APACER: A SIX-STEP MODEL FOR THE INTRODUCTION OF COMPUTER-SUPPORTED LABORATORY EXERCISES IN BIOLOGY TEACHING

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Abstract

This article describes a six-step approach used for the introduction of computer-supported laboratory exercises in Biology teaching. Following the model students will be guided from recognizing a problem question to the end report in a series of active tasks. The model was named APACER as an acronym of the six steps: Ask, Predict, Act, Comment, Evaluate and Report. The model was tested with 15–18-year-old secondary school students as group and individual work over a time span of ten years and several hundred students performing laboratory exercises in Biology. Work on development of the model can be described as reflective classroom practice. By observation of students' work, grading of their reports and evaluation of results from exams, it was recognized that students achieved much higher grades because of better knowledge and improved reports. Transfer of the model to other Science subjects is suggested.
Key words: *biology, computer-supported laboratory, ICT, laboratory exercises, secondary school students.*

Introduction

The exponential growth in knowledge and the emergence of cutting-edge technologies brings citizens to a situation where knowledge needs to be not only broadened but even replaced in shorter cycles. In the European Union, education for lifelong learning is recognized as a shift in emphasis from content towards competences (Illeris, 2008) as “a combination of knowledge, skills and attitudes appropriate to the context” (Recommendation of the European Parliament and of the Council, of 18 December 2006, on key competences for lifelong learning [Official Journal L 394 of 30.12.2006]). For an experienced teacher this can only mean that teaching for lifelong learning cannot follow the same old route; such change however is easier to suggest than to put into everyday practice. Everyone who wants to make substantial changes in school practice should be aware that educators nowadays live in an educational landscape where, besides the tested traditional and new strategies of teaching, the paths are littered with the ruins of temples to various educational theories and with ranting prophets of instant education (Šorgo et al., 2011). Because curricula are probably at their upper limits in terms of the time students can spend in school, the problem to be solved is how to use available time effectively. There is no universal method or strategy for magically transforming all contemporary teaching in the direction of competences and higher achievement in all domains of the educational arena; yet there

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is a strong evidence that raising the quality of learning can be achieved only by methods where students are fully engaged (Michael, 2006; DiCarlo, 2009). In Science teaching, and Biology as a part of it, hands-on activities are recognized as one avenue towards better teaching and learning. The importance of such work is even greater because, through laboratory work, students can in addition to acquiring knowledge; also develop skills, an understanding of the nature of science and an increased interest in science (Johnstone and Shuaili, 2001).

In recent decades Information and Communication technologies (ICT) have greatly influenced school-work in the processes of teaching and learning, access and creation of information, communication and school administration. It is possible to broadly divide classroom-teaching applications into two groups. In the first group are applications common to all subjects, like exploring the internet, building communities or using multimedia. In the second group are applications that can be used primarily in one subject or in a group of related subjects. In Science subjects such applications include usage of ICT in the school science laboratory in the form of virtual or real laboratory. Many benefits have been reported in usage of computers equipped with data acquisition systems as instruments for collecting, storing, analysis and presentation of data (Šorgo and Kocijančič, 2006; Šorgo et al. 2008).

If a teacher accepts the engagement of students as an opportunity for better education, (s)he must facilitate transition from expository (cook-book) labs towards inquiry- and problem-based labs (Domin, 1999, Lagowsky, 2005). Computerized laboratory is no exception; otherwise, cook-book labs would merely be transformed into computerized cook-book labs with no additional value in comparison to the classical approach. Moreover such exercises can be regarded as a backward step because all that is left to a student is to sink a sensor into something and insert graphs into a prepared report (Šorgo, 2010).

