendizaje significativo, se crearon instrumentos, que John Trowbridge y James Wandersee llaman organizadores gráficos guiados por la teoría (2000, pp. 100-129). Uno de ellos es el mapa conceptual, fue creado por Novak con lo propósito de extraer significados de una amalgama de información, teniendo actualmente muchas aplicaciones. La otra es la Uve del conocimiento, también llamada Uve epistemológica o Uve heurística y fue creada por Gowin, que es excelente, por ejemplo para desempacar y hacer transparente un contenido poco claro de una fuente de información. En el fondo, ambos nos ayudan a procesar y tornar conceptualmente transparente la información, para facilitarnos el proceso cognitivo de construcción de nuevos significados. En este trabajo, después de una breve introducción será desarrollada la base epistemológica y psicológica del TAS, una referencia a los entornos constructivistas de aprendizaje facilitadores del aprendizaje significativo, la caracterización de los mapas conceptuales y la ejemplificación de su uso en diversas aplicaciones que han demostrado ser muy eficaces desde el punto de vista del aprendizaje significativo.

Keywords

Meaningful learning; human constructivism; constructivist learning environment; graphic organizer; concept map.

Palabras clave

Aprendizaje significativo, el constructivismo humano, el medio ambiente constructivista del aprendizaje, organizadores gráficos, mapas conceptuales.

1. Introduction

It was in the early 80s I had the first contact with the semi behaviorist and the cognitivist theories of learning, including the theory of Ausubel.

In 1981, Joseph Novak was invited by the Portuguese Chemical Society to present in Lisbon his *concept maps*, which are graphic organizers guided by the MLT. Since then I never stopped to appreciate the merits of the MLT and I used concept maps with my high school students, later with University students and also with many teachers to whom I gave training. In 1992, I went to Cornell University, where I participated in a Seminar where Prof. Novak made me see the importance that also has the knowledge Vee, of Gowin, for the meaningful learning.

The current teaching must be based on *good epistemological*, *psychological* and *educational grounds*, which was not the case with traditional teaching. In the *traditional schools*, teachers used almost exclusively the exposition of the programmatic contents, with all the shortcomings that Ausubel points to this traditional expository teaching (Ausubel, 2003, p. 7). Such teaching is bad because the teacher uses prematurely "pure verbal techniques" and exposes, in a prolonged and often monotonous way, often scattered and not integrated contents, sometimes incoherent and arbitrary, therefore without logical meaning, having no account if students have adequate cognitive readiness to learn meaningfully. Furthermore, the traditional teacher uses a sporadic assessment, almost exclusively summative, when he must use a systematic and essentially formative assessment.

It is *impossible to change* this traditional behavior without *transform the epistemology* and, consequently, the ideas about the nature of scientific knowledge and the process of its construction (Bell and Pearson 1992, in Gil-Pérez, 2002).

The MLT, as well as the graphic organizers based on it (Trowbridge and Wandersee 2000, pp. 100 - 127), particularly the Novak's concept map and the Gowin's knowledge Vee, are cemented on what Novak called *human constructivism*. This is the focus of the next section.

2. The human constructivism

In the Preface of the book «*The Practice of Constructivism in Science Teaching*», published by the *American Association for the Advancement of Science*, we can read that "*there is widespread acceptance of constructivism*" that "*constructivism has become increasingly popular*" and that it represents a "*paradigm chance*" in science education (Matthews, 1998, p. 2).

But when we refer to constructivism is important to characterize *what kind of constructivism* is, because the word «constructivism» is *polysemic*, which originated that *several variants of constructivism* arose, contextual, dialectical, empiricist, rationalist, pragmatist, personal (based on Piaget), social (based on Vygotsky), radical (of von Glasersfeld), sociological (based on the Strong Program of Edinburgh School), and so on (Matthews, 1992, p. 34; Bickhard, 1998, p. 104-108, von Glasersfeld, 1996, Nola, 1998, p. 33, Kragh, 1998, p. 127).

Some *radical and sociological constructivist ideas* have been strongly criticized, for example, ideas of the so-called «*Strong Program of Edinburgh School*» and ideas of the «Frankfurt School», that the science historian Helge Kragh consider in line with the *historic attacks on Science* (Kragh, 1998, p. 126). Due to psychological idealism, anti-realism, anti-objectivism and skepticism of many constructivist ideas, many thinkers have rejected the constructivism. But there are several authors, for example Bickhard (1998), who consider the rejection of constructivism a wrong position. John Staver claims (1998, p. 501) that even many critics of constructivism have recognized their beneficial contributions for education. I believe, based on many «*science studies*» and others about the nature of human cognition, also based on philosophers like Johannes Hessen (1987), who was professor at the University of Cologne in the last century, and in epistemologists like Popper, for example, that *constructivism does not must fall into anti-realism, anti-objectivism, relativism and skepticism* when do not defend the strong objectivity of science and naive realism that some scientists have revealed. For example, none of the many thinkers who collaborated on the book "*A Ciência tal qual se faz*" (Gil, 1999) deny some intrinsic rationality and objectivity to the science.
In accordance with Niaz et al. (2003, p. 787) and other authors according to which it is not possible to implement a coherent and authentic constructivist pedagogy without an underlying constructivist

epistemology, well characterized by its epistemological, sociological, psychological and educational facets, it is important to ask: what is then the constructivism that underlies the MLT and the creation of their graphic organizers?

The constructivism that underlies the MLT is the *human constructivism* of Novak, and the first contact I had with it was through a paper he presented at the Fourth North American Conference on Personal Construct Psychology, San Antonio, Texas, in 1990. In this paper Novak says: "*Human Constructivism, as I have tried to describe it, is an effort to integrate the psychology of human learning and the epistemology of knowledge production*" (Novak, 1990, p.15). On the other hand, Mintzes and Wandersee consider human constructivism as "*a vision of creating meanings that encompasses a theory of learning and an epistemology of knowledge construction*" (2000, p. 58). This theory they refer is the *Meaningful Learning Theory* and the *epistemology* behind it is *constructive* and *humanistic*, based largely on Gowin and Novak ideas.
Such as any good theory, *human constructivism* is based on broad principles (Novak, 1990, 2000; Gowin, 1990; Mintzes e Wandersee, 2000):

- Human beings have a capacity for meaning making that can be optimized.
- Thinking, feeling and acting contribute together to change the meaning of the human experience.
- Although there is an idiosyncrasy in individual concept structures, there is sufficient commonality and isomorphism in individual meanings so that the dialogue is possible and sharing, changing and enriching meanings is possible.
- The education must promote the construction of shared meanings.
- The shared meanings can be facilitated by the active intervention of well-prepared teachers.
- The scientific and artistic production, at the highest level, is a highly creative and original construction of new meanings and therefore of highly meaningful learning, the ideal where must be pointed the learning at schools.

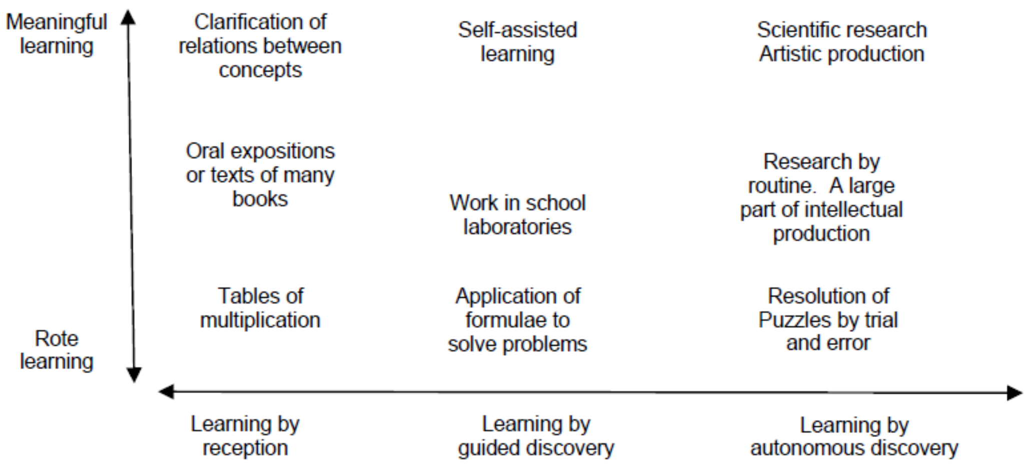

Image 1. Two dimensions of learning (adapted from Ausubel, Novak e Hanesian, 1980, p. 21, Novak e Gowin, 1999, p. 24 and Novak, 2000, p. 28).

In the preface of the book «*Ensinando ciência para a compreensão – uma visão construtivista*» (2000, p. 17), coordinated by Joel Mintzes, James Wandersee and Joseph Novak, we can read the following:

> "In contrast to the notion of radical and social constructivism, the human constructivism takes a moderate position about the nature of science. On one hand considers the opinions of the logical positivists intellectually indefensible; on another hand, considers that many constructivists created a relativist mental world that ends up destroying itself. Prefers, instead, a view of science that acknowledges an external and knowable world, but that largely depends on an intellectually demanding struggle to build heuristically strong explanations through extended periods of interaction with objects, facts and other individuals".

The *moderate position* that the *human constructivism* has about the nature of knowledge is due to its *surpassing character* of the great *historical antitheses* that emerged in the philosophy of knowledge. Thus, the human constructivism considers that knowledge, whatever it may be, is constructed based on a *complex interaction* between two major components, one *conceptual* and another *methodological* and *experimental*, and that this interaction nvolves several epistemological blocks. It is very well translated in the knowledge Vee, epistemological Vee, heuristic Vee, of Gowin:

