Student Active Learning in Science (SALiS)
The theoretical and organisational framework of a TEMPUS IV project

Ingo EILKS* and Marika KAPANADZE**

**University of Bremen, Germany; **Ilia State University Tbilisi, Georgia*
**University of Bremen, Dep. of Biology and Chemistry, Leobener Str. NW 2, 28334 Bremen, Germany, ingo.eilks@uni-bremen.de, +49 421 218-63280/8*

Abstract
Educational theory suggests that learning science follows the theory of social constructivism. This theory asks for organizing the teaching-learning-process in a student-active mode to be characterized by high individual as well as collaborative and cooperative student activity. This paper sums up essential tenets from this theoretical justification for more student-active learning in science. It discusses different dimensions of making the student more active in the science classroom as a theoretical underpinning of the EU-project TEMPUS-SALiS. The framework of the project will be presented.

Keywords: Science Education, Constructivism, IBSE, Active Learning, EU-projects, SALiS

1 Justifying more Student Active Learning in Science

Science teaching in many classrooms all over the world can still be characterized as being a teacher-centred approach. The teacher is presenting the content while the students are passive and thought to absorb the information showered on them by the teacher. If laboratory work is embedded at all, it is very much often limited to the teacher demonstrating experiments. Interaction with and among the students is limited to short periods of guided questions and short answers. As a result, we all too often find out that what we had taught and what our students had actually learned are very different. The most often reaction by the teacher is to try to explain better. The teachers hope that the better they will present the content the better their students will learn [1]. This interpretation of learning is not in line with what educational theory suggests, e.g. [2]. Educational theory suggests that, knowledge cannot be transferred intact from the mind of one person into the mind of another. Learning with meaning and understanding only takes place if the learning becomes an activity within the mind of each individual learner [3]. Meaningful learning is the active integration of new information with knowledge already possessed by the learner. The subsequent interpretation of this new information will then depend heavily on what the learner already knows and what cognitive processes will occur in the mind of the learner. This means that the quality of education should not be assessed in terms of the effort being put in by the teacher. The quality – and quantity - of learning is much more dependent on the effort being put in by the learner.

Today, our understanding of effective science learning is generally referred to the theory of constructivism [2]. Constructivism suggests applying teaching methods making the learner the active player and to encourage the learner to become cognitively engaged in developing understanding of the topic being taught. The more elaborated interpretations of constructivism not only seek to make students active thinkers, but to promote interaction and collaboration between them. The socio-constructivist framework suggests learning in interpersonal communication and social interaction as being essential for any effective learning [4]. Socio-constructivism explains that effective learning requires a process that mainly functions through cultural and social mediation about content [5,6].

From these theories, we know that science education should apply methods fostering activity in the students' contemplation with the content and also make science education a collaborative and cooperative practice. Instead of studying the mental content of individual minds, collaborative and cooperative learning focuses on the processes of interaction, participation, discourse, and negotiation. Cooperative learning leads to co-constructing knowledge and to building up collaborative knowledge where the group is able to attain a level of understanding that could not have been achieved through the mental processing of any one individual from within the group alone [7]. This is true for the learning of pure subject matter knowledge as well as the learning within contexts or learning via practical work. If all the different dimensions of making the student active – hands-on and minds-on – are used in science education, the classroom environment has high potential for effective learning, student motivation, and the development of skills beyond the rote learning of subject matter knowledge. More general educational skills will be promoted including inquiry skills, organising and structuring of projects, or team working abilities. In the result higher cognitive achievement, better development of higher-level thinking skills, increased student self-confidence and satisfaction and better attitudes towards subject matter will be the result [6].

2 Dimensions of Making the Science Classroom Student-active

Considering the theoretical framework briefly discussed above (see also [8]), we can allocate different domains where more student activity in the classroom will lead to more effective science learning.

Activating students' prior knowledge. One of the first assumptions of constructivist learning theory was that learning depends on the learner's prior knowledge and interest. Neglecting students' prior knowledge and interests will lead to diminishing motivation and will limit learning to rote memorization. The result will be memorization of isolated facts detached from their scientific origin and potential contexts of application leading to inert knowledge with no chance to be applied. Putting the content into a context connected to the students' prior knowledge and interests is essential for effective learning. The prior-knowledge should be activated and associations a student might have with the topic should be made explicit. Making prior-concepts explicit and making students aware about the potential discrepancy between their prior-conceptions and scientific explanations can be used to motivate contention with science learning [9].

