Improvement of Science and Technology Literacy by means of ICT-Based Collaborative Action Research Including Hands-on Experiments

Josef Trna, Eva Trnova & Petr Novak

Masaryk University, Faculty of Education, Porici 7, 60300 Brno, Czech Republic trna@ped.muni.cz

Abstract. Science and technology literacy improvement is a necessity for the development of society. Innovations of teaching/learning methods should contribute to bridging the science and society gap. Research findings, based on video-study, describe the roles of experiments in science education and show that experiments used by teachers are not always appropriate for the development of students' knowledge and skills. Action research is an *important event-based method for the upgrading* of teachers' professional competencies and students' motivation. ICT-based collaborative action research uses a web-environment and international collaboration between teachers and students. Innovations of action research lead to an emphasis on hands-on experiments.

Keywords. Action research, Collaboration, Hands-on experiments, ICT, Science education.

1. Introduction

Science and technology literacy improvement is a necessity for the development of society. Science education plays an important role in educational systems and has the goal of enhancing scientific literacy in students [1]. provides Scientific literacy support for citizenship in a democratic society [4]. Science education has the potential for enabling students interrelate science with economical. to technological and environmental aspects.

Innovations of teaching/learning methods should contribute to bridging the science and society gap. Students' learning through school science is expected to be the core focus in defining and developing teaching strategies in the context of a constructivist approach to science education. During the lifetime of a teacher's professional teaching duties many new science discoveries appear and innovative educational technologies emerge. However science teachers tend to create their own individual pedagogical content knowledge [6] with little influence by poor quality in-service training. High quality in-service science teacher training for practising science teachers is very important in reducing the gap between scientific and educational research and the development of curricular materials and evidence-based teaching methods for school practice [2].

We try to improve in-service science teacher training by the application of innovations in action research. ICT-based collaborative action research, such as our modification, uses a webenvironment and international collaboration between teachers and students.

2. Video studies of the role of experiments in science education

Video study as a research method was applied to the study of experiments in school science education (physics) in lower secondary schools. The basis of the video-study method is an analysis of video recordings of lessons. The Centre for Pedagogical Research in the Faculty of Education, Masaryk University, deals with the video-study method in the project "Physics Video-study"[5]. This method was transferred from universities in Germany (Kiel) and Switzerland (Zürich, Bern). The video-study method used consists of several phases:

(i) Making video recordings with the assistance of classic camcorders located in the class-room.

(ii) Software processing of recorded data by use of Videograph (a multimedia player of computerised video recording).

(iii) Record transcription, which means word-forword transcription of an audio record into text.

(iv) Video recording coding is systematic registration and classification of phenomena stored on the video recording. For this process, it is always essential to adopt and/or create a relevant categorical system first.

(v) Evaluation of acquired data in a chosen statistics program (Statistica).

We analysed physics video-lessons recorded by the Centre for Pedagogical Research in lower secondary schools (the 7th and 8th grade) [5]. The coding of experimentation phases was

Josef Trna, Eva Trnova & Petr Novak (2010). Improvement of Science and Technology Literacy by means of ICT-Based Collaborative Action Research Including Hands-on Experiments M. Kalogiannakis, D. Stavrou & P. Michaelidis (Eds.) *Proceedings of the 7th International Conference on Hands-on Science*. 25-31 July 2010, Rethymno-Crete, pp. 131 – 137 http://www.clab.edc.uoc.gr/HSci2010 completed according to the categorical systems. The process of coding was accomplished on 62 video-recordings of physics lessons, the topics "Composition of forces"(27 lessons; 8 teachers) and "Electric circuit"(35 lessons; 11 teachers) were concerned; all were filmed in 2004-05.

Two important research results are presented: (a) Roles of experiments in science education Research findings based on video-study describe phases of the use of experiments and show that experiments used by teachers are not always appropriate for improvement of students' knowledge and skills [7] (see Fig. 1):



Figure 1. Representation of experimentation phases in physics lessons

The category "experiment is not in progress" is the most frequent one (77%) in the analysed lessons. If we compare the results of all phases, there are unsatisfactory results: the total time spent on experimentation is insufficient and the proportion of the phases is unreasonable.