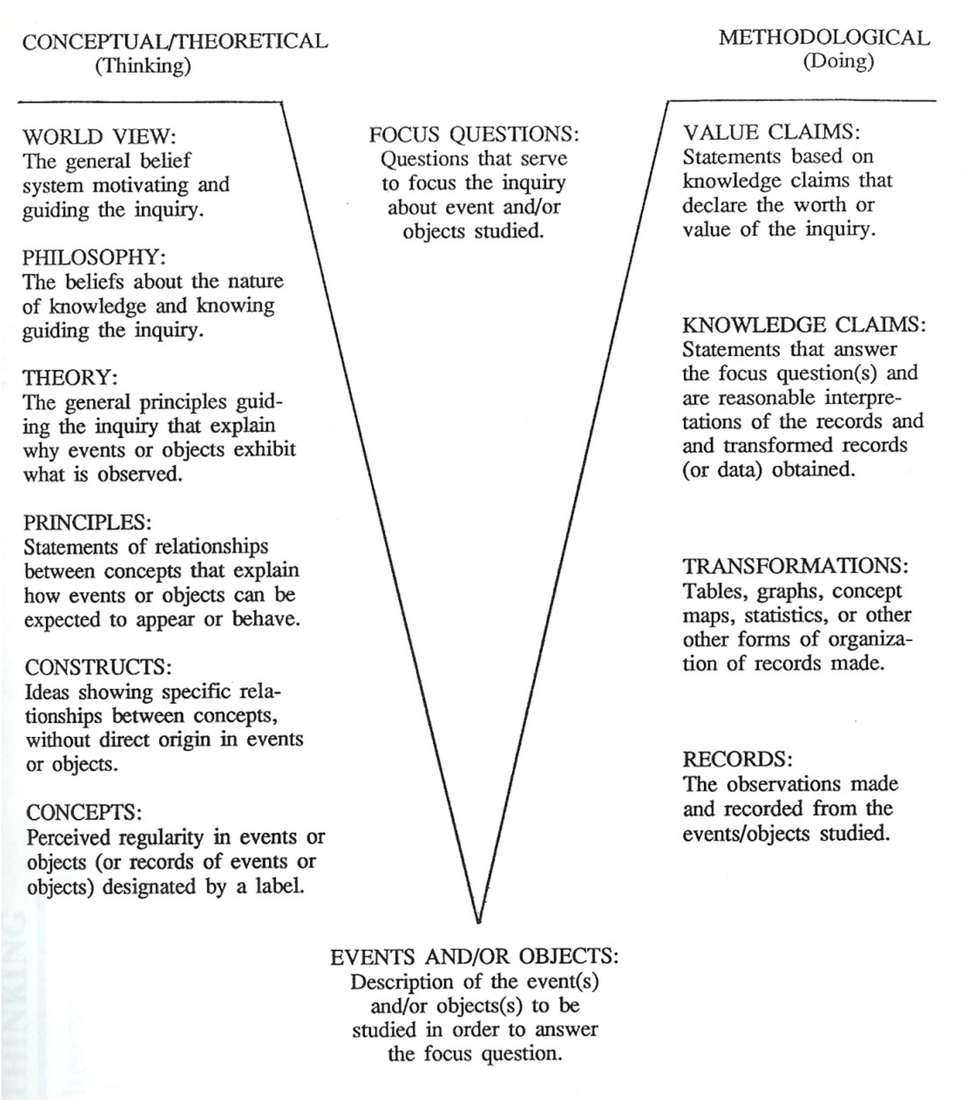

Image 2. The knowledge Vee, heuristic Vee, or epistemological Vee, of Gowin, in its general form

In *psychological terms*, the human constructivism considers the knowledge *assimilation* as a *personal* and *idiosyncratic* process, yet deeply *influenced by social contexts*, real or virtually lived. In this process, the *subject* behaves as a *multifaceted being* where *thinkings*, *feelings* and *actions* combine to give *meaning* to the life *experience*. The subject is immersed in a world of *information*, but this *is not knowledge in itself*. It is necessary make interact and integrate the information into the cognitive structure. *Language* is *fundamental* in coding, shaping and acquiring new meanings and also contributes to the assimilation of knowledge by each individual as an idiosyncratic process.
The *human constructivism* has *educational implications* that must be highlighted here:

- The fact that the student has to be considered the structuring element of his learning.
- The fact that the ideas can make sense for a student without being accepted by another student and the teacher.

- The idea that students should be involved in a process of heuristic and personal search but also in a fruitful interaction with other students and the teacher.
- The importance that the student's preconceptions, and particularly their misconceptions, have in their learning.
- The essential role of the teacher, that should intervene (exposing ideas when and only when is necessary) to provide the students with adequate evidence and provide them with the concepts and theoretical models of science.
- The importance of providing students with a humanistic vision of science, to assert its fallibility, as everything that is produced by human beings.
- The importance of dialogue and debate of ideas in the classroom. In the words of Novak and Gowin (1999, p. 37) "*learn the meaning of a given knowledge implies dialogue, exchange, share, and sometimes make compromises.*" Share yes, but not learning. *Learning* is an activity that *can not be shared*, it is rather a matter of individual responsibility. On the contrary, the *meanings can be shared*, discussed, negotiated and subject to consensus (*idem*).

3. Constructivist learning environments

It was in the 90s that we began to feel the effect of constructivist ideas in the research about classroom environments (Valadares, 2001). An instrument, named *Constructivist Learning Environment Survey* – CLES, was created by Taylor and Fraser (1991), to assess the perceptions of teachers and students about some *dimensions* that were considered *important in classroom environments* (Sebela 2003). These dimensions are:

- *Personal Relevance* – existence of a relation of the taught subjects with the daily experiences of students.
- *Uncertainty* - highlight the importance of beliefs, theories, experiences and values in the scientific research.
- *Shared Control* - control of the environment shared by all, based on an ongoing and formative assessment.
- *Student Negotiation* - dialogue and sharing of ideas among students with an emphasis on peer assessment.
- *Critical Voice* - nothing and no one is above constructive criticism. (*idem*)

A new version of this instrument was created (Taylor, Fraser and White, 1994) and also other similar instruments. Many researches have been made to validate them and to draw conclusions (Cannon, 1997, for example). These and other researches that were made in the ambit of a *Science Teaching Master* (I created at the Open University of Portugal, in 1997) show that the constructivist learning environments can significantly improve student learning (Soares, Valadares and Malheiro, 2006).

To fundament in a more objective way these *constructivist learning environments*, I go to detach three important aspects: the teacher role; the learner role; the educative relationships that must be established (Valadares, 2007).

Beginning by the *teacher*, he will have to know and to have in account, permanently, the points of view of the pupils, their ideas and conceptions, to provide adequate activities to defy the assumptions of the students, to place problems whose relevance is recognized by them, to conceive the strategies on the basis of ample and inclusive initial concepts, and to assess continuously the learning of the students in a perspective as "*formatrice*" as possible. The so-called "*formatrice assessmen*" is a very elaborated kind of formative assessment completely integrated in the teaching-learning process that was proposed by a group of researchers of the "Academie d' Aix-Marseille", having as finality to be *as pro-active as possible*, contributing to open and facilitate the path of students, foreseeing their own difficulties in each subject.

The *learner* has to have *active engagement* in the learning (including the learning of group colleagues), should be *open to criticism*, and *inquirer* in permanent search of knowledge, should be *intentional* in what concerns to the search of answers to the challenges that are placed to him, to *know dialogize* with colleagues and teacher, should be *reflexive*, to think about what he made and be *amplifying*, in order to enlarge his learning to the world outside the school.

Finally, teacher and students must try to establish *good and strong pedagogical relationships*, based on good *interpersonal relations*, being essential that could be established a *climate of cooperation* with the greatest attention to the *students representations* and to the meta representations or representations of the representations (typical example: what he thinks about what I think about him).

Based on Brooks and Brooks (1997), with personal adaptations, I finished this section comparing the constructivist learning environments with the traditional learning environments.

Traditional learning environments	Constructivist learning environments
- Curriculum is presented in parts, integrated in a whole, emphasizing basic skills. - Curriculum is rigidly followed, without to have in account the meaningful learning. - Classroom activities are based on textbooks and workbooks. - Students are considered "*tabulas rasas*" onto which information is recorded. - Teachers generally are limited to disseminate information to students, without caring about their learning environments. - Teachers seek only the correct answers to validate students' learning, and depreciate answers that reflect their mental models. - Assessment of students learning is viewed as separate from teaching, is episodic and essentially sumative, almost exclusively based on tests. - Students work primarily alone.	- Curriculum is presented as a whole, showing the general concepts, and then broken into parts. - Curriculum is followed so that the meaningful learning is facilitated - Classroom activities are based on primary sources and chosen materials. - Students are viewed as representational and computational beings. - Teachers generally interact and share ideas with students, caring about their learning environments. - Teachers seek the students' points of view in order to understand their mental models, to explore these to better learning. - Assessment of students learning is multifaceted, integrated into the teaching, and based on the systematic observation of the students activities and works. - Students work primarily in groups but also individually.

A look at learning environments (adapted of Brooks and Brooks)

4. Some essential ideas about the Meaningful Learning Theory

The MLT dates back to 1963 when David Ausubel published a work entitled "*The Psychology of Meaningful Verbal Learning*". It is a theory about human learning, based on the *study of the mechanisms* through which the *acquisition* and *retention* of a *great quantity of meanings* is processed (Ausubel, Novak & Hanesian 1980). It is a *constructivist theory*, as is based on the principle that it is the human being, as an organism, which is constructing and managing the product of their own learning.

The key concept of the MLT is *meaningful learning*. This important concept, as Ausubel conceived it, represents a process through which *new knowledge is related to the cognitive structure of the learner*. This is a process which is *substantive* (it is the 'substance' of the concept that is related), and thus occurs in a non-literal way. And is a *not arbitrary* process, since new knowledge is precisely related with some adequate and relevant contents which are present in the cognitive structure, called *subsumers*, *integrating ideas* or *anchor-ideas*.

The term anchor-idea (or only *anchor*) is the least suitable of the three presented above, because the meaningful learning process is not a simple anchorage, a simple union between the new knowledge and the knowledge that learner already has.

As far as this process takes place, when the new content goes acquiring meaning for the subject, a transformation of the subsumers of cognitive structure goes occurring. In the *meaningful assimilation*, new knowledge interacts with a subsumer, this is modified, and the new knowledge acquires a personal meaning, as illustrated in the following scheme:

S + I → S'I'

Subsumer new information

It is the presence of relevant concepts and propositions, clear and inclusive ideas in the mind of the learner, that will provide meaning to new knowledge in interaction with these ideas. Meaningful learning is this *cognitive mechanism*, but also is the *product* of the same, that is, the attribution of meaning to new information, accompanied by a modification and enrichment of the subsumer, which thus becomes more explanatory and potentially richer to underpin future learning. It is therefore a process simultaneously *constructive* and *reconstructive*.

In order to have *meaningful learning* two *conditions* must be fulfilled:

- The confrontation of the learner with a *potentially meaningful content*, which requires that:
  - this content has *logical meaning*, what means that it is conceptually consistent to the point of being potentially linkable to the cognitive structure of the learner, in a substantive and no-arbitrary process;
  - - there are *appropriate subsumers* in the learner's cognitive structure that enable interaction with that new content.
- That the learner has a *potentially meaningful attitude*, that is, a willingness to learn meaningfully.

According to Ausubel, what we learn are words or other symbols, concepts and propositions. Therefore, with regard to the *object* that is *learned*, the *meaningful learning* can be classified into: *representational*; *conceptual*, and *propositional*.

The representational learning, which consists of associating labels to things, occurs since an early age and naturally leads to meaningful learning of concepts, without which it is impossible to learn meaningfully propositions, since these depend on the meanings of the concepts involved in them. The *concepts* are therefore the *focus* of the meaningful learning, and with them we think and communicate.

When the criterion used is the *hierarchical organization* of cognitive structure, meaningful learning can be of three types: *subordinate*, *superordinate* or *combinatory*.

Thus, through the assimilation process, the subsumers go increasingly assimilating concepts and propositions and, consequently, broadening its scope. This process is called *progressive differentiation*, and the meaningful learning that occurs by this mechanism is called *subordinate learning*.

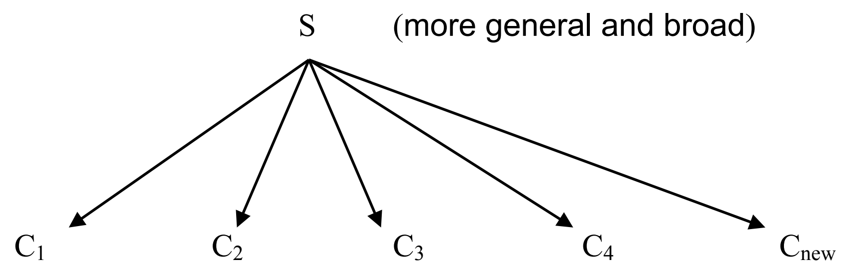

Image 3. In the subordinate learning the new concept or proposition is subordinated to pre-existing subsumers that are more general and broad.