Activating students' minds. Learning science, beyond cold memorization of facts and theories, is never a passive diffusion of knowledge. Only actively constructed knowledge has chance to become applicable knowledge, transferrable to new situations. If new information is presented challenging the prior understanding of the learner cognition will be accommodated, resulting to new knowledge. Therefore, science education should try to activate the students' minds by challenging them in a cognitive conflict in the learner. New information should contradict and challenge prior conceptions that might be not scientifically reliable. Tasks shall be used to challenge students' thinking and guide the learning in an inquiry-based mode, especially in connection to the learning in the laboratory [10].

Activating hands. Learning can make use of more channels than only the acoustic and visual channel. The more senses are activated the better is the chance for learning. Student-active learning should include hands-on student activity. Students' practical work is a unique chance to raise motivation and learning effectiveness [10]. Microscale- and low-cost-techniques can help making students' laboratory work available even with low budgets and bad equipment [11]. However, also other physical and social activities should be embedded into the science classroom, e.g. working with physical models, using ICT, or operating drama and role play [12].

Activating cooperation. Cooperative learning proofed to offer a whole range of strategies for effective and motivating learning in science by promoting student-student-cooperation. Student-active science learning asks for applying cooperative learning with positive interdependence of the learners instead of the teacher-centered approach or traditional, unstructured group work [12]. Promising examples are e.g. the Jigsaw Classroom [13] or the Learning Company Approach [14].

Activating communication. In the heart of social constructivism is also the idea that learning is meaning making in communication to others, preferably not only the teacher. Communication and negotiation between the learners provoke meaning making and shaping of concepts in their minds. Student-active learning in science should provoke various forms of communication. It asks for multi-directional forms of communication. Pedagogies like the 1-2-4-All method can help students to organize meaning making by negotiation and cumulative communication [15]; methods like the ball bearing can help to train communication and operate reciprocal teaching [16].

3 TEMPUS-SALiS – The Organisational Framework

All the above discussed theories promise to make science education more motivating, more effective in subject matter learning and to raise its potential for the promotion of a broad range of cognitive and non-cognitive skills. Unfortunately, classroom practice in many countries of the world still seems to be dominated by a teacher-centered teaching paradigm with low student-activity in minds and hands. That is why within the cooperation of the Ilia State University in Tbilisi, Georgia, and the University of Bremen, Germany, the project initiative 'SALiS - Student Active Learning in Science' was launched in 2009. Together with further 10 partners from Bulgaria, Germany, Georgia, Ireland, Israel, and Moldova, an application for a reform network was submitted to the TEMPUS program of the European Union. The project was successfully approved in summer 2010 and was conducted from 2010 to 2012. The budget was approx. 800.000 €.

SALiS aimed at promoting science teaching through a better inclusion of student-active and inquiry-based experimental learning in science classes. The project intended to promote i.e. inquiry-type lab-work as one of the foundations of modern science curricula and pedagogies to raise motivation, support development of higher order cognitive skills, a better learning of science concepts, and to promote a broad range of general educational skills.

Recognizing that the teachers are the core for any innovation in educational settings, the project aimed at innovating science teaching in the above mentioned sense by improving teacher training. For the purpose described, all participating institutions jointly developed curricula and materials for science teacher training. These curricula and materials enabled pre- and in-service science teachers to strengthen hands- and minds-on student learning through innovative approaches to lab-work instruction, e.g. inquiry-type strategies, open lab tasks, or cooperative learning in the lab environment. Additionally, respective infrastructure was installed in the participating universities from Georgia, Moldova and Israel. In the two years of SALiS several outcomes were reached:

- The SALiS consortium jointly developed teacher training modules, school teaching materials, and a concept of implementation of SALiS via the use of low-cost lab equipment.
- We collected and disseminated good practices from all partner countries and made them available to the other partners by translation and adoption.
- A lab guide for low-cost- and microscale-experimentation in science education was developed and translated in seven languages. A database of more than 150 experiments in different languages for low-cost- and microscale-experimentation was made available via the SALiS website (www.salislab.org).
- SALiS strengthened the science education infrastructure in the six beneficiary institutions through equipping science teacher training laboratories including guides that describe the usage of such laboratories in teacher training including questions of safety, logistics and maintenance issues.
- The project created the foundation for upgrading science education in many schools in the beneficiary countries by the training of science teachers. Qualification of staff for in- and pre-service teacher training concerning the SALiS philosophy took place, experiences were shared during visits and placements between the partner institutions. Through a thorough implementation of the SALiS training modules and the staff training in all partner institutions the dissemination became broad and sustainable.
- Although the essential components and facilities of SALiS are available in all the EU partner institutions, the whole process also led to an improvement in the teaching skills and available training modules in the EU partner institutions.

Further information can be obtained via the SALiS website: www.salislab.org.

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