(b) Frequency of simple experiments in science education

Our next research using video-study was aimed at the identification of simple experiments in physics education. The categorical system for the identification of simple experiments was created:

Table 1. Categorical system for coding – simple experiment

Characteristics:	
1 - Simple experiment(a) - transparency (clear description of the phenomenon) (b) - no additional phenomena) (c) - easy realisation (no) a
intricate equipment)	
2 - Non-simple One or more of (a), (b), (c)	
experiment characteristics are missing	

The outcomes of this video-study research are presented in Fig. 2 and Fig. 3:



Figure 2. Electric circuit: Frequency of simple and non-simple experiments



Figure 3. Composition of forces: Frequency of simple and non-simple experiments

The diagrams in Fig. 2 and Fig. 3 indicate that the category "simple experiment" is the most frequent one (79% and 86%) in coded physics lessons. It is interesting to find out that the simple experiments are the most used experiments in physics education. It is also a stimulating fact that the frequency of simple experiments depends on the topic.

The common results of both video-studies give us two crucial issues: (a) experiments used by teachers in science education are not always appropriate for the improvement of students' knowledge and skills and (b) simple experiments play an important role in science education.

3. ICT-based collaborative action research

Action research is known by many other including participatory names, research. collaborative inquiry, emancipator research, action learning, and contextual action research. but all have the same basis. This method is "inevitably threatening to the traditional professional cultures of both teachers and academic teacher educators. As a form of mutual professional learning requires it а transformation of both school and academic

cultures" ([3], p.45). Action research is simply "learning by doing": to identify a problem, to do something to resolve it, to see how successful their efforts were, and if not satisfied, to try again. The diagram (Fig. 4) demonstrates this process:



Figure 4. A simplified diagram of action research methodology (Elliot, 1997)

A particular action is conceptualized and applied, structuring routines for confrontation with data. A plan of action based on the information from the data collection and review of current literature, will allow the teacher to make a change and to study that change. It is necessary to determine which action is responsible for the outcome. So, it is crucial to develop a time-line to gather evidence (data) to be collected. Evidence includes such methods and tools as questionnaires/surveys, observations (video or written notes), collaborations (video or audio tapes of meetings, peer coaching) interviews, tests, students' portfolios, etc.

Action is central in the teachers' activity, but reflection should be in the core of their professional development. From the interaction between practice and reflection (see Fig.4) in action research, theory informs practice and practice refines theory in a continuous cycle. The ensuing practical applications that follow are subjected to further analysis, in a transformative cycle that continuously alternates emphasis between theory and practice.

Our innovative idea is to use action research in a web-based environment realised through the international collaboration. Expected positive outcomes are targeted in two developmental directions: in-service science teacher training and students' learning of science.

Our study has its origin in the project "European Teachers Professional Development

for Science Teaching in a Web-based Environment" (Comenius project - 129455-CP-1-2006-1-PT). Project outcomes are a set of curricular materials for science teachers' professional development in a web-based environment.

ICT-based collaborative action research (ICT-BCAR) in science education is defined and described by modified conditions. Action research is mainly used by one teacher in one class, but can be explored in modified conditions for example by two collaborating teachers, working on-line in two classrooms, in two different countries, using English in addition to home languages, and on-line instruction by use of ICT. An important aspect is that participants collaborative action research are coin researchers. The principle of collaborative coresearchers presupposes that each participant's ideas are equally significant as a potential resource for creating interpretive categories for analysis, as negotiated among the participants.