But at the same time that the concepts are differentiated and become enriched, cognitive relations between concepts are going increasingly found. When these bridges between cognitive concepts, sufficiently differentiated, are established, that is, when occurs what Ausubel named *integrative reconciliation*, more general and broad concepts called *superordinate concepts* may result. When they are constructed, what occurs is called a *superordinate learning*.

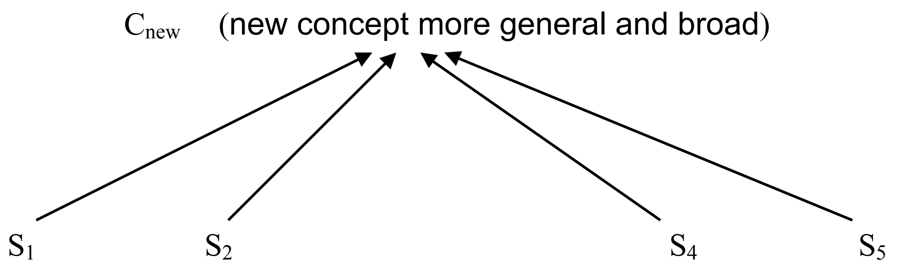

Image 4. In the superordinate learning the new concept or proposition originated is more general and broad than the pre-existing subsumers.

But it can also occur the *combinatorial learning*, in which new concepts are neither assimilated to subsume the former, as happens in the superordinate learning, nor are subsumed by them as happens in the subordinate learning.

We learn meaningfully by combining these systematic mechanisms: *progressive differentiation* of more general and comprehensive concepts, that increasingly are becoming more general, broad and richer, integrative reconciliation between concepts already sufficiently specified and differentiated to yield more general concepts and processes by which new ideas are linked to ideas of the cognitive structure that are neither higher nor lower in the hierarchy, for example by analogies. These mechanisms have implications on how ideas should be taught to the students and, in this regard, Ausubel says (2003, p. 24):

"Educational psychologists tend to divide, unpredictably, the order of presentation, 'descending' or 'ascending', and subsequent organization in cognitive structure. In general, neobehaviorist psychologists have favored the ascending order and constructivists the descending order."

Whilst Ausubel believes that one should start with general ideas, which will be gradually differentiated, also appreciates the existence of another mechanism with upward direction: the *integrative reconciliation*. The subject who learns meaningfully goes of the general to the particular and vice versa, in a process that introduce the new information in a hierarchized cognitive structure, systematizing it in an organized manner

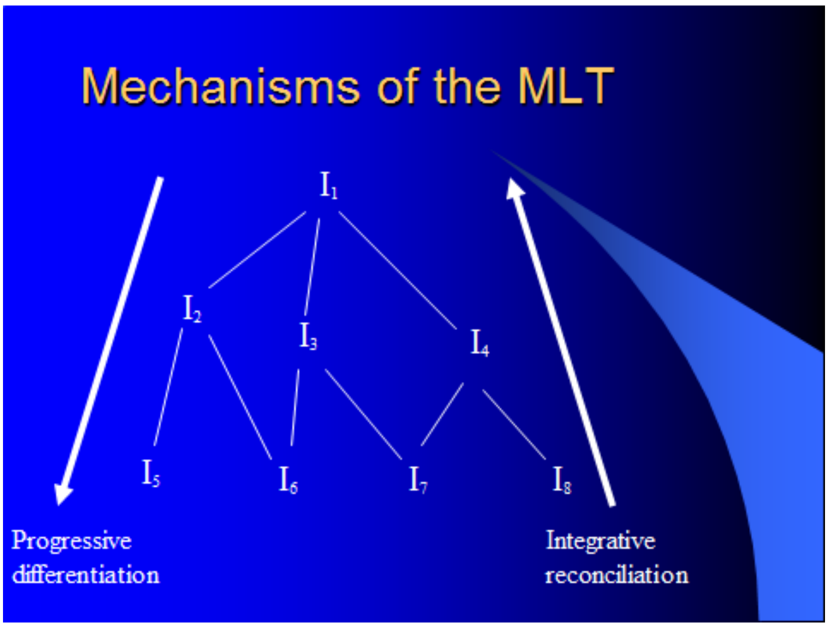

Image 5. In the meaningful learning, concepts go being linked in descending order and in ascending order

How not always, at any given stage of a student learning, he has the appropriate subsumers to learn meaningfully a "particular sphere of knowledge," then a way to facilitate learning and retention in these circumstances is “introduce appropriate subsumers up and make them part of the existing cognitive structure before the presentation of the learning task” (Ausubel, 2003, p. 65).

The concept of *meaningful learning* is also the *central concept* of the *Theory of Education* of Joseph Novak (1997). If Ausubel had already conceived the idea of the important role that the learner' cognitive structure has is in the *meaningful learning* process, Novak developed this idea making this fundamental concept less strictly cognitivist and *more humanistic*, considering the *transdimensional nature of the learner*, which like any other human being, *thinks*, *feels* and *acts*.

This human constructivist view, of Novak, in which the student is not seen as a thinking machine, but as a human being whose intellectual dimension is closely linked to other dimensions, goes in the same direction that the modern sciences and technologies of cognition defend. It is enough to remember the well-known work of António Damasio, «O Erro de Descartes», where this neurobiologist writes the following words (Damasio, 1995, p. 15):

“The lower levels of the reason neurological building are the same that regulate the process of emotions and feelings and even the bodily functions necessary for the survival of the organism. In turn, these lower levels maintain direct and mutual relationships with virtually every organ in the body, thus placing the body directly in the chain of the operations giving rise to the performances of the highest level of reason, decision making, and by extension, social behaviour and creative capacity. All these aspects, emotion, feeling, and biological regulation play a role in human reason. The orders of the lower level of our organism are part of the same circuit that ensures the superior level of reason.”

Pretending that science education leads to a rich, substantive, not literal, learning of concepts, laws and scientific theories, able to enhance students to solve various scientific problems, the human mind trans dimensionality should be taken into account (Fernandes, 2000, Gardner, 1994), therefore the planning of teaching must use different media, different strategies and different ways of expression.

Joseph Novak consider very important that students reveal their cognitive structure, that «negotiate» and exchange meanings with each other and with the teacher, and that meaningful learning mechanisms are applied in schools. These are the reasons why he created his well-known but underused metacognitive tool called *concept map*. This work ends with this graphic organizer based on the MLT and with a handful of excellent applications that this organizer can have on education.

5. The concept map and the facilitation of meaningful learning

In a generic way, a *concept map* is a diagram that indicates relationships between concepts. In the context of MLT, it is a hierarchical diagram that seeks to reflect the conceptual organization of a knowledge body or part of it, as this organization is understood by whoever builds the map. Its existence derives from the conceptual structure of a given knowledge body, so it corresponds to a set of concepts linked together by linking words to form up meaningful claims.

The following picture shows a simplified model to construct a concept map in order to respect the *principles of meaningful learning*, specifically the principles of *progressive differentiation* and *integrative reconciliation* of concepts.

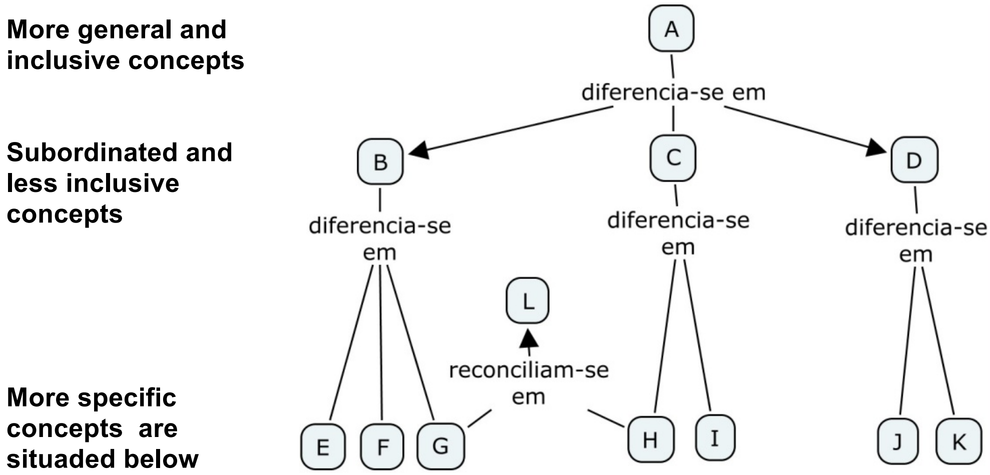

Image 6. A concept map model that respects the principles of progressive differentiation and integrative reconciliation

It is clear a *hierarchy of concepts*, and a *progressive differentiation* from the more general and inclusive concept, A, until to the most specific, E, F, etc. The examples, being in general concrete, are sent to the base of the map. Lines joining concepts traduce relationships between them, including cross relationships. It is also possible see an *integrative reconciliation* of concepts G and H that were subsumed in a more general concept than them: the concept L. This hierarchical arrangement according to the vertical direction, from top to bottom, is the most common, but it is perfectly conventional. Consider the following example

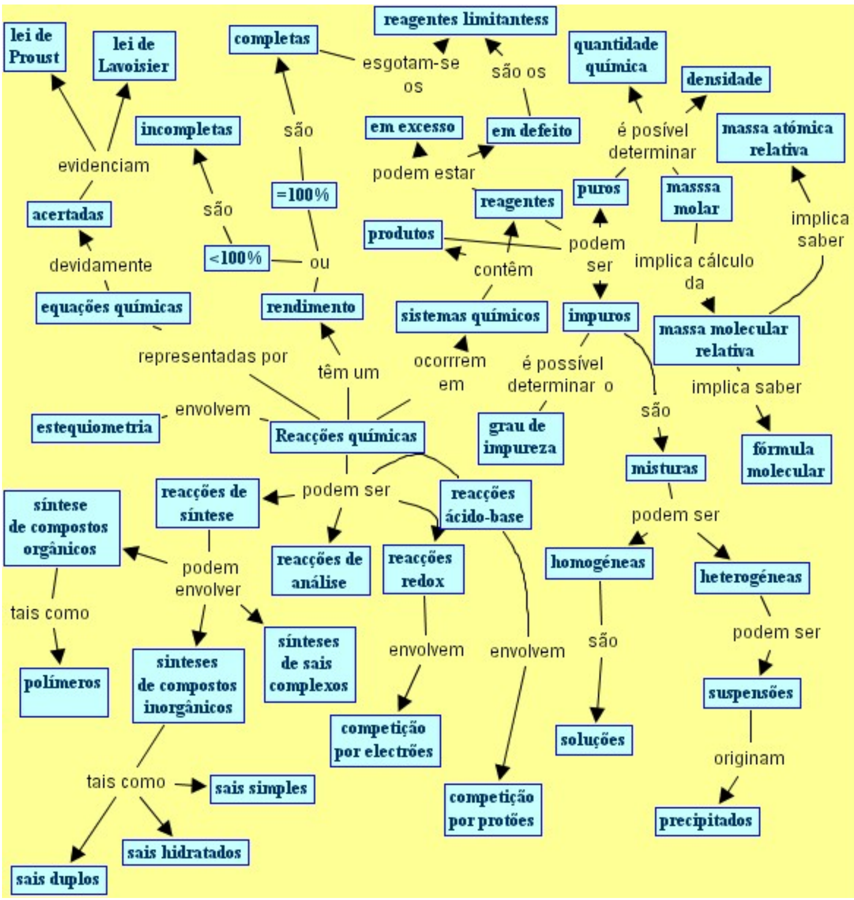

Image 7. A concept map about chemical reactions (Gouveia e Valadares, 2005).

