Interdisciplinary science concept maps to orient middle secondary school students learning outcomes

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Abstract. The initial and continuing training of natural science teachers should be implemented in interdisciplinary contexts. This paper shows how concept maps can generate training activities in which teachers of various disciplines can discuss macro concepts such as water, air, wind, temperature, motion, power, energy, etc. mapping the students’ learning pathway. Drawing concept maps and discussing them in training sessions from the perspective of students, teachers and trainers can be a decisive professional experience in changing the ways of improving concepts representations of all the actors of classroom activities and educators.

1. Introduction

Among the alternative methods involving communication, interaction, group dynamics, creativity and emotional intelligence overcoming the blockage of concepts representation the use of concept maps is a strategy recommended both for students and for educators \cite{1–2}. Teachers are familiar with concept maps and accustomed to constructing them mentally but rarely use them during classroom activities in writing as a graphical representation on the blackboard or screen \cite{3–5}. It turns out that by using concept maps in school practice pupils can assimilate fundamental interdisciplinary concepts such as water, air, wind, earth, etc. much more easily \cite{5}.

We investigate if the use of concept mapping in a two-day teacher training programme is a useful educational tool for making students and educators reflect on their own knowledge, identifying shortcomings in learning, and constructing a more meaningful knowledge of nature or life by approaching in a large interdisciplinary perspective the concept of air \cite{6-9}.

2. Concept and macro-concept: interdisciplinarity of the concept “air”

Physics, as queen of inductive sciences, emerging in the first stages of the development of human knowledge, has formulated and then used concepts that have levels of importance and generality that transcend Physics-specific language \cite{10}. If we take as example the concept of AIR, considered in Greek mythology and philosophy as one of the four fundamental elements, the evolution of human knowledge
and human representations about AIR as a complex concept had a continuous ascending spiral. Greek philosophers made the difference between low atmospheric AIR and high atmospheric ETHER. More believed that AIR as a primordial element is alien to intelligence and soul that they could not explain with other terms. Anaximenes believed that atmospheric air was like a dome surrounding the Earth, Plato knew that the air could be dry (warm) and wet (cold), that it had mobility, that it could change its shape, and that it could penetrate the bodies. Was said that the “parts” that make up AIR, this elemental element are so small that man cannot feel them. Aristotle considered to be warm and wet AIR is somewhere between the other two primordial elements FIRE and WATER and made a net difference between AIR and ETHER, considering it the first linked to the human nature of life and the second to the deity, of the celestial spheres.

Today we know precisely that atmospheric air is a mixture of gases in which we can have vapors of volatile substances, that the earth's atmosphere is a living environment for plants and animals because it contains oxygen but are animals or plants that can live in the absence that air is something extremely precious to mankind and society and that we must take care of maintaining its quality. But we have a lot of question to the deity and celestial significance of AIR [11].

**Figure 1.** The map drawn by in-service Romanian teachers (trainees) during the programme related to the concept maps.

AIR like many other scientific concepts is a common notion of several sciences and areas of knowledge. Air from a notion originally defined by philosophers who simultaneously did science has become a key concept in physics closely linked to the physics of gaseous state. When the Physics divorced on amiable terms from Chemistry, the concept of air with all that Physics had discovered about this primordial element had passed into the thesaurus of concepts of Chemistry. The new field has enriched the concept in a decisive manner by giving accurate and concrete representations about the chemical composition of the atmosphere, the gases and their combinations, the oxidation and reduction reactions, the reactions in the gaseous medium, the state transformations, etc. Because the biological processes that support life require scientific explanations, Biology took the knowledge, or physics and
chemistry, representation of the AIR macro concept, and enriched them with other complex representations that could explain aerobic or anaerobic metabolic processes. Geography has taken over the concept of AIR and has been struggling for centuries to explain complicated laws and statistics of air mass movements. In the last fifty years, human society has felt necessary to pay more attention to the quality of the living environment and the future of human society, and a new interdisciplinary science has been born. The ecology for which the AIR macro concept is a key to understanding the values promoted by this science. The evolution of knowledge and representation of the AIR concept, through these hard sciences mentioned, has significantly influenced the concepts of ineffable concepts such as SOUL or SPIRIT, DEATH or LIFE.

Physics and other natural sciences, but also Theology and Philosophy use the concept of AIR in relation to a wide range of subordinate concepts that constitute a grid of dense or deeper concepts depending on the precision desired to represent an entity of knowledge. The reports between concepts at micro or macro scale and their degree of ordering in the process of knowledge must be flexible and fluid in order to translate from the unknown to ready to be used in practice. The specificity of the concepts in a learning situation should not become an obstacle to solving future cognitive problems (obstacles).

When a tourist has a problem of orientation in the field, as it happens sometime in life but also in knowledge, it is good to make appeal to a visual representation that can help us – a map [12]. This graphical representation is called concept map in pedagogy and synthesizes the relations between groups of concepts [13]. Teachers sometimes address concept maps in words as: observation sheets, worksheets, recapitulative charts, data chart or tables, etc. When designing and implementing such instructional or assessment tools in class, teachers do not think in general theoretical terms but have practical approaches responding to an instructive - educational situation. [14-15] It is important to substantiate the design and

![Diagram](Image)

**Figure 2.** The map drawn by in-service Romanian teachers (trainees) during the programme related to interdisciplinary approaches.
operationalization of a concept map so that it is possible to clarify the hierarchical relations between concepts and establish key concepts (concept node) and what is the most important refine representations that teachers or students have about certain concepts. A carefully designed concept map facilitates the achievement of objectives, synthesizes ideas, organizes content, facilitates didactic communication, focuses on learning, responds to more learning and teaching styles, encourages debate and critical thinking, etc. [16].

