

SHOULD BE CONCEPT MAPPING USED IN THE SCIENCE TEACHING?

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Abstract

Students' understanding of physics develops through everyday experience. Teachers must help students overcome their prior naive notions and move toward a more scientific understanding. This process is fundamental to student learning and it is one of very important objectives of physics teaching. In this article the strategy of concept mapping which can help students rationalize their perceptions in light of accepted scientific understanding is described. Concept maps are drawings or diagrams showing the mental connections that students make between a major concept and other concepts they have learned. This technique provides an observable and assessable record of the students' conceptual schemata – the patterns of associations they make in relation to a given focal concept. Concept maps allow the teacher to discover the web of relationships that learners bring to the task at hand – the students' starting points.

Key words: *concept learning, students' understanding of physics, constructivist learning theory, misconception, logical structure of concepts, concept mapping.*

Introduction

Constructivist learning theory (Mintzes, Wandersee, Novak 1998) holds that individuals build, or construct their own meaning in and outside our classrooms. What the teacher presents interacts with the student's existing knowledge and experiences sometimes resulting in unexpected learning outcomes, frequently called alternative conceptions or prior knowledge. What a student knows and the associations made between ideas and concepts are the student's cognitive structures. Therefore, learning consists in part of integrating new material and content with the student's prior knowledge. Pedagogies consistent with constructivism such as the conceptual change theory (Duit, 2003) engage the learner's prior knowledge and develop the learner's understanding so that it is consistent with scientific knowledge.

What is Concept Mapping?

Graphic organizers are common in the American reading research and are defined as visual representations that communicate the logical structure of concepts. Concept maps are a specialized type of graphic organizer developed by Novak and Gowin (1984). Maps are non-linear, two dimensional graphic representations of a set of concepts constructed so that the interrelationships among

those concepts is evident. The maps are hierarchical with the more general topic at the top and the more specific concepts below. Concepts are connected by words or propositions. A student might link the concepts of force and Newtons with the proposition “is measured in.”

This technique provides an observable and assessable record of the students’ conceptual schemata – the patterns of associations they make in relation to a given focal concept. Concept maps can be used in a manner consistent with constructivist teaching especially conceptual change, since the maps reveal students’ existing ideas. Teachers can now use the maps to design instruction that challenges the students’ existing ideas until the students’ knowledge is reorganized and more consistent with scientific understanding. Concept maps allow the teacher to discover the web of relationships that learners bring to the task at hand – the students’ starting points. It also helps the student express their understanding and demonstrate how their ideas are being changed by instruction.

Maps are an excellent metacognitive tool helping students control their own learning. Metacognition, the act of thinking about one’s own thinking, is a critical element in the conceptual change process. As students alter their maps over time, they become increasingly aware of the changes in their thought processes. This awareness helps them to learn how to learn and encourages reflection on the nature of acquiring knowledge.

Concept maps are consistent with constructivist teaching since the maps reveal students’ existing ideas and provide both the student and the teacher with a means to organize and reorganize the science content they are learning. Concept mapping facilitates meaningful learning by requiring the learner to make decisions about importance of ideas and how these ideas relate to what is already known. By making these decisions the learner arranges ideas in way that is more easily incorporated or assimilated into their existing cognitive structure. Teachers can now use the maps to design instruction that challenges the students’ existing ideas until they are reorganized and more consistent with scientific understanding.

Effectiveness of Concept Mapping

Marzano et al (2005) notes that nonlinguistic representations such as graphic organizers have a positive effect on student achievement with an average effect size of 0.75. They cite the “dual-coding” theory of information storage that postulates that knowledge is stored in two forms: linguistic form and an imagery form. Linguistic or verbal knowledge is stored separate but linked to visual knowledge. Linking between the verbal and visual knowledge provide the learner with additional options for retrieving the knowledge stored in their memory. Marzano notes “the more we use both systems of representation-linguistic and nonlinguistic-the better we are able to think about and recall knowledge.”

Nesbit and Adesope’s (2006) meta-analysis of graphic organizer including concept maps consisted of reviewing 55 studies involving over 5,000 participants. They concluded “in comparison with activities such as reading text passages, attending lectures, and participating in class discussions, concept mapping activities are more effective for attaining knowledge retention and transfer. Concept mapping found to benefit learners across a broad range of educational levels, subject areas, and settings” (p. 434). In the physics classroom, Pankratius (1990) found that “mapping concepts prior to, during, and subsequent to instruction led to greater achievement as measured by posttest scores.”

Constructivism and Concept Mapping in Today’s Czech Classrooms

In Czech classrooms today there is a current clear traditional approach towards instruction that is characterized by the dominant status of the teacher and receptive passivity of the students. Scientific findings are acquired in a form that excludes their later application and utilization to new problems or contexts. The students can’t use their knowledge in concrete situations because they don’t recognize their relation to new situations. They can’t transfer their experience to the real situation. One of the possible ways to gain active knowledge is a constructivist approach to the instruction of scientific subjects. In this approach the present instructive teaching practice is completed by chosen learning problems through creating adequate learning environment. First of all, a student matches

new knowledge with his/her experience and view to world. This process is individual, relative and unpredictable. The teacher's goal must form rich and communicative setting in content that will address the subjective field of experience and at the same time will include new problems that will attract to creative self-orientation. The mastery of a teacher lies in the fact that he/she can predict the chain of sequences between former situation constructions at a student and scientific knowledge which are taken by the student as a state of expected clash and sorts out and overrule by the way of tests and errors. In the environment the individual has the subjective extent of knowledge and experience.