This map is hierarchized from the middle to the periphery. The concept more general and inclusive is «chemical reactions» and is differentiated in various branches toward the periphery. The concept map has many applications as we see from the following examples.

5.1. The use of concept maps to "negotiate meanings"

More than the value of a concept map itself, always limited, since there is a more or less crude representation of a conceptual framework, what is fundamental is the mode how it shows the meanings that its builder has, and permit negotiate them with others. Here is an example. An experienced Physics teacher knows that many students, even with several years of study of this discipline, have absolutist conceptions of space and time, which difficult the understanding of Einstein's theory of relativity. The student's cognitive structure, heavily influenced by spontaneous thought based on daily life, where the bodies are moving at low speeds, and by the Newtonian physics that was built for such bodies, may be represented by a concept map like the following:

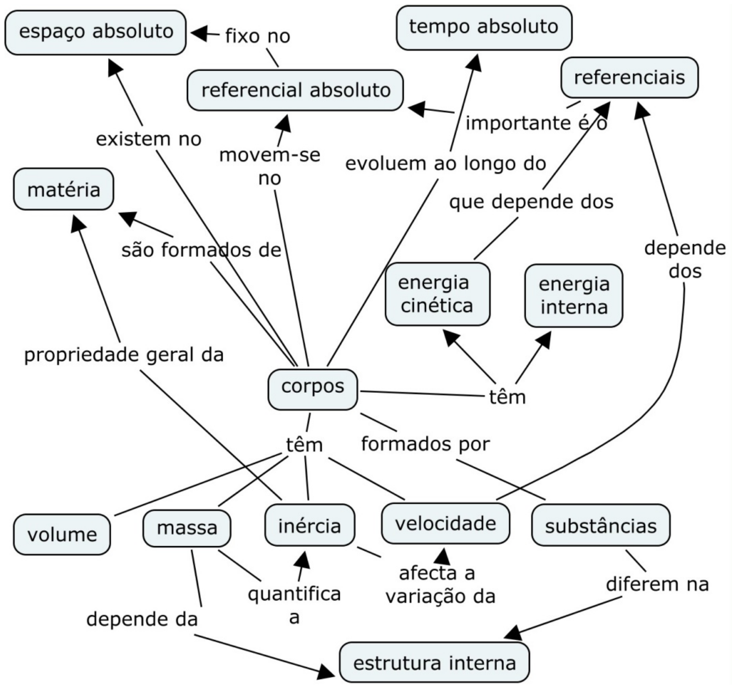

Image 8. Concept map that reveals the classical and absolutist conceptions on space, time and mass

Based on a map like this, it is possible for the teacher, through appropriate questions, elicit a fruitful discussion that will lead to a relativistic representation of space and time and to a more meaningful and correct concept of mass. I am thinking of questions such as: Speed affects internal structure? Inertia that is quantified by mass depends on the speed? What influences the internal structure? What is the reason why, when the speed of a particle, higher than 10 % of the speed of light in vacuum, is increasing, actuated by a constant force, is necessary to wait increasing time to obtain the same increase of velocity? Etc.

In fact, at speeds higher than 10% of the speed of light in vacuum, it is no longer possible to admit the separation between an absolute space and an absolute time, because the phenomena occur in a four-dimensional space-time referential. On the other hand, it is essential to discuss what means that a particle at increasing velocity and subjected to a constant force, requires more and more time to experience a similar increase in speed. It will be because the particle structure change? Its inertia, and therefore its mass, increases with speed? Or this is a consequence of the relativistic time dilatation?

The teacher may lead students to change the concept map as he is teaching the concepts of relativistic space, time and mass, or alternatively, he can put a new base map and proportionate a fruitful discussion of these concepts based on it.

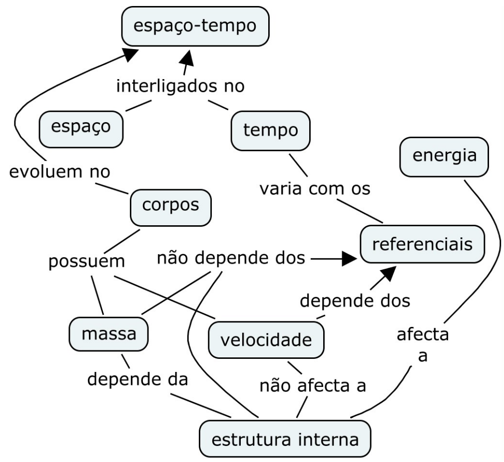

Image 9. Concept map that can provide the basis for "negotiation" of the meanings ofspace, time and mass at high speeds

5.2. The use of concept maps as assessment tools

Concept maps show to be very useful not only as an aid in determining the student's prior knowledge, but also to investigate changes in the cognitive structure produced by teaching. Thus it becomes possible to obtain information that can serve as feedback for teaching and the curriculum. Obviously, this is not an accurate and complete representation of the student' prior knowledge, but still allows the detection of *misconceptions* and other *conceptual blockages* to learning whose detection is useful for the further conceptual enrichment of the student.

The following concept map was built by a student to the teacher's request (the author of this work), after having completed an excellent experimental work, where determined a good value for the *mechanical equivalent of heat* and after having made a report of good quality. The concept map constructed by the learner allowed to detect conceptual difficulties and misconceptions that the work and the good report did not permit identify.

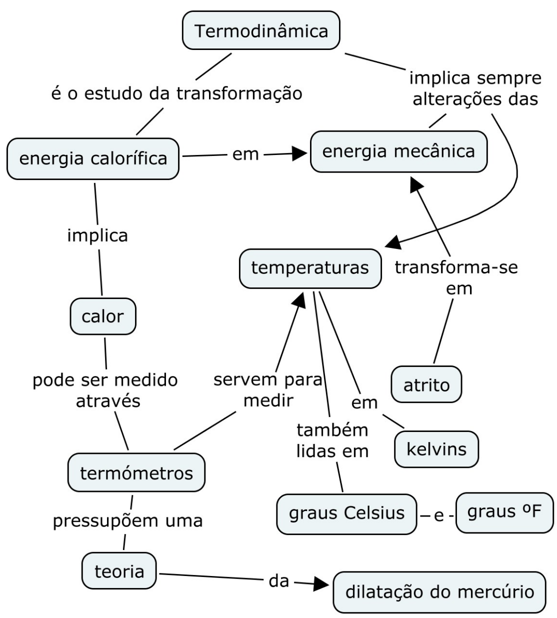

Image 10. Concept map constructed by a student after an experimental work on Thermodynamics; note the conceptual confusion between heat and temperature and confused ideas about heat

5.3. The use of concept maps in the curriculum area

Concept maps can be constructed for the content of a lesson, a discipline, a set of disciplines or an entire educational program. Everything depends on the generality or specificity and level of inclusivity of the concepts that are on the map. Broad and integrator concepts can serve as a basis for planning a curriculum of a particular course, while more specific concepts, little inclusive, can guide the selection of materials and teaching activities. Good curriculum planning involves a careful analysis of the concepts which are central to the understanding of the discipline, or part of the discipline, that is being considered. Concept maps can be extremely useful in this task.

The following concept map was constructed by the author of this work to guide the content development of a course on teaching models.

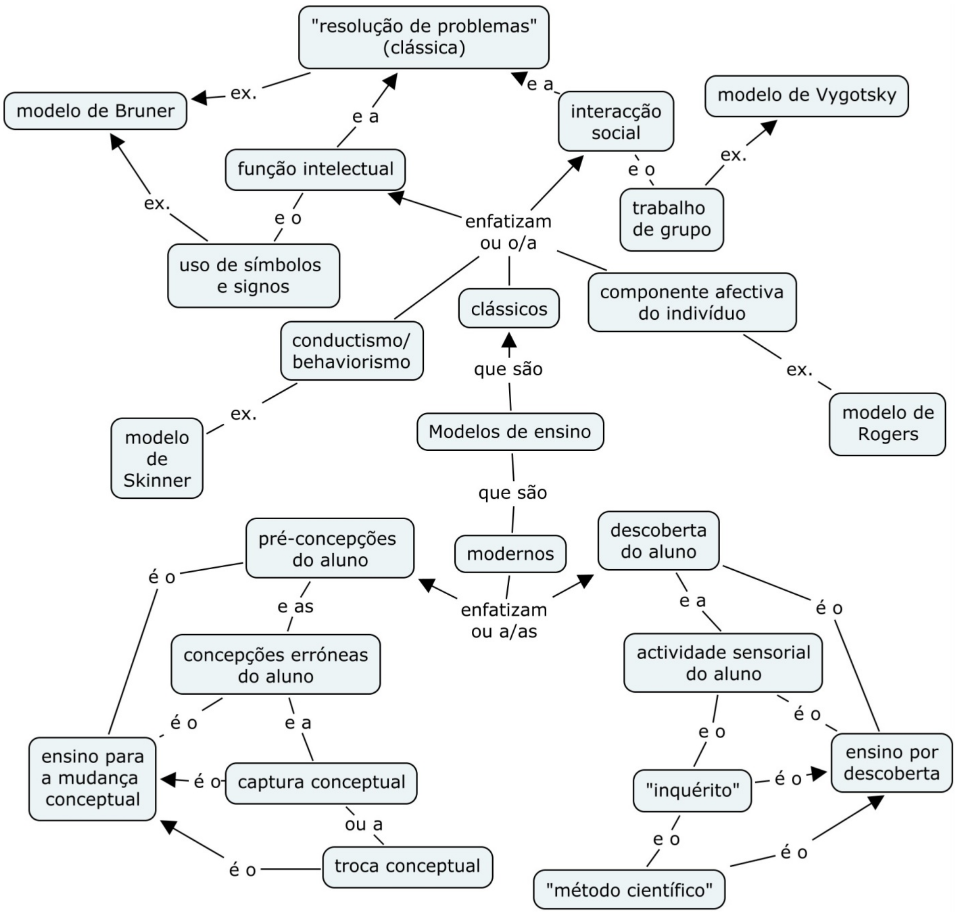

Image . A concept map constructed to guide the content development of a course on teaching models

6. Conclusion

The concept map, of Joseph Novak, is a graphic organizer that allows us to represent the conceptual framework of a knowledge area or how the concepts are connected and organized in the cognitive structure of who builds it. Although requiring some care in implementation, and many times requires initially a lot of time in its good construction and exploration, this instrument has immense utility in learning, teaching and assessment, particularly in a formative perspective. It is an instrument which facilitates meaningful learning of knowledge, as is based on the mechanisms of this kind of learning, and has many applications, some of which have been mentioned here, because it facilitates the structuring and clarification of any conceptual framework that becomes easier potentially meaningful. The correct use of concept maps should take place in a constructivist learning environment that was characterized here, and this instrument also may contribute to this kind of environment that is fruitful to the negotiation and sharing of ideas facilitator of the meaningful learning. In fact, such an environment stimulates the metacognition, promote the co-responsibility of students and contributes to positive interdependence between them, in favor of increasing the average yield of all of them.

