The “GeneLab”- a gene and biotechnology outreach laboratory

Summary:

The “GeneLab” is an outreach lab for biotechnology and gene technology within the Centre for Math and Science Education (Z-MNU) under the direction of the Biology Education Department at the University of Bayreuth. As “learning environment laboratory” for secondary school students, pre-service teacher education, and in-service teachers’ professional development, it offers experimental modules in the context of gene and biotechnology.

Aims:

Student modules:
Students should gain specific knowledge regarding key questions of molecular biology and basic techniques herein. They should carry out authentic experiments on their own, unavailable at school due to resource as well as time limitations. Additionally, the modules should further other areas of genetic education and combine genetic education with an ethical reflection.
Pre-service teacher education:
Pre-service teachers should develop pedagogical content knowledge (PCK; Shulman, 1986) regarding teaching microbiology, molecular biology, biotechnology, and gene technology. First, as one part of PCK, they should be able to prepare and to carry out experiments within these issues which they should implement later on as future teacher at school. Second, with regard to the student modules, they should exemplary reflect on their PCK of a specific issue which they develop by combining student modules with their teacher education. Additionally, pre-service teachers should also increase their content knowledge as well as parts of pedagogical knowledge.
In-service teachers’ professional development (PD):
In-service teachers should achieve a higher level of PD by participating both on the student courses, and, especially, on specific lab days with regard to hands-on teaching biotechnology issues at school.

Main activities:

Students: day-long experimental modules; pre-service teachers: (a) term-long experimental courses, (b) outreach teacher education module; in-service teachers: day-long experimental courses.

Narrative:

The “GeneLab” is an outreach lab for biotechnology and gene technology within the Centre for Math and Science Education (Z-MNU) under the direction of the Biology Education Department at the University of Bayreuth. The target groups are secondary school students, pre-service teachers (i.e., university students for biology education, in combination with chemistry or English language education), and biology and chemistry in-service teachers as well as teachers of other subjects like ethics.
Secondary school student courses:
Together with their teachers, classes attend a day-long experimental module in the GeneLab (offered during the term brakes). The students increase their knowledge about key issues in molecular biology and gene technology and apply the basic techniques herein. Since 2003 already 4409 students, accompanied by 174 teachers, have attended the programs. In parallel, science education research has provided a consistent evaluation regarding instructional efficiency. Results have been published in international peer-reviewed journals (e.g., Scharfenberg & Bogner, 2010). We offer student modules including authentic experiments. For instance, the module Genetic Fingerprinting (11th grade) includes: the isolation of students’ deoxyribonucleic acid from oral mucosa cells; the polymerase chain reaction with a selected human mini-satellite sequence; and agarose gel electrophoresis of the isolated and amplified DNA probes. Additionally, students discuss and value the pre-implantation diagnostics (PID) and its ethic-moral consequences. Within biology education, gene technology is a necessary subject in the current syllabuses for Bavarian secondary schools. All modules conform to these syllabuses.
Pre-service teacher education:
In 2003, the GeneLab started a lab course for biology pre-service teachers regarding experiments which the university students may include in their later science education at school. The future teachers prepare and carry out experiments in microbiology, molecular biology, biotechnology, and gene technology (in total, up to now, 90 university students). Additionally, in the student lab round 2006, the GeneLab started the newly developed teacher education module Learning and Teaching in an Outreach Lab which is combined with the student module Genetic Fingerprinting. The pre-service teacher module consists of six elements. First, the university students complete a half-day seminar about the specific content of the student module as well as about its biology educationally relevant aspects. Second, guided by the university lecturer, they build up the equipment to all work areas for the eight student groups (maximum of 32 students). Third, they participate on three subsequent lab days together with the student groups from the participating schools. During these days they undergo a three-fold change starting from (a) the role of a school student (i.e., they participate in parallel to seven school student groups as eight group at this day and carry out all experiments); (b) on the second experimental day, they tutor two student work groups (tutor role) according to the assignment-assistance model of tutoring (Kersaint et al., 2011); (c) on the third experimental day, they change to the teacher role (i.e., they teach one hands-on phase to the students, in the other ones: tutoring). A final reflection seminar wraps up the module. Accompanying explorative research has shown some effects on pre-service teachers’ PCK.

Shulman, L., 1986: Those who understand: Knowledge growth in teaching. Educational Researcher, 15 (2), 4-14.
BME (2011).Education in Bavaria. www.km. bayern.de/education-in-bavaria.html .