This is why the research team of the Department of Physics, Faculty of Science, Palacky University Olomouc proposed to the Czech Science Foundation, the project *Constructivism and its Application in Integrated Concept of Science Education*. The grant was awarded in January 2005 and the research took 3-years to complete. The overall goal of the project was to develop constructivist approach in the area of the theory of Physics, Chemistry and Biology instruction.

One of the objectives of the project was to apply constructivist approaches to science education in order to influence Czech pedagogy. The project also sought to develop an instructional theory and corresponding curricular materials that make scientific inquiry accessible to a wide range of students. The team hypothesized that this could be achieved by recognizing the importance of scientific preconceptions of the students. The theoretical basis of the work in the project was constructivist theory that works with scientific preconceptions. A part of the research was to measure the scientific preconceptions of the students. This survey was administered at selected basic schools at the end of the school year 2005/2006 in the Czech Republic to 418 respondents (196 boys, 222 girls). The students solved problems and tasks that enabled research team to determine how students understand the basic scientific concepts such as energy, matter, light, motion, density, temperature and so on.

The most difficult task for students was concept mapping. This item was used only in the pre-test. In this pre-test 75 students of fifth grade of primary school (42 boys and 33 girls) had to draw a concept map with the central concept being the "Sun." Students were given the following concepts: heat, temperature, light, thermometer, light, life, oxygen, plants, energy, (eye)sight, Solar System, colors. Students could use additional concepts that they knew and connected in some way with the concept "Sun." The student maps were evaluated based on the hierarchy and connections between concepts with the pointers. Only a few students (2%) were able to pass these tasks (Holubová, 2007).

Prospective science teachers (23) in the initial science teacher training also solved evaluated the pre-test to make recommendations. Most of the prospective teachers (83%) did not understand fully the concept map item of the pre-test. They asked for more information on this item. Designed students' concept maps demonstrated that university students never used this strategy in their previous science education. Students suggested not to use this item in the subsequent research of the primary students pre-conceptions (Holubová, 2007).

This result documents that concept maps are not frequently used in science instruction in Czech classrooms. Students do not understand fully the content of the science concepts that were taught and do not build internal structure of the science concepts. It is not possible to generalize. Of course, there are some science teachers (especially on primary level) who use the concept mapping strategy in science instructions but they remain the exception.

The implications are that concept mapping is a good instructional strategy to begin integrating into Czech classrooms as a way to begin and change the dominate teacher-centered pedagogies. Concept mapping can engage the students in monitoring their learning and demonstrating the growth of their knowledge and understanding. Introducing teachers and future teachers to concept mapping is one way to foster constructivist teaching methods in Czech classrooms. Below are described strategies that can be used to develop teachers' skills in using concept maps in their classrooms.

Constructivism and Concept Mapping in Today's US Classrooms

The use of concept mapping in American classrooms has a long history of research and support. Novak (2002) and Quinn, Mintzes and Laws (2004) showed that concept maps enhance learners' academic learning by promoting an inquiry-based learning environment. Graphic organizers and concept maps are frequently included with textbooks as worksheets for students to complete or for

teachers to introduce content. Concept mapping is also a common strategy taught in teacher preparation programs especially in science methods courses. Methods textbooks such as *Teaching Science to Every Child* by Settlage and Southerland, *Secondary Instruction in the Middle and Secondary Schools* by Chiappetta and Koballa, and *Teaching Science in Elementary and Middle School Classrooms; A Project-Based Approach* by Krajcik, Czerniak and Berger include concept mapping.

The teacher professional literature also contains examples of how to incorporate maps into a classroom. Kern and Crippen (2008) describe a series of four formal activities used in their secondary classrooms. The mapping for conceptual change activities are located within science unit of instruction although the location may differ from unit to unit. The first mapping activity takes place prior to the unit and is a survey of the student's prior knowledge. The second activity is used to identify persistent misconceptions and to determine how well the new content has been incorporated by the student into their existing knowledge. This activity is used to engage the student in a cycle of mapping, feedback, and reflection on their understanding. The focus on the third activity is restructuring knowledge and engaging the students in metacognition. The final mapping activity is part of the unit's final exam and is assessed by the teacher for scientific understanding and conceptual change. They conclude that "Mapping for conceptual change is an embedded strategy that helps students learn how to think, recognize the importance of metacognition, master a strategy for identifying relationships among concepts, and implement a study skill for conceptually understanding science."