For the teacher, the transition to problem-based and inquiry-based labs is by no means easy (Šorgo, 2010, Šorgo et al., 2011). The obstacles are many, starting from overloaded syllabi, where the most convenient way to cover all of the content is direct instruction; unfamiliarity with new equipment or lack of funds to buy such equipment; textbooks written as encyclopedias and lacking appropriate model exercises; external exams favoring the lowest levels of knowledge, and a strategy of "If it works do not fix it", as some of the examples. In addition to these reported obstacles, the most probable "hidden" reason why cook-book labs are preferred among teachers and students is that such labs almost always guarantee success. Students and teachers know that following the tested recipe leads to predictable results in a comfortable way.

The purpose of this study was twofold. The first aim was to seek meaningful integration of ICT into biology teaching, and the second was to offer students knowledge at the higher cognitive levels. After years spent searching for an appropriate model for successful introduction of inquiry- and problem- computer-based labs, the six-step model (in the Slovenian language VNIROP) was developed. The model is based on the concept of cyclical models (Neill, 2004) and is closest in concept to the 5E model (Balci et al., 2006). The difference between those models and this particular model is that this one designed to promote is not only the cognitive dimension of laboratory work but practical skills as well, which makes it more suitable for developing competences as a complex construct. The model was tested in practice on countless occasions over the decade of the author's work as secondary school teacher (e.g., Šorgo and Kocijančič, 2004, 2006, Šorgo et al., 2009) and lately in work with university students.

Methodology of Research

Equipment

The data acquisition system CMCS-3, developed in the ComLab-SciTech pilot project, supported by the European Commission's Leonardo da Vinci programme (http://e-prolab.com) and equipped with sensors produced by Vernier was used in the initial phase of development of the computer supported laboratory. Original software was written to support this interface. Later Vernier's LabPro system was introduced. Standard laboratory equipment and glassware from the school's science laboratory was used. Teaching was performed by the author. The school biology laboratory is equipped with one teacher's set and four student sets of the e-ProLab data acquisition system (DAQ) (Murovec and Kocijancic, 2004) and software (http://www.e-prolab.com; accessed February 9, 2010), four Vernier LabPro systems and a number of Vernier sensors (http://www.vernier.com; accessed: February 9, 2010).

Research Sample

Computerized laboratory activities as group work were performed at the upper secondary school "Prva gimnazija Maribor" (First Grammar School of Maribor, Slovenia) with students aged 15–17, as part of their regular classes. Individual labs were performed by students in their last year of schooling during their preparation course for the Matura examinations. In the time span between 1999 and 2008, over 50 different computer-supported laboratory exercises from different fields of Biology were tested. Several hundred students were involved in such work.

The APACER Model

The name of the proposed model (Figure 1) is an acronym derived from the first letters of the six steps. The step by step model was established because it facilitated task control, which can result in teacher intervention when necessary. All steps can be performed at school, as homework or as a combination of each.

Ask → **P**redict → **A**ct → **C**omment → **E**valuate → **R**eport

Figure 1. Six steps of the APACER model.

Data Analysis

Evaluation of student work is based on observation of the students during their work, on correction and grading of student reports, and on written and oral exams. Evaluation of the teacher's work can be described as reflective practice (Wang et. al, 2010). Owing to the lack of appropriate teaching materials in the Slovenian language, exercises were adapted from external sources or developed by the authors and later introduced to classrooms. Some of the exercises became permanent over the years, and some were abandoned because of unsuitability. On some occasions, short questionnaires were given to the students after experimental work (Šorgo and Kocijančič, 2004, Šorgo and Kocijančič 2006, Šorgo et al., 2008). Parallel to the development of these exercises, we developed a didactics to accompany computer-supported laboratory. By nature, this research approach is closest to reflective practice and action research, where the researcher is a part of the process and the intention is to improve the initial state.

Results of Research

Step one: Ask

Asking questions and giving answers is common practice in schools and has been reported as beneficial, especially in inquiry- and problem-based settings (Chin and Osborne, 2008, 2010, Zion and Sadeh, 2010). In existing laboratory manuals, questions are mostly posted at the end of the text to be solved after completion of the exercise. Throughout these manuals, tasks are given as commands (calculate, prepare, scale, measure, etc) and not as questions. If questions at the beginning of the text are present, they mostly function to help students to understand the process and procedure, and not to aid in recognition and formulation of a problem.

