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THE USE OF INQUIRY BASED EDUCATION IN A SIMULATION SOFTWARE ENVIRONMENT IN PRE-SERVICE ICT TEACHER TRAINING

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Abstract

The article deals with the possibilities of using inquiry based education methods as part of pre-service ICT teacher education. The question is how this teaching method can be used within a specialised subject focused on teaching technical principles, in this case concerning the functionality of various computer networks and their components. The first task was to find appropriate software for such a method of teaching. Software simulating a computer network was chosen and modified curricula was used so that students could obtain crucial competencies for understanding networks by independently exploring them for themselves: how a prepared network operates, finding connections and formulating a written conclusion. The goal was to direct students to actively experiment with the assigned networks and research answers to the assigned questions. However, instead of simply being given outright answers, students were advised how to proceed in order to find solutions for themselves. Another aim was to familiarize future teachers with this method in the role of pupil. The data for the research was acquired from participant observation and the evaluation of the lessons via questionnaires and a group discussion on the benefits and drawbacks of this approach in the lessons in comparison with similar subjects taught traditionally. It was found that successful students started to ask questions which they were interested in and to go on inquiring to answer them. Although the students realized the benefits of the teaching approach, many of them were not prepared enough to work with this method (particularly due to the lack of knowledge of basic theoretical concepts).

Keywords

inquiry based education (IBE), ICT teachers' education, computer networks, simulation software.

Inquiry based education in information technology teacher training

Inquiry based education (IBE) is an activating teaching method where students' knowledge is developed by a system of asking questions and solving problems (Papáček, 2010). As stated by Edelson et al. (1999), this method is based on authentic activities that motivate students, providing a perspective for associating new and current knowledge and the chance to make use of newly-acquired knowledge. The student studies the real world, makes his own observations and proposes possible explanations for the investigated problem (Bell et al., 2010). The role of the teacher also differs as he becomes an informed guide for problem solving and leads the student in a similar way to during research itself (Papáček, 2010).

In inquiry-based education, students should proceed as they would so in real research (Papáček, 2010). According to Bell et al. (2010), the basic phases of inquiry include determining the problem and posing questions, generating hypotheses, planning experiment design and implementation, analysing and interpreting acquired data, creating resulting models, drawing conclusions and evaluating research. If trainee teachers are to learn how to use the IBE method in practice, it is essential for them to experience it as an undergraduate student.

In compliance with constructivist teaching theories, the authors prefer an approach where the student is active, solves problems, gains experience and is led to creating cognitive models of the observed events. As presented by Hajduković Jandrić et al. (2011), the creatively active approach of a student in lessons is a prerequisite for success. Apart from this, there is a need for simulation tools, which enable a method of observation where hypotheses are verified by setting limit and untypical situations. These are capable of generating in-depth problems and if students are able to solve them, they will have reached the higher levels of Bloom's taxonomy - being able to analyse a situation, create and independently argue in favour or against a hypothesis.

Approaches included in inquiry based education can be categorised according to what part of the inquiry process the teacher takes over for the pupils or students. Eastwell (2009) differentiates four types of inquiry: confirmation, structured, directed and open.

According to Stuchlíková (2010), confirmation inquiry is where pupils or students are provided with questions and procedure and results are known. The pupil's task is to confirm these results. Structured inquiry is where the teacher gives questions and possible procedure and students are to formulate an explanation based on their implementation of the procedure (Stuchlíková, 2010). Directed inquiry is where the teacher provides a research question and students create a methodological procedure and carry it out (Stuchlíková, 2010). Open inquiry is where students pose themselves a research question, think up a procedure for it, carry it out and formulate an explanation (Stuchlíková, 2010).

The application of IBE in the teaching of practical informatics

As one of the natural and technical sciences, informatics provides possibilities to use this method to teach new concepts, understand the principles of the field and to create outlines and relationships between key concepts. Computer Networks is one of the subjects taught in practical informatics lessons. It involves students acquiring a broad theoretical knowledge whilst putting an emphasis on practical skills. However, students often rate this subject as dull and lacking educational effect (Sun et al., 2013). Yet the study of network protocols is fundamental to the understanding of network behaviour and characteristics (Breslau et al., 2000). For those reasons, it is suitable for lessons to include activities where appropriate simulation tools enable the study of the behaviour of individual network protocols in various conditions as defined by the user (Bote-Lorenzo et al., 2012). Discovering how hubs and switches work or how a broadcast packet behaves in various network devices are examples of such activities.