Our research produced results that ICT-BCAR offer meaningful and motivational support for the development of professional competencies of science teachers and for the The "action" process of students' learning. factor of action research (see Fig. 4) was ICT-BCAR in action among teachers and students from Portugal and the Czech Republic. This collaboration was intended to upgrade teaching and learning using motivational methods and the introduction of innovative school simple (handson) experimentation. Students were involved in the process of learning and were encouraged to play a teaching role with respect to their peers. Two selections were necessary:

(1) Selection of topic and objectives: All science topics are not equally suitable for ICT-BCAR. We used the following criteria for the topic selection: the position of the topic in the curriculum of the countries, the importance of the topic for students' cognitive development, and the level of interest for students. Based on these criteria. the topic chosen was "photosynthesis". In the teaching of the topic of photosynthesis it was agreed between the two teachers that the objectives of the collaborative action research were to: motivate the students to learn about photosynthesis; develop knowledge and skills relevant to this topic; improve the interactions among students, between teacher and learners and, finally, instigate interaction between the teachers.

(2) Selection of students: The factors important for the selection of students were age and ability. The students should be approximately the same age, promoting an interest to collaborate, communicating in the English language and skilled in the use of ICT. Students were selected from secondary schools and 15-16 years of age.

Clearly ease of communication strongly influences the collaboration between teachers and students. To communicate internationally, the teachers and also the students used email, ICQ, Skype, and video-conferencing. The teachers prepared a schedule of their own and their students' activities for each of the collaborative lessons. In this way the teachers collaboratively developed (in their own language and in English) worksheets. power-point presentations, videos, experiments, learning tasks, etc. Reflection is a very important part of collaborative action research. In seeking evidence they used tests, questionnaires, observations, interviews, portfolios.

The analysis of inquiry outcomes supported the fact that ICT-BCAR offers meaningful and motivational support for the development of professional competencies of science teachers and for the process of students' learning. As example of the research results we present only those based on the questionnaires [8] (Tab. 2):

Do you believe that the online environment influenced your performance and learning? N =27/21							
Yes		89% / 90 %					
No 11%/ 10 % In the statements listed below are some of the aspects related to the activities shared with your Czech colleagues. Choose the option which best expresses your opinion.							
N=27/21	Disagree	Partially Agree	Agree	Strongly Agree	No opinion		
The partnership helped you to better understand certain aspects on this topic.	7% 0%	33% 29%	42% 47%	14% 19%	4% 5%		
You would have achieved the objectives of this topic better by interacting only with your classroom classmates.	33% 29%	52% 29%	4% 29%	4% 0%	7% 13%		

4. Hands-on activities in ICT-based collaborative action research

Two main barriers in promoting the use of innovative science education technology were

the efficient dissemination identified. of information to teachers and the motivation of teachers to learn and use innovative science educational technology. ICT-BCAR is a start towards alleviating these barriers by improving the familiarity of use of ICT for collaborative work with other teachers and students across the world. Our new core idea is to use action research in a web-based environment realised through the international collaboration of science teachers. Expected positive outcomes are targeted in two developmental directions: inservice science teacher training and students' learning of science.

Our innovations in action research lead to the emphasis on hands-on experiments. There is a methodical link between hands-on activities and action research. Hands-on activities we simplify as "learning by doing". Action research we can also assume as an analogical "education by doing". The main actor of action research is the teacher, who "is doing" the new "action" to discover an innovative method in education.

Hands-on activities can be applied as the changed parameter in action research in science education. The using of ICT provides an additional opportunity good for the dissemination and upgrading of new hands-on activities or unknown variants of these activities amongst teachers. It is proposed that a web-based environment can provide a very effective technology for initiating and substantiating science teachers' collaboration. Our study used the benefits of an ICT environment to change the normal conditions of implementation of handson activities.

We achieved collaboration between Portuguese and Czech students. We divided them into collaborative groups using of ICT technologies. Students implemented hands-on activities in the web-based environment. We created several types of the applications in school science education:

(a) On-line implementation according to peer instructions: Some hands-on activities were implemented by one group of students according to the instructions of the second group through Skype.

(b) On-line joint implementation: Some activities were done by both groups at the same time together and they consulted about their results.

We present examples of these two applications of hands-on activities into ICT-BCAR:

(a) On-line implementation according to peer instructions which was implemented by Czech students according to the instructions of the second group of Portuguese students using Skype. The Portuguese students performed role of teachers. They had to prepare peer instructions, they created and tested a hands-on activity at first and they studied the theory of photosynthesis to be able to explain it. The Portuguese students prepared the below mentioned procedure of the hands on activity.