Asking questions was found to be the hardest step in the proposed model. The reasons were many, but the most important was that if someone wants to ask about something, such a person needs at least some initial knowledge about the topic. In finding meaningful research questions, students need considerable support from the teacher; otherwise it is unrealistic to expect students to find solutions by themselves alone (Pekmez, et. al. 2005). Everyday practice shows that school experiments are mostly set up to be bullet proof against failure, which means that there is almost nothing left resembling discovery (Got and Duggan 1995).

Because of pressure from the existing curriculum that prepares students for the Matura examination as a prerequisite for entering university studies, it was impossible to introduce student-driven open inquiry more than once in regular class time. Such work was done by students in the form of short projects on an individual basis in their final year at general secondary school, during their elective Biology course. In regular classes a problem situation was prepared by the teacher, and students had to create research questions within given framework. The information given to the students was very sparse.

Example 1*: People breathe because they need to exchange gasses between their body and the environment.*
Task*: Inhale and exhale several times and ask research questions about breathing.*

Example 2*: Those animals, popularly known as warm blooded, which produce heat through a metabolic process, have to control heat exchange between their body and their environment, in order to prevent both losing heat and overheating of their body.*
Task*: Ask questions about the mechanisms that control heat exchange.*

Group work with three or four students was found to be most suitable for producing quality questions. After a couple of minutes, one student from each group had to report the questions to the other groups. In a debate the most suitable questions were chosen. The role of the teacher was to facilitate debate among students and sometimes to suggest unforeseen problems and not to provide answers.

Step 2: Plan

The options for planning laboratory work can be categorized as open, semi-open, and closed.

In open-planning students are completely free to plan how to perform an experiment and what they need for it. The good news is that students can be imaginative and creative, but the bad news is that, because of equipment unavailability or high costs, and often in the case of Biology ethical concerns, such experiments cannot be performed in a school.

In computer-supported laboratory, the planning can be regarded as semi-open. In initial lessons students were trained to use data loggers and some of the sensors. In the semi-open system they were given a list of sensors and other laboratory equipment available in the school laboratory and were allowed to choose what they needed. The third option is designated as closed because students are given a list of available equipment from which they have to assemble the experiment. One innovation was the field in the form, where they have to predict, test and control. This field was added after years of correction of reports where control was regularly missing. The most important part of this phase from perspective is prediction of hypothetical results (Šorgo and Kocijančič, 2004) because students have to decide on axes, units, ranges, etc.

Before starting the next step, students must fill in the form. The form was used to help students in organizing their work and teachers in identifying mistakes or weak points in the planning.

Name, Surname, class:					
Title of the experiment:					
Goals and objectives:					
Theoretical background: Sources/Literature:					
Hypothesis or research question;					
Material:					
Plan:					
Test:			Control:		
Expected results:					
The task was:	Very hard	Hard	Something in the middle	Easy	Very easy
Explain your choice					

Table 1:. Form used in planning experiments.

In the case of individual work, students had to e-mail the forms to the professor, and the corrected forms were later discussed. In the case of group work with younger students, they had to prepare the theoretical background as homework and prepare the plan in groups. Plans were shared with other groups to allow the flow of ideas between groups. In such a way many alternative concepts were identified, for example that heat flows from the human body and that cold flows inside the body.

Step 3: Act

In this phase each group or individual has to carry out the experiment according to their plan. This part was performed as with every other regular school experiment in a school laboratory under supervision of a teacher and teaching assistant. Most often one or two lesson hours were needed to perform an experiment. Results such as graphs and tables were saved to be included in their reports.

Figure 2. Measurement of temperature in the lab Importance of Insulation for Organisms. Experiment was designed by a student.