The environment for implementation of IBE in Computer Networks

The requirement for practical experience of this issue leads to the creation of an educational environment which can be divided according to its authenticity.

A hardware laboratory containing real hardware devices meets the requirement of offering students a highly realistic experience (Marsa-Maestre et al., 2013). There are, however, drawbacks to this approach - limited possibilities for experimenting (the laboratory does not allow absurd settings that would prove the unattainable), the need for the physical presence of students (Momeni, Kharrazi, 2012) and the high cost of equipping such a laboratory (Marsa-Maestre et al., 2013).

Virtualized networks are made up of a number of virtual computers, running on one physical computer, which are connected to a computer network with the required configuration (Marsa-Maestre et al., 2013). Thanks to virtualization, there is no need to worry about the mother computer being damaged by an unsuitable setting (Sun et al., 2013). Yet again, the teaching of networking concepts does not seem to be ideal here, as the solution requires no inquiry into the principles of how the network works.

Simulation software is a special application which allows students to create and configure a network without the need of physical network devices (Makasiranondh et al., 2010). This is less costly and cuts out the need for a laboratory technician (Makasiranondh et al., 2010; Sun et al., 2013), but it does not enable students to gain manual skills such as cabling and physical connectivity (Makasiranondh et al., 2010). However, Al-Holou et al. (2000) claim that this software could be used to improve a student's understanding as it enables the simulation of limit situations which impose risks in real-life situations but lead to an improved understanding of concepts.

The simulation environment for the implementation of IBE in Computer Networks

There is a wide range of simulation software on offer but a lot of it is designed for research purposes, being unsuitable for teaching due to its extensiveness and difficulty to control. Students require user-friendly tools which help them create appropriate cognitive models (Makasiranondh et al., 2010).

For the needs of the innovation in education project, it was necessary to find educational simulation software allowing various topologies of computer networks to be created, configured and to have their functionality tested. Cisco Packet Tracer met those requirements, offering significant priorities for experimental teaching within a subject. It actually allows the created network to be tested by sending messages from one device to another whilst offering the possibility of real time testing or step-by-step testing. Step-by-step testing allows messages to be passed through the network to be atomized and information about operations with the message to be displayed in detail. These can be used to verify hypotheses concerning the running of a network and the causes of non-function and hence to learn the principles of how network elements and protocols work.

For the teaching of Computer Networks in the Cisco Packet Tracer environment, official educational activities accessible as part of the CCNA Discovery Home Small Business Networking (Cisco, 2013) were analysed. These activities have been drafted in the form of training sessions. Students are gradually assigned step-by-step tasks leading to the creation and running of a simulated network and conclude with the application being verified to check whether they have proceeded correctly. An example of one of the activities is illustrated in Fig. 1.

Step 1: Set up the network topology

a. Add two PCs and a Cisco 2950T switch.

b. Using straight-through cables, connect PC0 to Fa0/1 on Switch0 and PC1 to Fa0/2.

c. Configure PC0 using the config tab in the PC0 configuration window:
1. IP address: 192.168.10.10
2. Subnet Mask 255.255.255.0

d. Configure PC1 using the config tab in the PC1 configuration window:
1. IP address: 192.168.10.11
2. Subnet Mask 255.255.255.0

Step 2: Test connectivity from PC0 to PC1.

a. Use the ping command to test connectivity
1. Click on PC0.
2. Choose the Desktop Tab.
3. Choose Command Prompt.
4. Type: ping 192.168.10.11 and hit enter.

Fig. 1: Activity in Packet Tracer from the CCNA course (Cisco, 2006)

These activities are unsuitable for use with the IBE method, as they do not give students the chance to independently discover the functionality of a network and actively build on their knowledge. At the same time, the Packet Tracer environment allows activities like searching for the cause of an existing simulation network system error, searching for limits of functional reliability of a given network configuration or the mental transition from one class of elements to another, and so on.

Project to teach the principles of computer networks with inclusion of IBE

One of the questions that arose whilst educating pre-service ICT teachers in the principles of computer networks was how to actively involve students in the study of this abstract issue. The project went ahead as part of the pre-service preparation of ICT teachers and pedagogical ICT professionals studying first degree courses at the Faculty of Education of the University of South Bohemia in autumn 2013. The project was attended by 10 trainee teachers and another 4 students of the non-teacher information technology field. Eight two-hour lessons were taught. Most activities were based on IBE in the Cisco Packet Tracer environment. Apart from that, students could attend lectures where simulation software was not used.

