Brain-based Teaching in Computer Science
Neurodidactical Proposals For Effective Teaching

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ABSTRACT
Brain-based teaching is neither a method nor a concept. It is rather a way of teaching that tries to support the learning and memory process in all phases from lesson design over input and practice up to the transfer of knowledge and competencies in real situations. The proposals for brain-based teaching come from neurodidactics or educational neuroscience that combines findings of brain and memory research, didactics, pedagogy and psychology. This paper aims at presenting concepts and methods that can facilitate learning and proposals for designing computer science lessons by considering the functioning of the brain and the memory.

Categories and Subject Descriptors
K.3.2 [**Computer and Information Science Education**]

General Terms
Human Factors.

Keywords
Computer science education, brain-based learning, neurodidactics.

1. INTRODUCTION
Brain-based teaching is not new - and it is no panacea. It is neither a method nor a concept. It is rather a way of teaching that tries to support the learning and memory process in all phases from lesson design over input and practice up to the transfer of knowledge and competencies in real situations. Proposals for brain-based teaching come from neurodidactics, an interface between brain and memory research, didactics, pedagogy and psychology. This research field confirms learning theories and teaching concepts like constructivism [1, 2] or progressive education [3]. This paper presents some examples of brain-based lesson design and teaching methods as well as their application in practice.

2. BRAIN-BASED LESSON DESIGN
Summarizing recommendations of neurodidactical research the following facts shall be kept in mind in lesson planning: Biological facts that cannot be changed but considered, environmental facts that can be created, personal facts that can be influenced, and brain and memory functions that can be supported [5]. Brain-based lesson design tries to consider as many factors as possible. Concerning the lesson structure they all approaches have two important principles in common: Alternating attention levels have to be considered and learners have to be active.

Sousa [6] e.g. suggests nine components that should be considered (certainly not all of them fit in all lessons): anticipatory set, learning objective, purpose, input, modeling, check for understanding, guided practice, closure and independent practice. Furthermore he proposes to divide each learning episode in two prime-time phases of about 20 minutes, one at the beginning containing the most important information, and one at the end of the lesson for a closure. The downtime between these phases should be used for practice. The model of Learning under Self-control follows the phases of attention and memory, too, and proposes the following structure:

1. Activation phase (about 10 minutes)
2. Core-information phase (about 5-10 minutes)
3. Consolidation phase 1 (about 5 minutes)
4. Repetition phase 1 (about 5 minutes)
5. Consolidation phase 2 (about 10 minutes)
6. Repetition phase 2 (about 10 minutes) [7].

Caine and Caine [2] propose three fundamental lesson phases:

1. Orchestrated immersion (creation of a learning environment that fully immerses the students);
2. Relaxed alertness (optimal state of learning that combines high challenge and expectations with low threat, confidence, competence and intrinsic motivation.
3. Active processing and personal engagement ofstudents.

3. BRAIN-BASED TEACHING METHODS
One of the key findings of neurodidactics is that knowledge cannot be transferred but has to be newly created in the brain of each student. That means that learning is always an active process where knowledge has to be constructed. This corresponds to the approaches of progressive pedagogy and constructivism [1, 3]. The teaching and learning methods proposed in these approaches contain some neurodidactical principles and they are effective [8].

Discovery Learning: Instead of getting detailed instructions from a teacher, discovery learning focuses on "[…] teaching things to oneself, in order to solve one's own problems." [9].

Social or Observational Learning [10] means learning by imitating and, is based on the so-called mirror neurons that are active whenever observing and imitating others.

Learning by Doing wants the students to be active, which is more effective than teacher-centered instruction [6, 11, 12].

Learning by Teaching: "Whoever explains, learns!" [6]. By teaching others learners recall information from memory, which restarts the whole memory process and enhances retention [11, 13].

COOL – Cooperative Open Learning: The COOL teaching concept, initiated by a team of Austrian teachers, is based on the Dalton Plan and its key principles *freedom of choice*,, *cooperation* and *budgeting time* (self-responsibility of the learning process). During COOL lessons the students work independently on written assignments. They can decide on when, where, with whom and

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how to solve the tasks until a predefined deadline. This requires a change in the role of teachers, who act as coach or tutor [16].

4. BRAIN-BASED TEACHING PRACTICE

4.1 Brain-based Methods In Creative Projects

One regional part of the Austrian teacher support program IMST[1], "Informatik kreativ unterrichten" (Creative Informatics Teaching) aims at fostering creativity in computer science education by funding creative school projects. The majority of these projects use brain-based teaching methods. One example is described here.

The project "Let's make the adolescents talk", which was carried out in a vocational school for computer scientists, is based on Learning by teaching. The students had to create short creative podcasts or webcasts about different topics like algorithms, object orientation or databases. Besides the aspect that learning by teaching others is very effective the project leader assumed that for adolescents it might be easier to understand the explanations of their peers who use the "same" language. During the design and the production of these "micro learning-modules" the students were very motivated and active, discussed the topics and tried to help each other to understand the concepts. With each step in the project they could also increase their self-esteem, an important factor in learning [14], because they were proud of their products [15]. Furthermore, the multimedia learning modules supported the memory process by taking benefit of the modality effect [16].

4.2 Implementation of a Brain-based Concept

One example of a teaching concept integrating neurodidactical principles is "Brain-based Programming" [4]. This concept has been developed in order to improve the learning outcomes of introductory programming courses at university level and implemented last winter term in one of seven parallel courses (90 minutes/week). It is mainly based on *COOL* (Cooperative Open Learning) using the method of pair programming, *Discovery Learning* with reading exercises and step-by-step-instructions as well as *Learning by Teaching*. Students with good programming skills (*professionals*) or some competencies (*amateurs*) "worked" as peer tutors and supported there al *beginners* in small learning groups during the first two parts in the lessons: the *question* and the *discovery phase*. In the third phase, the lab, all students worked in pairs and tried to solve different programming exercises of their choice in the sense of pair programming. In this way all students were active, always according to their individual preconditions and competencies [4]. The results of the pilot study show that considering brain-based principles in teaching programming can improve learning and that it is worth continuing and extending this concept.

5. DISCUSSION AND OUTLOOK

Brain-based teaching and learning is not a panacea as some commercial publications may claim, but it can help students in learning difficult and complex subject matters. Many proposals of neurodidactics are not new but refer to well-known teaching concepts like constructivism and progressive education and teaching methods like cooperative and discovery learning or learning by teaching. But they are scarce and further empirical research is necessary. The pilot project of "Brain-based Programming", for example, could demonstrate that a neurodidactical approach on different levels (lesson structure, classroom setting, teaching methods and material) can be successful. In a follow-up project that is being planned now we want to test the adapted concept in schools and have a closer look at specific aspects like the use of pattern recognition in classroom or the impact of cooperative methods from the point of view of neurodidactics. Future research should also study the effectiveness of different brain-based methods.

[1]IMST = Innovations Make Schools Top

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