In order these instruments can be explored to facilitate meaningful learning, it is necessary to know the ideas that permit use them correctly, otherwise we run the risk of the concept maps stimulate memory learning.

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Journal for Educators, Teachers and Trainers
The LabOSfor electronic, peer-rewieded, open-access Magazine

ISSN 1989 - 9572

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Journal for Educators, Teachers and Trainers, Vol. 4 (1)

http://www.ugr.es/~jett/index.php

Fecha de recepción: 31 de diciembre de 2012

Fecha de revisión: 25 de enero de 2013

Fecha de aceptación: 06 de febrero de 2013

Valadares, J. (2013). Concept maps and the meaningful learning of science. *Journal for Educators, Teachers and Trainers*, Vol. 4, pp. 180 – 194.

Journal for Educators, Teachers and Trainers
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Abstract
Higher Education is currently undergoing relentless change worldwide in order to respond effectively to the aspirations of the 21st century. Consequently, prevalent literature in Higher Education calls for more emphasis on the students' learning process through increased metacognition and critical reflection. This paper starts off with the assumption that learning takes place through the integration of thinking, feeling and acting. As a result, this paper will present a model of teaching and learning in Higher Education through the integrated use of Vee Heuristics and Concept Mapping. This research will suggest that when using Concept Maps, Vee Heuristics along with an awareness of how students prefer to learn, the students will go through a metacognitive learning process which would eventually lead to critical reflection and meaningful learning. Using University students' work products, this study traces the effect of a learner's mental operations on the learner's use of Vee Heuristics and Concept Mapping as the learner embeds and retrieves new and scaffolded knowledge. The data collected reveals the powerful effect which this combination of learning tools yielded on student achievement and transformation.

Resumen
La educación superior está sometida actualmente de forma implacable a un cambio a nivel mundial, para responder de forma efectiva a los retos del siglo XXI. De esta forma, la literatura fundamental sobre educación superior pide poner énfasis en los procesos de aprendizaje de los estudiantes a través del aumento de los procesos metacognitivos y de reflexión crítica. Este artículo parte de la base de que el aprendizaje tiene lugar a través de la integración del pensamiento, los sentimientos y la acción. De esta forma, se presentará aquí un modelo de enseñanza y aprendizaje en educación superior a través del uso de integrado de "v" heurísticas y mapas conceptuales. Esta investigación sugerirá que, cuando se utilizan mapas conceptuales junto a "v" heurísticas, siendo sensibles a cómo los estudiantes prefieren aprender, éstos pasarán por un proceso de aprendizaje metacognitivo, que les pueden llevar eventualmente a la reflexión crítica y al aprendizaje significativo. Utilizando las producciones de estudiantes universitarios, este estudio describe el efecto de las operaciones mentales de un alumno en el uso de la "v" heurística y de los mapas conceptuales, cómo el aprendiz incrusta y recupera nuevos conocimientos y andamiajes y cómo el aprendiz incorpora y recupera el nuevo conocimiento organizado. Los datos obtenidos revelan el poderoso efecto que esta combinación de herramientas de aprendizaje tiene sobre la transformación del conocimiento y el rendimiento del estudiante.

Keywords
Learning process, metacognition, meta-learning, higher education, concept maps, vee heuristics, transformative learning.

Palabras clave
Procesos de aprendizaje, metacognición, metaprendizaje, educación superior, mapas conceptuales, "v" heurística.

1. Introduction

The Higher Education sector is undergoing relentless change worldwide in order to respond effectively to the aspirations of the 21st century (Biggs & Tang, 2011; Altbach & McGill Peterson, 2007). Altbach et al (2009) in a UNESCO report reveal that globalisation and massification which consequently lead to an increasingly student diversity are creating pressure on universities around the world to put in place innovative approaches to pedagogy. Across Europe this challenge in Higher Education is being addressed through the Bologna Process. The official website about the Bologna Process states that there are 47 European countries that are committed to the Process which aims to create a European Higher Education Area (EHEA).

The EHEA (Bologna, 1999; Prague, 2001; Berlin, 2003; Bergen, 2005; London, 2007; Leuven, Belgium, 2009; Budapest & Vienna, 2010; Bucharest, 2012) identified three key priority areas:

- **Mobility**: facilitates mobility of students, graduates and higher education staff;
- **Employability**: prepare students for their future careers and for life as active citizens in democratic societies and to support their personal development;
- **Quality**: offer broad access to high-quality higher education.

In order to address the reform in Higher Education for the 21st century that would react efficiently to high-quality higher education, prevalent literature in Higher Education calls for more emphasis on the student learning process through increased critical reflection (Cowan, 2006; Biggs & Tang, 2011; Prosser & Trigwell, 1999; Brockbank & McGill, 2000). Many students probably enter the University relying on learning strategies that have worked well for them in their previous learning experiences including rote learning through memorisation and recall of facts. This may have been a successful strategy to pass exams, but would not contribute to assist University students to become critical reflective learners and practitioners in their future careers. In the premise that the learning process should be highlighted in order to meet the new challenges, one should get interested in the nature of learning and then consequently ask: What kind of learning should take place in Higher Education?

2. Theories of learning

The history of Higher Education has emphasized cognition (knowledge) and content where learning is often thought of as an intellectual achievement (Brockbank & McGill, 2000; Land, 2004). However, Brockbank & McGill (2000:54) suggest that *"teaching that is primarily about the transmission of knowledge will not engender the concept of a critically reflective learner because the one-way process of transmission is antithetical to the means by which a person can become a critically reflective learner"*. Similarly, Barnett proposes that learning as seen in this way is too simplistic and that *"being a historian is no longer a sufficient rites de passage, higher education hears from society that an academic framing of knowledge is an inadequate preparation for the life ahead"* (Barnett, 1994:20).

Learning involves a more complex process and the diverse numerous learning theories up till this day confirm this notion. There is little agreement among learning theories about how learning truly occurs for example, one of the major dominant learning theories is behaviourism. According to the behaviourists, learning takes place when new behaviours or changes in behaviours are acquired as a consequence of an individual's response to stimuli. Behaviourist theories suggest that performance and behaviour are the primary factors affecting learning. Internal processes such as thought; ideas and consciousness could not be "*reliably measured*" (Hergenhahn & Olson 2005:46) and therefore are to be disregarded. In an era where quantification is important, it is not surprising that behaviourism still prevails (Jarvis, 2006). Behaviourism has received criticisms from different researchers (Bandura, 1977; Sternberg, 2009) for example Daniels, Lauder & Porter, 2009:3 claim that behaviourism is a weak theory because "*human beings were assumed to have no free will but rather learned through a system of environmental stimuli and responses"*.

In contrast and as a reaction to behaviourism, the cognitive theorists assume that the learner's mental processes are the major factor in learning. These processes include how individuals perceive, interpret, and mentally store the information they perceive from the environment. These theories focus on the ways that the learner's processing and application of information change one's thoughts and internal mental structures (Jarvis, 2006; Hergenhahn & Olson 2005). Areas of cognitive psychology one finds information processing, intelligence, reasoning, language development and memory. Historically, the cognitive development in humans has been studied in a variety of ways.

The oldest is through intelligence tests, such as the widely used Stanford-Binet Intelligence Quotient (IQ) Test. Since then, IQ testing has been extensively used but it has come under increasing criticism for defining intelligence too narrow. Nonetheless, cognitive psychology is probably the most dominant approach today and it served as a springboard to revolutionise the dominant behaviouristic perspective and cross boundaries from viewing learning as occurring mainly through performance and external behaviour to viewing learning as occurring through internal mental processes (Gredler, 2005).

One of the forerunners in challenging this definition of intelligence as measured by traditional intelligence tests is Howard Gardner's multiple intelligences theory (Gardner, 1983). Gardner's most influential research demonstrates that there are multiple ways of taking in the world around us and that all people exhibit one or a combination of at least eight or nine different intelligences, which operate in varying degrees depending upon each person's individual profile of intelligence. Although Gardner's theory of Multiple Intelligence has its utility and is very influential in education it does not go without criticism (Kincheloe & Berry, 2004). Nonetheless, this perspective helped educators around the world to view their students in a very different light, and "*educational researchers have tried to redress the balance by exploring the impact on learning of individual differences, giving taxonomies of learning styles*" (Brockbank & McGill, 2000:33).

The early years of the twentieth century produced a vast number of psychological and educational researches and related instruments that reveal a learner's preferred learning style (Kolb, 1984; Honey & Mumford, 1992). This is substantiated in the review by Coffield et al (2004) where this project's team identified seventy-one models of learning styles. The term 'learning styles' is used "*as a description at the attitudes and behaviours which determine an individual's preferred way of learning*" (Honey & Mumford, 1992:1). They argue that two people of similar intelligence and background who undergo a learning opportunity may be affected in very different ways, for example, one is enthusiastic while the second person is disaffected. Debello (1990) suggests that a learning style refers to "*the way people absorb, process and retain information.*"

Griggs (1991) suggests that learning style is one of the keys to an understanding of student learning and likewise Reay (1994) argues that without knowledge of how learning occurs it will be impossible to design a training programme which would make maximum use of everyone's learning ability. However, the term 'learning style' is often confused with cognitive style and its definition has varied over the years (Messick, 1976; Witkin et al, 1977; Tennant, 1988; Riding & Cheema, 1991).

There is vast literature about learning styles and numerous models (e.g. Coffield et al, 2004; Sharp et al, 2008) and "*nearly as many definitions of learning styles as there are theorists*" (DeBello, 1990:203). However, critics pose serious questions whether learning styles has had any effect on learning. Stahl (1999:1) states that "*the reason researchers roll their eyes at learning styles is the utter failure to find that assessing children's learning styles and matching to instructional methods has any effect on their learning.*" Furthermore, he stretches this argument by claiming that those teachers who attended learning styles workshop had one thing in common "*after one year, they had all stopped trying to match children by learning styles.*" Lafferty & Burley (2009) claim that "*learning styles are a myth…..they are at most an approximation of reality and offer little to learning process.*" Critics of learning styles seem to concur that learning styles reveal one's preferred way of learning but do not actually explain how learning occurs (Coffield et al, 2004; Debello, 1990; Sharp et al, 2008).

In a nutshell, the critical literature pertaining to learning styles are concerned with and address the following issues:

a) reliability and validity of the instruments are highly questionable.
b) no justified and comprehensive definition of learning is given as a starting point
c) consequently, the instruments used do not focus on the actual mental processes involved in learning but they mainly focus on psychological/cognitive aspects.
d) the learning styles' instruments may reveal parts of who the learner really is but stop there. They do not provide metacognitive strategies which are effective in helping both the teacher and the learner to respond adequately to different learning tasks so as to be successful.

Although the confusion in the array of terms, theoretical frameworks, instruments, applications and interpretations do not help in favour of the learning styles debate (Cassidy, 2004), learning styles have helped educators worldwide to understand that each person takes in the world around him/her in different ways. Consequently, this has made teachers to stop and reflect about their own practice and to listen more to the learner's voice. This has brought about more "*respect for individual differences among children*" (Stahl, 1999:5). Similarly, Pritchard (2009:42,43) claims that teaching with an understanding of individual differences enhances learning "*when students are taught new and challenging material through instructional approaches that fit their learning style, the chances of their understanding and retaining the information greatly increases……the differentiation on instruction based on learning styles is imperative for meaningful education*." Surely, in common among the arguments for and against learning styles are that the learners who are **actively engaged** in the learning process will be more likely to achieve success (Pritchard, 2009).