Teaching approach

During lessons, the teacher made particular efforts to avoid tasks requiring students to set up and configure a new network by following certain directions. As a rule, the simulation environment was used to prepare a network with a given configuration and students were first required to explore the activity of such a network. While working through the tasks, students were to create hypotheses which they could test in the simulation environment. As stated by Wong et al. (2007), students require very brief knowledge to commence such experiments and all required knowledge can be acquired gradually.

The following types of inquiry activities were implemented during the project:

- discovering the functionality of network elements
- discovering the functionality of a network protocol
- revealing network errors

Discovering the functionality of a network

In a prepared functional network, students were required to discover the functionality of a particular element and answer the question “How does it work?” One example is a local network of star topology with a central hub as the active network element. Students were to define the functionality of this hub after having observed packet movement within the network. After adding more devices to the network, students could be challenged with further questions, for example “What are the risks posed by the creation of a local network using hubs as active devices?” Students sought the answer by experimenting with a simulated network (an example of the problem of frame collision is illustrated in Fig. 2).

In the second part of the task, hubs were replaced by switches and after having virtually manipulated the network, students were to answer questions set by the teacher, such as “How does the switch differ from the hub?” or “What other features must a switch have as opposed to a hub in order for it to meet these requirements?”

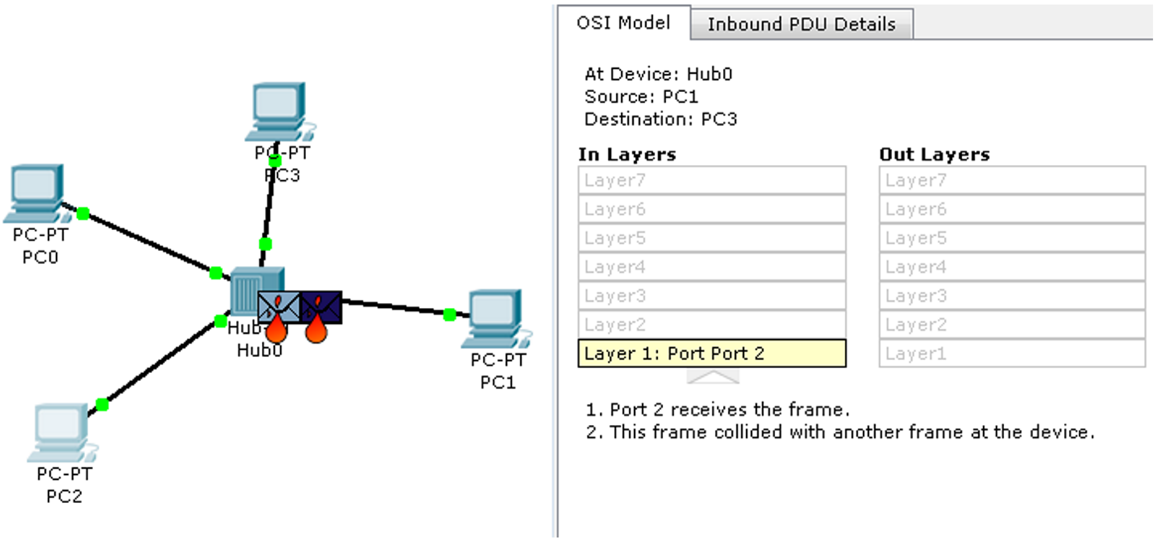

Fig. 2: Collision of frames when using a hub

Discovering the functionality of a network protocol

Students tackled the question: "What is the principle of the activity?", e.g. discovering the principle of assigning IP addresses from a DHCP server. By experimenting in the prepared network, students were to find out what kind of communication was going on between a client requesting an IP address to be assigned and a DHCP server and write a description of the model of communication. After having suitably adapted the network, the original task can be enhanced by explaining how DHCP addresses are assigned in an environment with two equivalent DHCP servers.

Revealing network errors

Another task was to reveal errors that had been deliberately included in an otherwise functional network and seek the answer to the question: "Why does it not work?" Students tested a partly functional network in order to reveal the network error. Where possible, they were to fix it. These tasks were especially used for encouragement at the start of a new topic.