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Methods of learning/trainin:
Pre-service teachers: evidence-based PCK development; in-service teachers: evidence-based PD development.

End user:
Pre-service and in-service teachers for biology education at two different stratification levels: the Gymnasium as a “university-preparatory secondary school” (highest level; up to the 12th grade); and the Realschule as a “professionally oriented secondary school”, where students may receive the “intermediate secondary school-leaving certificate” (intermediate level, up to the 10th grade; Bavarian Ministry of Education [BME], 2011, p. 1).

Involved actors:
Science education researchers with biology and chemistry teaching experiences for years at school.

Location:
Outreach laboratory at the University of Bayreuth.

Languages available:
German

Evaluation parameters:
Student modules: Since the program started, science education research in parallel has evaluated the modules regarding instructional efficiency of scientific learning. Results have been published in international peer-reviewed journals (e.g., Scharfenberg & Bogner, 2010).
Pre-service teacher education: (a) summative evaluation by the Faculty of Biology, Chemistry, and Geosciences; (b) explorative evaluation since the outreach teacher education module started.
In-service teacher PD: summative evaluation by the Ministerialbeauftragter in Oberfranken on behalf of the BME.

Klautke, S: A category-based video-analysis of students' activities in an out-of-school hands-on gene technology lesson., International Journal of Science Education, 30(4), 451-467 (2008)

Klautke, S: Learning in a gene technology lab with educational focus: Results of a teaching unit with authentic experiments., Biochemistry and Molecular Biology Education, 35(1), 28-39 (2007)

Klautke, S: The suitability of external control-groups for empirical control purposes: a autionary story in science education research., Electronic Journal of Science Education, 11(1), 22-36 (2006)

Scharfenberg, F-J; Bogner, FX: A new two-step approach for hands-on teaching of gene technology: Effects on students' activities during experimentation in an outreach gene technology lab., Research in Science Education, 41(4), 505-523 (2011)

Scharfenberg, F-J, & Bogner, F.X (2010): Instructional efficiency of changing cognitive load in an out-of-school laboratory. International Journal of Science Education, 32(6), 829-844.

Scharfenberg, F-J: Experimenteller Biologieunterricht zu Aspekten der Gentechnik im Lernort Labor: empirische Untersuchung zu Akzeptanz, Wissenserwerb und Interesse (am Beispiel des Demonstrationslabors Bio-Gentechnik der Universität Bayreuth mit Schülern aus dem Biologie-Leistungskurs des Gymnasiums), (2005)

Duration:
Student modules: day-long; pre-service teacher modules: (a) term-long experimental courses, (b) outreach teacher education module: six days; in-service teachers: day-long.

Optimum number of participants:
Pre-service teachers: twelve; in-service teachers: twenty.
Additional information or resources:
www.bayceer.uni-bayreuth.de/didaktik-bio/de/forschung/proj/detail.php?id_obj=23987;

Teachers’ Competencies

1	subject matter/content knowledge	x
2	nature of science	x
3	Multidisciplinary	x
4	knowledge of contemporary science	x
5	variety of (especially student-centred) instructional strategies	x
6	lifelong learning	x
7	self-reflection	x
8	teaching/ learning processes within the domain	x
9	using laboratories, experiments, projects	x
10	common sense knowledge and learning difficulties	x
11	use of ICTs	x
12	knowledge, planning and use of curricular materials	x
13	Information and Communication Technologies with Technological Pedagogical Content Knowledge	x

Mapping best practices with main principles

1. Building interest in natural science phenomena and explanations:

Evaluation research (Scharfenberg, 2005) has shown that the lab day furthers the students' emotional component of interest (Krapp et al., 1992 ; i.e., measured as affective rating of acceptance) which is based primarily on the hands-on activities. However, the lab day did not further the epistemic component of interest.

Scharfenberg, F.-J. (2005): Dissertation, University of Bayreuth (Online published: http://opus.ub.uni-bayreuth.de/volltexte/2005/176.
Krapp, A., Hidi, S. & Renninger, K. A. (1992): Interest, Learning and Development. In: Renninger, K. A., Hidi, S. & Krapp, A. (Hrsg.): The Role of Interest in Learning and Development (3-26). Hillsdale, NJ, Hove, London: Lawrence Erlbaum Associates Publishers.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Nature of science: Within the module Genetic Fingerprinting, students and pre-service teachers are confronted with key concepts describing the nature of science, for instance, the concept tentativeness : Parts of DNA which ten years ago has been assigned as junk DNA are now coupled with regulatory functions. In this case, a conserved regulatory element within an intron is associated with the brown/blue eye color in humans (Eiberg et al., 2008).