One of the major criticisms to both behaviourism and cognitive psychology is the disregard of the affective domain (Forgas, 2000). These two major dominant paradigms in educational psychology did not give much importance to the study of emotions. "Emotions play a major role in behavior and in human learning since they are at the heart of our personhood" (Jarvis, 2006:177). Novak (1998:24) proposes that "*feelings or what psychologists call affect, are always a concomitant of any learning experience and can enhance or impair learning*."

Ample research shows that there is a direct link between emotion and motivation (Gorman, 2004; Slavkin, 2004) and much of the motivational theories such as Weiner's attribution theory or Maslow's hierarchy of needs continue to contribute and is still very influential in areas of learning. Upon reading about motivational theories, one can observe similarities with behaviourism (Skinner's operant condition and Hull's drive theory) and cognitive psychology (Bandura's perceived self-efficacy). However, neither tradition emphasized learning as a direct relationship with emotions and cognition or performance. Each of the different learning theories give us an aspect or another (cognition [thinking], affectation [feeling] or conation [performance/behaviour]) of the learning process and each theory has its truths and positive aspects in helping us to understand more about learning. However, it is very difficult to find a learning theory which explains in a comprehensive way how does learning occur.

Therefore, learning is a complex process involving different mental processes. We have all experienced learning, we usually know it when we see it and we tend to accept its crucial function in life. Learning is part of our being and if one want to be successful one must understand how one learns (Slavkin, 2004; Pritchard, 2009). Coffield et al (2004:1) pose a very simple question which triggers of critical reflection "*How can we teach students if we do not know how they learn?*"

This scenario leads us to an understanding that learning can no longer be viewed as a process which involves solely cognition. While students are going through a process of thinking during learning, they are also doing and feeling. Novak & Gowin (1984:xi) in their preface to this book claim: "*Human experience involves not only thinking and acting but also feeling, and it is only when all three are considered together that individuals can be empowered to enrich the meaning of their experience.*" As a result, understandings of learning have advanced significantly in the past few decades and increasing attention has been given to 'higher order' processes of understanding. Consequently, the term '**metacognition**' (thinking about thinking) has become a buzz word in educational settings. If one wants to be successful one must understand how one learns and then make sense of it so as to make one's mental mechanisms work most efficiently for him/her. This is the primary reason why educational research is nowadays focusing on **meta-learning** (learning about learning). "*Meta-learning covers a much wider range of issues than metacognition, including goals, feelings, social relations and context of learning*" (Watkins, 2001:1). Meta-learning is to make sense of one's own experience of learning and in this way the learners would be equipped with a life-long learning skill.

3. The Learning Experience within Higher Education

University students are more assumed to be more focused on passing their exams than to enhance themselves as critical and reflective learners. "*They tend to study without reflecting on the purpose or strategy and to see the course content as discrete items of information*" (Kinchin, Baysan & Cabot 2008:377). This approach promotes *surface learning* where "*students see tasks as external impositions and they have the intention to cope with these requirements*" (Prosser & Trigwell, 2002:3) as opposed to *deep learning* where "*students aim to understand ideas and seek meanings*" (Prosser & Trigwell, 2002:3).

However, one cannot solely blame the students for this kind of experience. University teaching tends to ignore how students prefer to learn and many times it does not embrace the notion that students are capable of transformation (not only accumulation) and so leads to non-learning outcomes (Kinchin, Lygo-Baker and Hay, 2008). As we have read in the previous paragraphs, historically, Higher Education has emphasized cognition (knowledge/content) at the expense of other mental processes which directly affect meaningful learning: "*the prevailing wisdom maintains the acquisition of facts and skills as the important outcome of learning, often to the exclusion of emotion and action*" (Brockbank & McGill, 2000:30). Very often this led to a 'banking' (Freire, 1972) or 'factory' (Dwyer, 1995) model of education and consequently to passive intellectuals without the capability for critical reflection or transformation. Barnett (1997) argues that it is ironic how Universities although aware of critical thinking yet they seldom practice what they preach "*Higher Education, which prides itself on its critical thought, has done no adequate thinking about critical thinking*" (Barnett, 1997:2). Consequently university students are rarely provided with opportunities for self-exploration. On the other hand, the university system would have become so ingrained in traditional methods of teaching and learning that it would be very difficult to introduce or implement different approaches to teaching and learning. This is 'the let sleeping dogs lie' philosophy (Barnett, 1997:2). Very often we tend to forget that the way in which learning occurs is as important as the content so that the goal of education revolves around the mastery of oneself rather than the mastery of subject matter (Orr, 2004). Various authors propose that in order for students to become agents of their own learning they need metacognitive strategies (Gamache, 2002; Bruer, 1993).

In order for tertiary students to become professional practitioners they need to go through a critical and reflective educational journey which would eventually lead to a process of transformation. Through a transmissive approach, education is associated with the transfer of information therefore it would be instructive and imposed. On the other hand, through a transformative approach, education is associated with engaging the learner in constructing and owing meaning therefore learning would be constructive and participative (Sterling, 2004). If one wants to challenge the *status quo* one has to first and foremost transform oneself before being able to transform others (Mezirow et al, 2000). Tertiary education is the ideal environment for this transformation to take place so that students would later on be able to contribute to society as agents of transformation.

Brockbank & McGill (2000) and Barnett (1997) propose that in order to generate the conditions for critical reflection and transformation, the practice of teaching in Higher Education must include not only cognition (thinking) but also conation (doing) and affectation (feeling). Barnett & Coate (2005:15) while criticizing that the notion of curriculum is "*pretty well missing*" in Universities and that despite all the expansions barely any debates about what students should be learning and experiencing take place, they suggest that "*no curriculum can be complete…..without these three building blocks being present*" (Barnett & Coate, 2005:65).

With all of the above in mind this study will investigate and present a model of the integrated use of Concept Maps and Vee Heuristics, paired with an awareness of the students' own learning processes, in teaching and learning in Higher Education. The implication is that students are encouraged to go through a process of reflection and to embark on a journey of transformative learning. These two tools will be presented without any pretensions to being a quick fix, sure tool, but can definitely serve as a stepping stone to challenge the ever prevailing transmission model of education in Higher Education. Gamache believes "*that what struggling university students need are practical, specific activities that will lead them toward an alternative conceptual framework within which they can* ***re-create themselves as active learners****. [My emphasis] Rather than just absorbing theory, students actually engage it through a process of active self-reflection and self-direction*" (Gamache, 2002:291). Active self-reflection and self-direction are two kinds of metacognition (Gage & Berliner, 1998).

4. Research Question and Methodology

The path that this study pursues is not to seek absolute truths but rather to shed light upon a pedagogical process which captures personal structures of knowledge and their development so as to generate meaningful learning and critical reflection. This study will also explore whether the use of these tools could lead to enhancing student/teacher interaction which goes on within the context of Higher Education. The main focus question will therefore revolve around the question ***"In what ways can teacher-student interaction influence meaningful learning?"***

The data collected in this pilot study is generated from University students pursuing the course in Bachelor of Education (B.Ed) at the University of Malta. The setting is not chosen for a particular reason but because it just happened to be the only Higher Education Institution in Malta which caters for teacher training. The lectures took place at the University of Malta and were held once a week for even consecutive weeks during the first semester of the academic year. Each lecture had duration of two hours. This programme was offered to B.Ed students who are in their second, third or fourth year of the course as an optional credit. As a result, the group of participants in this pilot study is self-selected since they came out of their own free will. It is also worth mentioning that in this way the students participating have different subject specialisation.

Using students' productions from the Bachelor of Education course at the University of Malta, this study traces the effect of learners' mental operations on the learners' use of Concept Mapping and Vee Heuristics as the learners embed and retrieve new and scaffolded knowledge. By analysing productions constructed by the students before and after the learning programme, as explained hereunder heading 6, this study will reveal a tangible transformation in the ideas held by students about a specific issue which is: *What is Education for Sustainable Development?* This question will be the vehicle through which data will be collected so that the learning development of the students can be observed and recorded.

5. Merging metacognitive tools for use in Higher Education

Learning is about change and changing oneself (Ramsden, 2003; Zull, 2002). Higher Education must nowadays highlight quality of education not just certification and learning should be about *"changing the ways in which learners understand, or experience, or conceptualise the world around them"* (Ramsden, 2003:6). This research is intended to clarify the mechanisms by which Concept Maps and Vee Heuristics support meaningful learning and critical reflection. It will also raise awareness of how students' mental processes work most effectively leading to conceptual transformation for both the teacher and the student.

More importantly, these two metacognitive tools lay open what's going on in the learner's mental processes so that they are empowered to embark upon a meta-learning journey. Consequently, it is anticipated that they will be better equipped and trained in decision making, reflective and problem solving skills (Ramsden, 2003; Biggs & Tang, 2009 Novak & Gowin, 1984; Gamache, 2002). Furthermore, these two tools don't occur in a vacuum but they build on the learner's prior knowledge (Novak & Gowin, 1984). They take into consideration the diverse and personal experiences therefore making learning more meaningful. This is manifested in the following paragraphs which present the students' responses in the Vee Heuristics, their Concept Maps and their written reflection about this reflective educational journey.

6. Data Analysis and discussion

The following paragraph includes the whole process of the Vee Heuristics along with Concept Maps that were generated throughout the whole credit. In this paper I shall only be presenting a sample of two different learners. During the first lecture the students were asked to reflect, answer and write about the three steps found on the left hand side of the Vee (Figure 1). Their responses were collected at the end of this lecture, were analysed and the learning programme was planned so as to accommodate the learners' different learning preferences. All the lectures were presented through Concept Maps where prior knowledge and new knowledge construction was negotiated through active discussion and participation. During the last lecture the students were asked to complete the right hand side of the Vee (Figure 2). Finally, they were asked to organize and compare and contrast all the steps in the Vee Heuristic by presenting as an assignment the left and the right hand side of the Vee, the first Concept Map depicting their prior knowledge and the second Concept Map illustrating their new knowledge construction. They were also asked to write a final reflection about their own personal growth during the programme, if any, and how do they think that this process has helped them to become more effective teachers if it did.

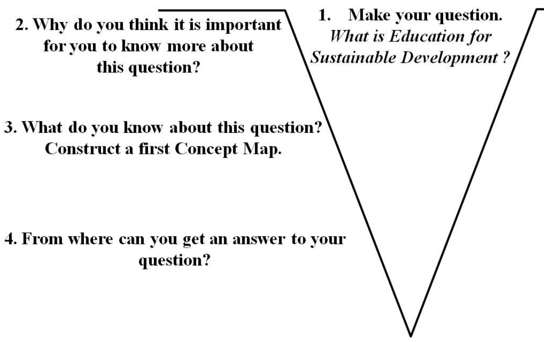

Figure 1: Vee Heuristic presented before the learning programme.