One example could be an activity where a network is made up of two subnets separated by a router. Communication in each subnet runs smoothly. However, by experimenting, students find out that packets do not "pass through the router". Students were to find the answer via controlled manipulation with the particular network. In Fig. 3, there is a window explaining the reason for the error. However, students can only progress to this window by experimenting.

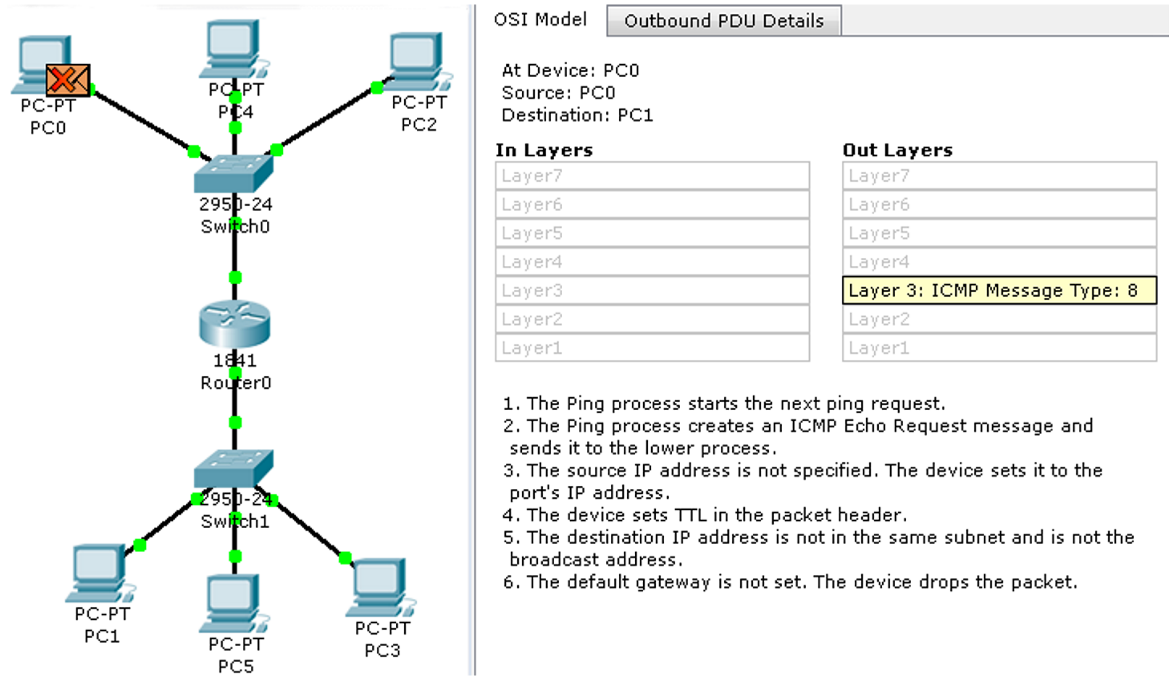

Fig. 3: Dropping of a packet due to the default gateway not being set

The role of the teacher and student

As opposed to chalk and board lessons, the roles of students and the teacher changed in IBE lessons. Here, the teacher did not impart wisdom but simply managed the course of the lesson and, where necessary, provided individual support regarding the procedure students had chosen to solve a problem. Students became active problem-solvers despite not being guided by an exact set of instructions.

Before commencing each task, the teacher set questions which students were to answer and, where necessary, suggested the procedure needed to solve the task. According to whether he revealed the possible procedure needed to solve the task or not, the teacher used either structured or directed inquiry based education. He gave advice on how to proceed or partial results to students who showed an interest or who were not able to proceed further on their own. In such situations, the teacher used leading questions to try to help students overcome any complicated passages they might have run into while problem-solving.

In compliance with the assigned task, the student himself determined the way he would work with the simulated network unless the procedure for a given task had been proposed by the teacher. According to this procedure, he manipulated the network, generated hypotheses and searched for answers to the set questions on his own. To do that, he first needed to get a good impression of how the scrutinized parts of the network work and consequently formulate written conclusions in a clearly understandable way. Students could continuously consult classmates or the teacher throughout the task.

Students who had completed the set task usually discussed their findings and conclusions with the teacher. The teacher played the role of presenter and, where necessary, summarised and generalized conclusions if students hadn’t come to them on their own. The teacher expanded by asking questions which students reacted to from their experience gained during previous manipulation.