Vanides, Yin, Tomita, and Ruiz-Primo (2005) highlighted the use of concept maps for assessing middle school (grades 6-8) science. Students benefit three ways because maps provide the students with an opportunity to think about the connections between science terms, a chance to organize their thinking and visualize the relationships, and finally a chance to reflect on understanding. The link between science and language literacy also helps students who are English language learners. Maps can be used by the teachers to evaluate student learning and provide students with feedback. "In general, concept map assessments provide a different perspective on student understanding that complements selected-response and performance-based instruments." Teachers can use criteria such as the complexity of the maps, existence of most important propositions, and the quality of the propositions to assign grades.

The use of graphic organizers and concept mapping is more common in the elementary classrooms than high school science classrooms perhaps reflecting the inclusion of graphic organizers in language instruction as well as science. Software such as Inspiration© is also commonly made available for elementary teachers. Although more and more teachers are using graphic organizers and concept maps, many do not engage the students in reflection and do not explicitly teach metacognition. The use of the maps in the classroom is an important step for the teachers but they must continue to modify their teaching to maximize student learning. In the preservice teacher preparation program, many students enjoy learning how to construct maps and do use them with children, but they find it difficult to engage in the metacognition themselves, resisting the reflecting on their own learning. Once in the classroom, pressures to address state standards further reduce the willingness to engage students in reflections. Teachers often think they have little time and that direct instruction will lead to better student performance. There is a need for continued professional development and the inclusion of concept mapping into more university classes.

Engaging Teaching: Using Concept Mapping in the Classroom

The teacher can present "expert" concept maps to the whole class to highlight key concepts and connections. These should be more detailed and flow from the global maps executed for the course design. Concept maps can then serve as "advanced organizers" (to preview material) and also for review. An instructor can continuously refer to a concept map in class to show how to "grow" the connections, and to keep the instruction focused. Students can visually see how a single concept presented in a class links to the main content themes of the course.

This technique also helps the teacher assess the degree of "fit" between the students' understanding of relevant conceptual relations and the teacher's concept map – which is often a "map" commonly used by members of that discipline and consistent with accepted scientific knowledge.

With such information in hand, the teacher can go on to assess changes and growth in the students' conceptual understandings from instruction. The concept map also allows students the ability to scrutinize their conceptual networks, compare their maps with those of peers and experts, and make explicit changes (Angelo, Cross, 1993).

Concept maps provide insights into the connections students are making among theories and concepts. At the same time, concept maps can be used to assess the connections students make between theories or concepts and information (Mintzes, Wanderee, Novak, 2000). Before beginning instruction on a given concept or theory, teachers can use concept maps to discover what preconceptions and prior knowledge structures students bring to task. This information can help teacher make decisions about when and how to introduce a new topic – as well as discover misconceptions that may cause later difficulties. During and after a lesson, they can use concept maps to assess changes in the students' conceptual representations.

Pros and Cons

- Concept maps help students focus on the “big picture”, enabling them to devote more of their time to conceptual understanding rather than rote learning;
- Concept maps force students (and teachers) to make valid connections among concepts;
- They provide a low tech (cheap) vehicle that enables students to represent graphically their knowledge, and to share it with the instructor and other students;
- They shift the emphasis from inert, static knowledge to contextually-embedded knowledge; from isolated facts to theoretical frameworks of related concepts;
- In addition to their role as assessment tools, concept maps offer a useful way to help students „learn how to learn“; they also serve as useful vehicles for course development and as graphic organizers before, during and after instruction.

However:

- Comparisons among students are more difficult because concept maps tend to reveal the idiosyncratic way that students view a scientific explanation, as a result...
- Evaluation can become more time-consuming for the instructor, especially in large classes, unless some variation (such as Select & Fill-in) is adopted;
- If you score maps, you must use a consistent (and tested) scheme;
- Students who have developed a strong facility for rote learning of verbal knowledge sometimes find concept maps intimidating;
- Constructing concept maps is a demanding cognitive task that requires training.

| Pros | Cons |
|---|--|
| Focus on the “big picture” | Comparisons among students are more difficult |
| Conceptual understanding | Evaluation can become more time-consuming for the instructor |
| Valid connections among concepts | Difficult tested scheme |
| Represent graphically students' knowledge | Concept maps intimidating for some students |
| Shift from isolated facts to theoretical frameworks of related concepts | Constructing concept maps require training |

Conclusions

Concept mapping emerges directly from David P. Ausubel's Assimilation Theory of meaningful verbal learning (Ausubel, Novak, and Hanesian, 1978). The underlying basis of the theory is that meaningful (as opposed to rote) human learning occurs when new knowledge is consciously and purposively linked to an existing framework of prior knowledge in a non-arbitrary, substantive fashion.

More than two hundred studies in science education have employed concept mapping in one form or another (Novak, 1998; Novak and Wandersee, 1990; Mintzes, Wandersee and Novak, 1998). Several of these investigations have examined the reliability and validity of the technique as a way of representing knowledge in scientific disciplines (Markham, Mintzes and Jones, 1994; Pearsall, Skipper, and Mintzes, 1997; Ruiz-Primo and Shavelson, 1996; Songer and Mintzes, 1994; Wallace and Mintzes, 1990). In general, these and other studies suggest that the technique has many of the desirable characteristics for which concept mapping should be used in science teaching.

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