Science in society: Within the module Genetic Fingerprinting, students and pre-service teachers discuss the role of science in society. In this case, they discuss and value the pre-implantation diagnostics (PID) and its ethic-moral consequences. PID is of particular relevance in Germany due to the current changes in the law.

Bell, R. (2009): National Geographic, online: www.ngsp.com/Portals/0/downloads/SCL22-0449A_AM_Bell.pdf, available 9th Nov. 2011.
Eiberg, H., et al. (2008): Human Genetics, 123 (2), 177-187.
Deutscher Bundestag (2011): www.bundestag.de/dokumente/textarchiv/2011/35036974_kw27_de_pid/index.html.

4. Understanding students' concepts and learning style about of science phenomena:

Pre-service teachers have different chances to understand students' concepts with regard to the subject being taught and to get information about students' learning style: (1) In the first module component, the half-day seminar about the specific content of the student module as well as about its biology educationally relevant aspects, pre-service teachers discuss the results of the conceptual change research with regard to gene technology (e.g., Franke & Bogner, 2011). (2) In the role of the tutor (second and third day participating the student module), pre-service teachers are confronted both with the current concepts their tutees (two work groups, i.e., eight students) hold and with different learning styles of the work group members.

Franke, G., & Bogner, F.X. (2011): The Journal of Educational Research, 104 (1), 1-14.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

The experiments conducted do not always reach the results expected by the teachers. One of the most important learning tools in this course is the 'error' if treated in an adequate way. The error is addressed and analyzed by tutors and participants not only so that teachers can reflect on what did not work, but also in order to develop awareness of science as a continuing process.

Bell, R. (2009): National Geographic, online: www.ngsp.com/Portals/0/downloads/SCL22-0449A_AM_Bell.pdf.
Skoglund, P., & Jakobsson, M. (2011): PNAS, online first: www.pnas.org/content/early/2011/10/24/1108181108.full.pdf.
Scharfenberg, F.-J., & Bogner, F.X. (2011): Research in Science Education , online first: www.springerlink.com/content/t33034537x3u315j/fulltext.pdf.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitating of results:

The students' experiments are embedded in a framework of minds-on-hands-on units, consisting of a theoretical minds-on phase (during which the teacher introduces the theoretical background of each experiment) as well as an associated experimental hands-on phase. Before they begin, the teacher introduces the students to the work area during an initial pre-lab phase. At the end comes a final interpretation phase and discussion of the actual results. All experiments are authentic, representing the 'ordinary day-to-day actions of the community of the practitioners'. The pre-service teachers have the chance to develop their PCK by working with new student groups on the three subsequent days. The tutor role provides the chance to counter against the self-experienced difficulties during the hands-on phases. Finally, the teacher role allows to include the own experiences from the two days before into a own instructional strategy. Moreover, university students also increase other elements of PCK in their first seminar (e.g. knowledge about the current syllabuses). Independently, they also increase their content knowledge as well as parts of pedagogical knowledge (e.g., regarding cooperative learning).

Hodson D. (1998). Teaching and Learning Science. Towards a Personalized Approach. Philadelphia, Open University Press.
Chinn, C., & Malhotra, B. (2002). Science Education, 86, 175-218

8. Doing science: experimenting, analyzing, interpreting, redefining explanations:

Both the students and the pre-service teachers take part on their specific module in order to do science, including experimenting, analyzing, interpreting, and redefining explanations. The students attend an experimental lab day. The pre-service teachers do science both in the role of the school student (1st lab day) and in the role of the tutor (2nd and 3rd lab day of their module; for details, see above 3rd paragraph of the section content).

9. Assessment: formative ~ of students' learning and the summative ~ of their progress:

Since the programs have been started we evaluate both the student and the pre-service teacher modules. Student modules: In total, we have published eight papers in peer-reviewed journals and two doctorate theses up to now (2005 to 2011). Pre-service teacher modules: In parallel to implementing the module into teacher education, we started an explorative evaluation. First results have shown effects on pre-service teachers' PCK. For instance, pre-service teachers differently assessed students' learning difficulties before and after the teacher education module.

10. Cooperation among teachers and with experts:

The GeneLab courses for in-service teachers' PD bring together teachers from different schools in the area around Bayreuth. Due to complexity of some new experimental approaches, cooperation between the teachers may arise. Independently, they come in contact with science education researchers at UBT, and, content-dependently, with UBT experts in different fields of biology and/or chemistry research.