3. Training programme on concept maps
The use of concept maps in an interdisciplinary approach (see Figures 1 and 2) can serve in the design and implementation of training activities for teachers in applied pedagogy. In order to start the training, it is very useful to identify teachers’ needs and design the learning model to be used. With this aim were carried out initial workshops with representatives of the targeted groups and the trainers who was involved in the training. The subject of these first investigations was whether concept maps are actually or consciously used by teachers and students in educational instructive activities [5].

In the second step a general concept map of the training course to be used was drawn up as one of the working tools of the AIR concept map. In collaboration with professors of different disciplines, the macro concept was discussed, and with the help of didactics, an orientation map of the pedagogical concepts to be discussed in the training session was established. The map drawn during the training session (see Figure 3a) was compared with those of other experts (see Figure 4) on the concepts of ineffable concepts such as Soul, Death or Life.

![Figure 3](image-url)

**Figure 3.** The map drawn by in-service Romanian teachers (trainees) during the programme.
Teachers of various specialties have been asked to build their own concept map on AIR. In turn, they asked their students of different ages to draw a map of the connections between the concept of AER and sub concepts or other macro-concepts. The teachers in the training programme were asked to give students full freedom in representing concept maps for AIR concept, possibly encouraging teamwork so that at the end of the event they could discuss with the pupils. Few examples of such kind of maps can be observed in Figure 4. The obtained maps were analyzed by the teachers in order to synthesize the observations and to distinguish in between the teachers and students map. The map legends provided details on the time scale and disciplinary scale and the authors of the representation.

Finally, the concept maps obtained during the training and in schools pedagogical research for various disciplines of study, at different age level of students were presented in a one day teachers training and discussed in symposia in order to have inter-or transdisciplinary utility. Finally, with the help of mentors and experts in mapping, learning the relationship between the map concept of AIR and the other interdisciplinary concepts or macro-concepts maps activated during the training was deepened or detailed. On this occasion, curriculum overlaps could be observed and established the most effective pathway for teaching and learning fundamental interdisciplinary concepts.

4. Details concerning training programme
Teachers have received from the beginning the concept map of the training session and were informed about the activities they were supposed to team up with the other colleagues. The 4-hour initiation
The session was followed by the observation of how a colleague implements different types of conceptual charts during classroom activities.

The target group of training was composed of both beginners and senior teachers. The purpose of the session was to improve the teaching of fundamental concepts transferred in instructional activities by different teachers in classroom at different scholar disciplines.

The session responded to the training needs of teachers wishing to benefit from the use of alternative teaching, learning and assessment methods. The activity gives them the opportunity to reflect on how they work in class and to change how they communicate and involve students in lessons, but also how they relate to teachers teaching different school subjects and teach in their disciplines the same macro concept. Some of the results of the training activities were used in the teachers’ conferences.

The “concept map” method is discussed on three levels of representation and operationalization: as a student, teacher and trainer.

The design of the training activity aims at reflecting on the knowledge transfer process, starting from a few questions the teacher trainers propose:

- 3 of WHY:
  i. Why must to do it from a theoretical perspective?
  ii. WHY in this context?
  iii. WHY with these students?

![Figure 5](image_url)  

*Figure 5.* Students’ map of AIR concept (14 years old – rural area school).
2 of HOW:
   i. How do I achieve my goals?
   ii. How will learners, teachers and students behave when I approach this macroconcept using the concept map method?

n BUT IF:
   i. BUT IF this method does not work?
   ii. BUT IF the concept map is not seen by students and students correctly?
   iii. But if students and teachers are not ready to apply the method?
   iv. BUT IF I WAS NOT CLEAR IN DRAWING?
   v. Etc.

The assessment of initial and experienced staff involved in the training programme had several components. Initial assessment was done by requesting teachers to draw a concept map and make a difference between their map and students’ map. This short evaluation sequence was followed by a debate that should lead to the conclusion that the concept map is an alternative method that can be applied regardless of school age in different classes during different activities and in teaching learning different school subjects.

The continuous evaluation of the activity was done through self-evaluation / evaluation during the workshops through the feedback provided by trainees and trainers.

The final evaluation involved:
   • completing a final questionnaire;
   • drawing up a portfolio containing at least three alternatives of the alternative method, including their comments in terms of teaching;
completing an observation sheet (experiment) of a lesson by a colleague who uses a conceptual lesson in the lesson;
• drawing up a draft of a teaching lesson that uses an innovative concept map.

5. Conclusions
The use of concept mapping method in professional training offered to teachers of various specialisms has a positive effect on science learning and the correct representation of macroconcepts. The Teacher Training Session demonstrated that using mapping of concepts both in lessons and in teacher training sessions is an effective method that changes the perception of teachers and trainers about designing and implementing instructional activities.

Educators’ debates in which the concept map of students can be compared to the concept map of teachers and trainers have proved to be extremely useful for developing critical thinking and integrating macro-concepts in an interdisciplinary context.

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