Pigments in plants

Procedure:

1. Put in a pestle 20 grams of fresh leaves of the plant selected and add a small amount of fine sand.

2. Crush the leaves with the aid of mortar, gradually adding 50 ml of alcohol. Mix. Record the colour of the solution (see Fig. 5).



Figure 5. Scheme of procedure

3. Filter the mixture to a beaker, throwing away solid waste in order to obtain "crude chlorophyll."



Figure 6. Chromatography

4. Place the filtrate of a Petri dish. Introduce a rectangular piece of folded chromatography paper, as shown in Fig.6.

5. Wait 15 minutes and observe.

6. Using pencils make a diagram that describes exactly what is shown on the paper.

Examples of students' discussion on-line using Skype after implementation of the activity:

A Czech student asked: Why did you crush the leaves?

A Portuguese student explained: It is necessary to extract the pigments found in the thylakoid membranes of the chloroplasts.

A Czech student asked: Why is alcohol added?

A Portuguese student explained: Alcohol is used to extract the pigments from the leaves.

According to our findings (observation, questionnaire, pre-test and post-test) both Czech and Portuguese students were motivated very much and they learned more in comparison with usual lessons (see Fig. 7).



Figure 7: Czech students on Skype

(b) The on-line joint implementation had the form of activities which were done by both groups at the same time together and they consulted each other about their results. The Czech and Portuguese students put plants in a dark place on the same day. They implemented the hands-on activity described below. They communicated during their work using Skype, email, they consulted and helped together. All groups took photos for documentation. At the conclusion of the hands-on activity all groups of students presented their results by means of video-conference.

Starch formation and photosynthesis

Procedure:

1. The watered plant is placed somewhere dark, e.g. a cupboard, for 3 days.

2. After removing the plant from the cupboard, cover some leaves with dark paper or aluminium foil and hold it in place with paper clips. Cover some leaves with dark paper and aluminium foil with a shaped hole in the centre. Envelopes must be placed over both sides of the leaves, and the

edges of the hole must be fastened so that light only reaches the exposed part of the leaf.

3. Expose the potted plants to sunlight for a day.

4. Cut 3 leaves: one which was completely covered by aluminium foil or dark paper, one which was covered with aluminium foil or dark paper with a hole, one which was uncovered.

5. Place each leaf in the boiling water for 1-2 minutes or until soft and limp.

6. Prepare a water bath and put it inside a beaker with alcohol and heat it gently until boiling. Introduce the leaves one by one in alcohol until they become whitish in colour, and then immerse them in cold water.

7. Put a little iodine water in three glass (Petri) dish. Spread out the leaf. Wait a few minutes for colour to develop.



Figure 8. Scheme of procedure

Based on our findings (observation, questionnaire, pre-test and post-test) this method of explanation was very effective and motivational for students and teachers as well.

5. Conclusions and implications

We have presented an innovative method for how to improve science and technology education by ICT-BCAR in a web-environment and by use of international collaboration between teachers and students. Our research supports the notion that ICT-BCAR is important for upgrading science teaching and learning.

The main advantages of ICT-BCAR for science and technology education are [8]:

1. Strong motivation of students and teachers especially by communication with colleagues in other countries, new information, applications of knowledge from abroad, personal contacts etc.

2. Exchange of experiences between teachers (teaching methods) by comparing curricular material (textbooks, learning tasks, experimentation etc.).

3. Inserting of new educational methods based on research by teachers' application of action research monitored by educational experts.

4. Acquisition of subject knowledge and skills.

5. Team collaboration among teachers inside the partner schools (support with ICT, English, organisation of lessons etc.).

6. Team collaboration among students within the partner schools (support with ICT, organisation of lessons etc.).

Action research in a web-based environment and hands-on experiments can be a very effective technology for science teachers' and students' collaboration leading to improvement in science and technology education. Such innovations of teaching/learning methods should contribute to bridging the science and society gap.

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