Findings from lesson observation

On the basis of participant observation (Kawulich, 2005) it can be said that students actively experimented with the network, completed set tasks and searched for answers to the posed questions. However, it became apparent that they were not entirely prepared for such a teaching method. Unexpectedly, they often did not consider how to proceed in their work but rather found answers by trial and error. If their efforts were slow to bring results, they sought help from their neighbours in the classroom. The presence of several students with previous experience of an issue from their past studies, e.g. from high school lessons, turned out to be useful as they helped classmates who could not manage.

It was observed that the new method of work encouraged successful students to go on inquiring. Those usually added other elements to the network and investigated their functionality in the new configuration. Other students continued to investigate the given issue outside the scope of the assignment, for example by adapting the network to include one switch and one hub and observe how the two devices interact with each other. These observation results were confirmed in the following year 2014, when the project was repeated with 16 students.

Students' evaluation of the lessons

These lessons contributed to students' understanding of the principles of computer networks. Observations found that students had been actively involved and had not tried to avoid problems. They had been independent and their understanding of the issue had improved. In order to verify this information against students' opinions, all participating students were asked to fill in a questionnaire and selected students were invited to a group discussion at the end of the course. The questionnaire consisted of open questions focusing on the benefits and drawbacks of the lessons. Students could also submit ideas and opinions on how to improve lessons. The questionnaire was voluntary and anonymous.

The majority of students found lessons beneficial and attractive. Some remarked: "The lessons themselves were interesting. There wasn't much time to be bored". They appreciated the possibility to learn from one's own experience and without the need to physically assemble a network. One of the students stated: "For me, the highlight of PT lessons was the possibility to experiment with networks with almost no risk of irretrievably ruining something if it were for real". Students commenting on the employed teaching method said that it encourages a more independent manner of work and thinking, quoting "Lessons encourage independent thinking, which is good".

There were also requests for more complicated problems (for example advanced routing) or to make the whole course more practical, not only working in the simulation environment. Another remark expressed displeasure over the teacher's scholarly discussions with more advanced students who had been experimenting, which the other students did not understand.

Four weaker students were later invited to a group discussion aimed at analysing the drawbacks of lessons. What emerged from the discussion was that the students had been prevented from working effectively in the simulation environment by their lack of knowledge of theoretical concepts. Although these had been covered in lectures, the addressed students had not attended them regularly.

The addressed students also admitted that they had often lacked sufficient knowledge of technical English to work adequately in the simulation environment. Their efforts to solve this problem by using an Internet translator were not particularly successful either. They denied feeling that they had learnt to work as technicians searching for a network error. In their opinion, more time would have been needed for that and they also felt they lacked the required theoretical knowledge.

The discussion corresponded to the questionnaire. Students considered lessons to have been more useful than chalk and board teaching on the whole. Those who took part in the discussion stated that, thanks to the style of teaching used, they could remember the mediated information better than when facts are simply presented. Students themselves had not observed that this teaching method trains metacognitive competences and the ability to work by way of inquiry. In their evaluation, they focused on the fact that they had gained knowledge of an issue in a particular subject.

The use of a simulation environment for computer networks lessons (regardless of the teaching method used) was found suitable. There was a clear environment and information was provided to explain why a sent message had not been delivered. As teachers, they projected the possible use of this solution into their future lessons, bearing in mind its low cost.

Conclusions

The effect of using IBE as a teaching innovation to achieve goals in a standard practical informatics topic was verified. The aim of innovated computer networks lessons using IBE in a group of pre-service ICT teachers was achieved. Their understanding of the principles of computer networks had improved through active "research" activity. The students themselves evaluated lessons as useful and attractive, despite not achieving the required competence of professional computer network administrator. There needs to be an analysis of whether the absence of previous experience of IBE learning and hence lack of knowledge of the inquiry-based approach is not a significant factor in achieving educational aims or whether shortcomings not related to the method used are the prevalent cause, i.e. unfamiliarity with the principles of this science discipline, poor English, etc. It has become apparent that IBE methods can also be applied in informatics, a science that is not always regarded as natural.

One of the significant results of the project is that trainee teachers who had never experienced this teaching method as a pupil were able to actively try it out here. The positive feedback brings hope that trainee teachers will adopt this method as their own.

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