Step 4: Comment

Students have to compare their results with their predictions (Figure 3). In some cases differences were astonishingly high, showing misconceptions. It was not enough just to comment on results in descriptive form, but they were required to address why the differences occured. Commenting on results was the second most difficult task in the model, after the posing of questions.

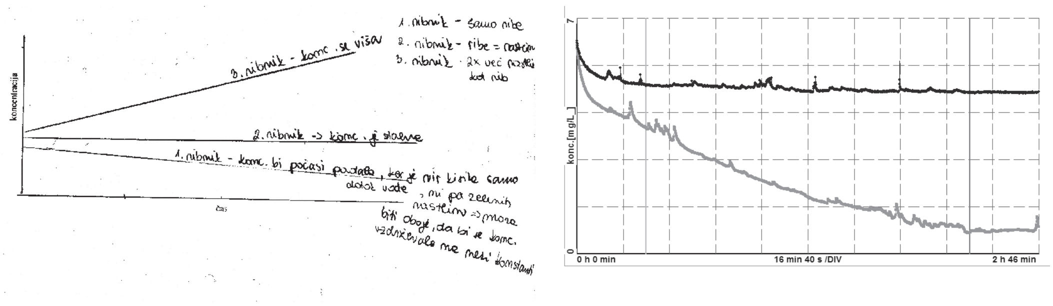

Figure 3. A difference between predicted results and measurements of oxygen concentration in aquaria.

Step 5: Evaluation

Students often combined the evaluation stage with the discussion and limited their comments in practice to variants of the statement: “We succeeded in geting results. The problem was that we needed more time.” Our initial intention was to separate evaluation of their work from commentary on the results (discussion). The weight of evaluation falls more on self-reflection than on the results.

Step 6: Report

Students have to prepare a written report, and whenever possible, defend their findings in an oral presentation. To structure their reports, an electronic form was prepared. The aim of such a form was not to regiment their work but to provide an impetus to recall the most important parts of a report. They were allowed to change the form to best fit their work.

Name, Surname, class:		Date:		Grade:	
Title of the experiment:					
Goals and objectives:					
Theoretical background: Sources/Literature:					
Hypothesis or research question;					
Material:					
Plan:					
Test:			Control:		
Results:					
Comments (Discussion) on experiment:					
Evaluation of the experiment					
The task was:	Very hard	Hard	Something in the middle	Easy	Very easy
Explain your choice					
Message to the teacher:					

Table 2. Form used in reporting experiments.

Discussion

The proposed model was used by the author in teaching practice on several occasions. Formal evaluation based on pre-test post-test settings with a test and a control group was never performed; this was because, with the use of the model, achievement was much higher even at first glance. The quality of reports was much higher and, last but not the least important, the benefit was the active role played by students in all elements of laboratory work, from planning to the end report. These observed improvements are in line with findings from reviews of active teaching strategies (Roth, 1994; Michael, 2006; DiCarlo, 2009) and use of learning cycles (Balci et al., 2006; Abdulwahed and Nagy, 2009). Structured inquiry and problem-based teaching using computer-supported exercises outperformed traditional expository laboratory exercises, a result which can be confirmed also in the research findings of others (Chin and Chia, 2006; van der Valk and de Jong, 2009; Sadeh and Zion, 2009). Last but not least, one important reason for introducing such laboratory exercises is the certainty that students like working with a computerized laboratory (Špernjak et al., 2010).

The most important problem we encountered was not in the achievement of higher level knowledge but in the overloaded curriculum, where a massive amount of content must be covered. The proposed model should be tested by the Science teacher community for approval or rejection. If the APACER model survives such a test it would be possible to transfer the findings to other teaching domains and to the traditional laboratory as well.

Conclusions

Based on our experience the proposed APACER model was found suitable for used in the Science laboratory. Structured inquiry and problem-based teaching strategies should be favored over traditional expository laboratory exercises.

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