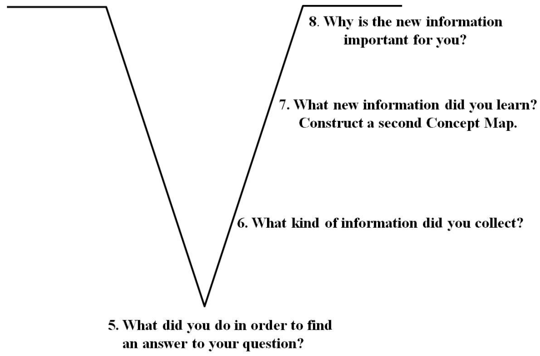

Figure 2: Vee Heuristic presented after the learning programme.

6.1. Learner 1 Maryanne

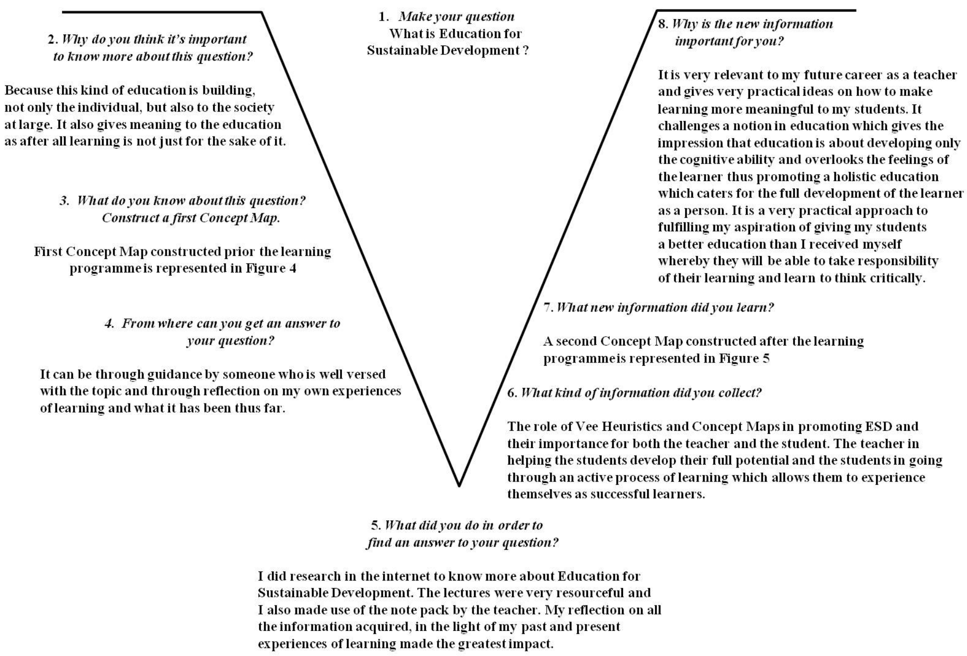

Figure 3: Maryanne's Vee Heuristic

This Vee Heuristic illustrated in Figure 3 reveals this learner's development in her thinking process. It is very clear to observe a difference between the left hand side of the Vee, which was done during the first lecture, that is prior the learning programme and the right hand side of the Vee, which was done during the last lecture that is after the learning programme. The information given for question No.3 reveals that this learner had few ideas of what ESD is all about and this is corroborated by her first Concept Map constructed before the learning programme as represented in Figure 4. It is worth noting that question No. 2 tries to capture the learner's feelings about the issue in question and from the learner's response one can deduce that this learner was very much interested in wanting to know more about the focus question. The reply in question No. 2 reveals her level of motivation and interest in studying this topic and one can observe that this learner found this topic interesting and relevant to what she was studying.

The replies given to questions No. 4 and No. 5 illustrate how this learner planned to learn more and what this learner actually did to learn more. This learner planned to learn through "*guidance by someone who is well versed with the topic*" and she carried out research on the internet and read the reading pack which was given so as to have more information and all of this reflects the learner's preferred way of learning. However, it is worth noting that she also planned to learn through reflecting on her experiences. From the responses given on the right hand side of the Vee one can easily observe how this learner developed her knowledge related to both ESD and the learning process. This learner gave specific details to answer questions No. 6 and 8 and the new knowledge constructed is also illustrated in her second Concept Map constructed after the learning programme as represented in Figure 5.

When observing the first and second Concept Map represented in Figures 4 and 5 consecutively, one can easily note that the number of concepts and propositions has increased therefore revealing that learning has taken place. The first Concept Map clearly depicts a linear way of thinking and it contrasts with the second Concept Map showing a change even in the way of thinking. Furthermore, she not only increased the number of concepts but also changed and developed the original concepts constructed in the first Concept Map.

The fact that this learner was eager to expand her knowledge reflects that she enjoys having more detailed information about what she is learning. This is present not only in her Vee but also in her four page detailed reflection where clear references to related literature were made. In this reflection she discusses how she looked at herself as being "*a product of a system of education which promotes transmission of knowledge regardless of the process of learning*" and how she changed and developed herself throughout this credit: "*This has opened my eyes and mind to a way of teaching and learning which are new to me and which I have found to provide a better teaching and learning as compared to other traditional methods of teaching which feed students with information rather than allowing them to go through a process of learning.*"

She also refers to the 'bigger picture' when discussing about teaching and learning: "*I will make use of Concept Maps in my teaching. This is because they give learners the opportunity to be active participants in the learning process.*" She also suggests that the Vee Heuristics helped her to "*give a true picture of who the students really are as learners. This will help me to cater for the needs of the students' in my classroom, appreciate them more with their diversity and help them to develop to their fullest potential. The Vee Heuristics and the Concept Maps build on the students' prior knowledge. As proposed by the constructivist theory, students learn best when information is based on what they already know.*"

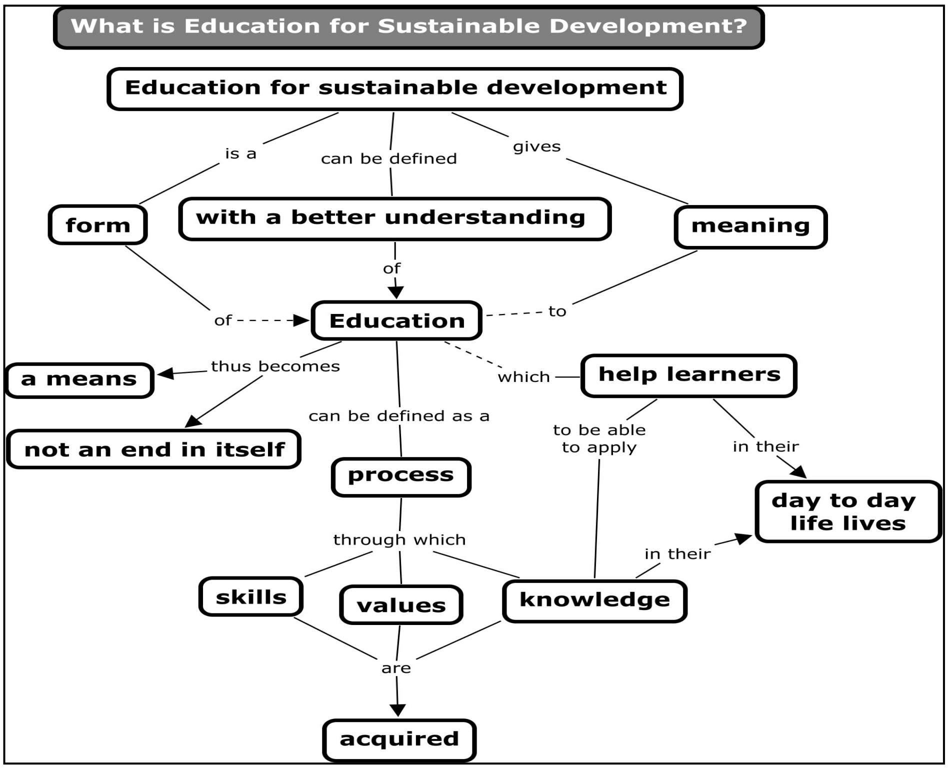

Figure 4 Maryanne's first CMap constructed before the learning programme.4:

She also wrote how she could implement all that she has learnt in the classroom and finally she wrote about the relevance of this credit towards her experiences as a University student and as a future educator: "*My experience during this unit was a very positive one. I feel that this unit was helpful to me beyond my expectations when I chose it as an optional credit. I have found it to be one which touches my present life as a student and my future career as a teacher. I feel that I have been challenged and encouraged at the same time.*"

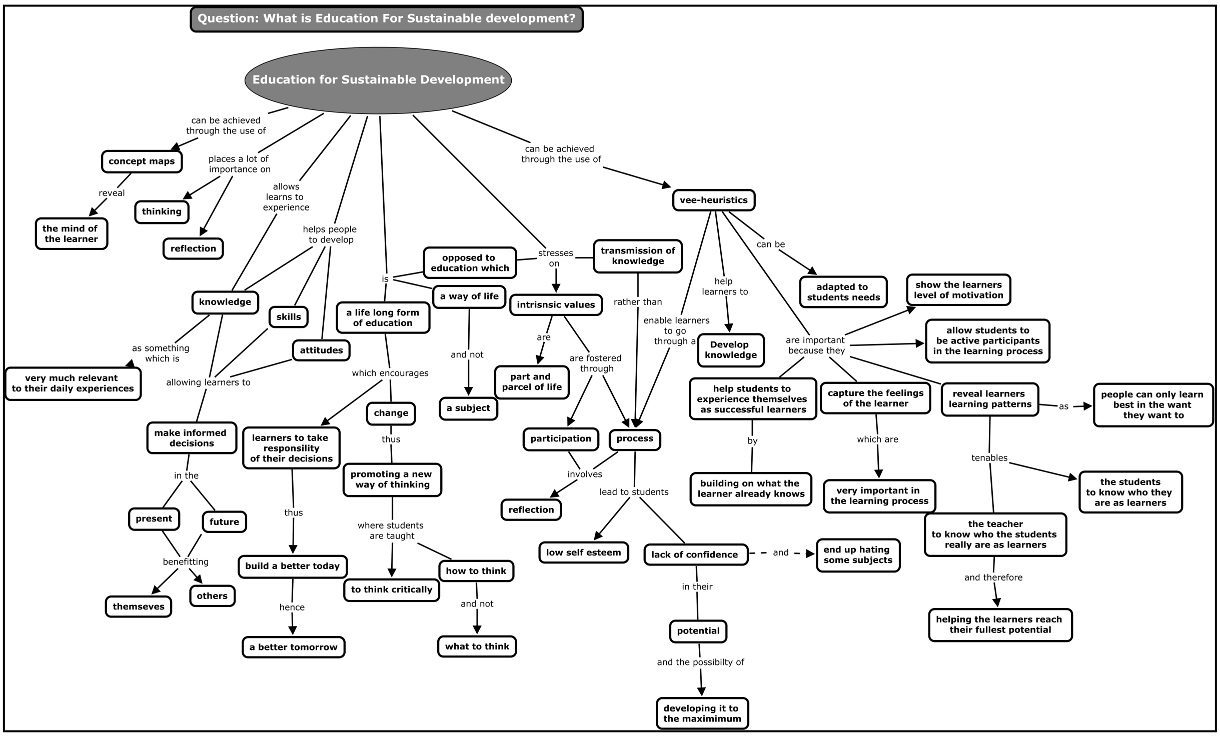

Figure 5: Maryanne's second Concept Map constructed after the learning programme.

6.2. Learner 2 Stefan

From this learner's Vee Heuristic presented in Figure 6 one can easily observe a significant difference between the left hand side of the Vee which was constructed during the first lecture before the learning programme and the right hand side of the Vee which was compiled after the learning programme. It is also worth noting the response given to question No. 2 in the Vee. This response is quite vague and surely reveals the low level of motivation which this student had for this credit. Actually, when discussing with this learner, he confessed that he attended this credit just because it was the only one that did not clash with his time-table. This is also manifested in response No.4 where we see this learner's uncertainty in going through this programme. This learner was not at all planning to learn from the lectures. However, of importance is to note that he planned to do his learning only through real life experiences. Nowhere did he mention that he planned to read or do research to find more information.

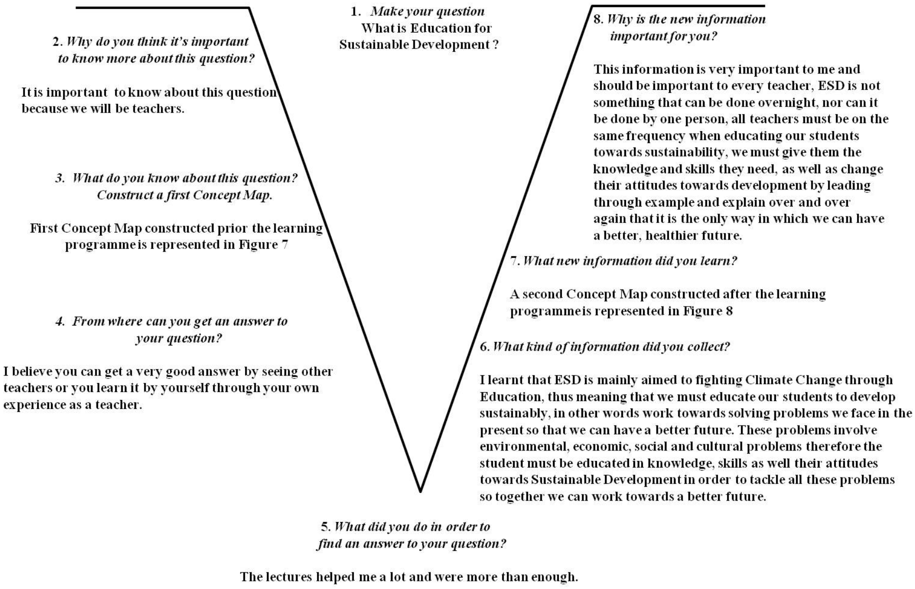

Figure 6: Stefan's Vee Heuristic

This was very important information for me as a teacher to know since I took it into consideration when doing my planning for this credit and I made certain that this learner is catered for during the planning of the programme since from the Vee I observed that he prefers to learn from real life experiences and avoids detailed information. This part of the Vee is in this way very important since it reveals the learners' preferred way of learning and as educators we have to take this into consideration if we would like meaningful learning to take place. Coffield (2004:17) states that *"teachers who understand their own styles and those of their learners can reduce the harm they may otherwise do"* and consequently they will develop more effective skills to interact with and respond to students.

The reply to question No. 5 "*The lectures helped me a lot and were more than enough*" suggests a few things. First, that this learner found the lectures helpful and interesting but on the other hand I must have overdone it with information from this learner's point of view. It also tells me that this learner did not feel the need to go and look up more information because what I did in the lecture was *'more than enough.'* This contrasts sharply with the Vee Heuristic as presented by Maryanne since that learner thoroughly enjoyed the extra information I provided.

The responses given on the right hand side of the Vee clearly contrasts from the responses given on the left hand side. This reveals that through the learning programme this learner's motivation to learn increased, furthermore he found this unit quite meaningful and this is proved in the reply to question No.8 where he stated: "*This information is important to me and should be important to every teacher.*" As we can observe from the first Concept Map represented in Figure 7, this learner did not have a clue of what ESD meant, however, the response given to question No.6 reveals that he has grasped the meaning behind ESD and this is also corroborated in his second Concept Map illustrated in Figure 8. In the response given to question No.8 one can note a sense of determination and commitment in this learner's tone revealing once again that this programme managed to have an impact on this learner who found himself doing this credit just by chance. It is worth noting that this learner's preferred way of learning through real life experiences is also mirrored in question No. 8 where he suggests to change attitude towards sustainable development "*by leading through example and explain over and over again*." Actually, one finds more information in the Vee Heuristic and Concept Maps than in the ten line short paragraph presented as the written reflection. Although all the information given in these ten lines was correct, the sentences were very short and straight forward.

From the first Concept Map generated during the first lecture as presented in Figure 7, one can easily observe a Concept Map presented as a chain revealing little or no knowledge about ESD. This kind of Concept Map also reinforces the answers given to question No.2 and No.3 in the Vee illustrated in Figure 6. In the second Concept Map constructed after the learning programme one can observe a change from a linear train of thought to a net of thoughts and ideas. Although this Concept

Map may have a few flaws in Concept Mapping skills, however, what is more important is that it reveals how this learner's knowledge developed. An increase in concepts and propositions is present and therefore learning has taken place.

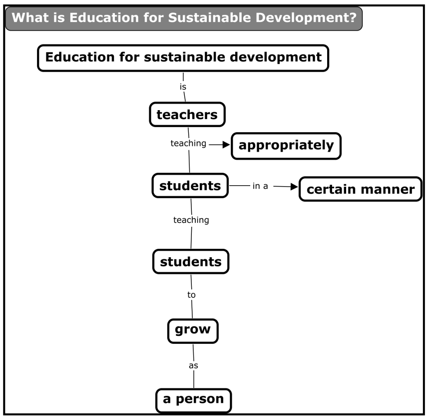

Figure 7: Stefan's First Concept Map created before the learning programme.

These Concept Maps differ from the other Concept Maps presented in this study because they lack details and this could be related to the fact that the dominant learning schema of this learner is typical to that learner who avoids details and likes to go straight to the point. However, the most salient points relating to what ESD is all about are present and therefore the difference in these two Concept Maps reveal that this learner has learned meaningfully although he started off this programme with a lack of interest and motivation. I have also to say that although this learner avoids details, this second Concept Map has more details than his paragraph written as a reflection. It is also worth noting the way in which the first Concept Map (Fig. 7) was constructed and the way in which the second Concept Map (Fig.8) was created. There is a difference in colours and even in the arrowed lines showing that this learner enjoyed more constructing the second CMap than the first one. The way in which this learning programme was presented and experienced may have helped in increasing this learner's interest and motivation.

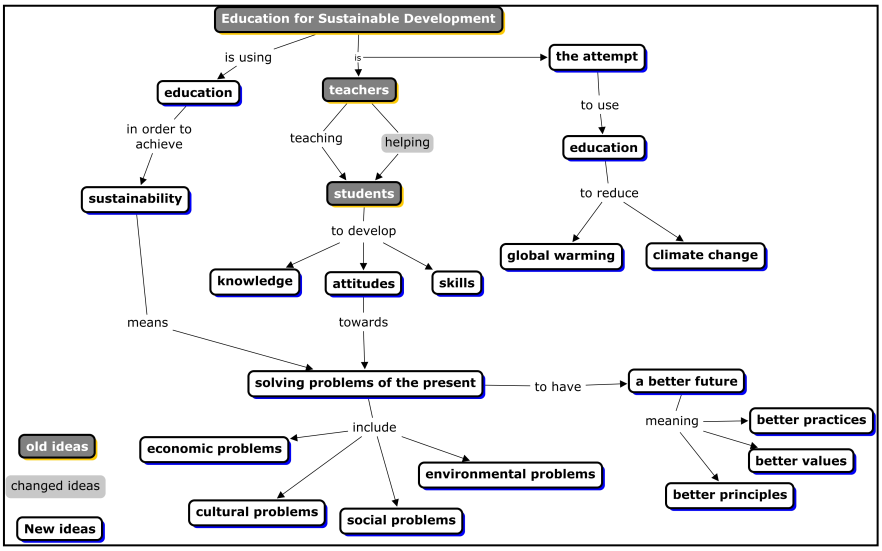

Figure 8: Stefan's second Concept Map constructed after the learning programme.

7. Concept Maps

One of the main focuses of this research revolves around the learning process as an interaction of thinking, feeling and acting. Although Concept Maps in themselves do not reveal the affective side of learning, however, the actual process of constructing a Cmap does involve these three mental processes. On the contrary to "traditional" teaching and learning where the students are asked to represent their knowledge through ways which mainly rely on memory in order to produce chunks of information (surface learning), when students are asked to represent their knowledge by constructing Concept Maps, they would be going through a process of metacognition (deep learning). Metacognition is a process which entails mulling, connecting, rehearsing, expressing, assessing, reflecting, revising and learning. Actually, when one is constructing a Concept Map, one goes through these processes and this is the reason why Concept Maps facilitate meaningful learning and challenge rote learning. Furthermore, when one is constructing a Concept Map one would not be simply reproducing chunks of information which would be totally irrelevant to one's own experience because it would have been studied by heart. When constructing a Cmap, since one would be presenting knowledge according to one's own cognitive structure, one would be creating knowledge according to one's own perspective and automatically this would be related to one's own personal experience and this is why learning becomes more meaningful.

8. Vee Heuristics

Novak (1998) reveals that the shape of a Vee was chosen above other shapes because by using this format, one can clearly recognize and differentiate that both thinking (concepts and theories) and doing (methodology) are implicated in the process of constructing knowledge. The right hand side of the Vee, reports the action part of knowledge construction taking place. One can, in fact, visually see what the learner is doing to develop his/her own knowledge. In addition, the learner can reflect and observe the development of the new knowledge taking place as opposed to his/her prior knowledge on the left hand side of the Vee. In this way, prior knowledge was developed; misconceptions were altered while new knowledge was constructed. So, the transmission model of education is hereby challenged since the learner is learning on his own, the teacher is only facilitating this process by providing the necessary tools. It is argued that rote learning does not impart meaningful learning and one way of taxing this approach is through the use of metacognitive learning. Research in this study and elsewhere prove that Vee Heuristics promote metacognitive skills. Similarly, Novak argues that *"giving learners the correct information does not displace their faulty conceptions! It takes a lot of negotiation of meanings, a lot of shared experience to help learners reconstruct their internal concept Maps to be congruent with the expert's knowledge"* (Novak, 1998:118). Therefore, this process facilitates more teacher/student interaction.

Moreover, this whole process makes the teacher stop and reflect on his/her own practice. In order to bring about transformation one must be ready to transform oneself first and foremost and the starting point should be to reflect critically. This will be the next stage in this research.

9. Conclusion

The integrated use of Vee Heuristics and Concept Maps along with an awareness of how students prefer to learn may promote the reflection and action that is required to stimulate change in Higher Education. This would hopefully lead to creative and reflective practitioners in our society and empower them to become agents of transformation.

This paper is part of a PhD in progress. This research will develop further so as to delve deeper from a teacher engagement point of view. This research will refocus from the influence on the student to the influence on the teacher but will consider that **both** the student **and** the teacher need to be actively engaged for transformative learning to take place. Various authors (Ramsden, 2003; Kinchin, 2004; Richards, 2007; Brockbank & McGill 2000) suggest that separating learning and teaching within Higher Education is a false myth and that engaging in reflective dialogue and interaction are contributing fundamental factors affecting the level of learning.

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