Methods for Teaching Programming Using Virtual Laboratory

Galya Shivacheva¹, Veselina Nedeva¹

(1) Trakia University – Stara Zagora, Faculty of Technics and Technologies – Yambol, 38, Graf Ignatiev, BG-8600, BULGARIA
E-mail: shivacheva_g[at]abv.bg

Abstract
Contemporary methods and forms are analyzed in the paper. Teaching forms and methods implemented in Faculty of Technics and Technologies – Yambol are introduced and compared in the Virtual Laboratory environment: explanatory-illustrative method; programmed method; heuristic method; problem solved method; model made method (V.A. Oganessian classification). The matrix of traditional and contemporary methods and forms is introduced. There is guidance for using a virtual laboratory in programming for a more comprehensive and effective implementation of the methods in the reviewed classification.

Keywords: Virtual laboratory, teaching methods, teaching forms,

1 Introduction
Teaching programming is a key part in learning informatics and includes abstract concepts and operators of program language, algorithms and data structures. Different training methods, implemented using various forms, can be used in order to gather theoretical knowledge in this area, acquire practical skills, needed for creating code and develop algorithmic thinking. The widespread use of modern information technologies by students in their daily lives requires a search for new forms of teaching methods and education that are familiar to the new generation.

The aim of this report is to present a comparative analysis of the use of virtual laboratories and traditional forms of education, such as lectures, practical exercises, coursework and independent extracurricular work, and give guidance for their use in order to achieve better learning outcomes in programming.

Babateen (Babateen, 2011) summarizes some of the characteristics of virtual laboratories (VL), which can be viewed as advantages for their use in education. The characteristics that are valid for, and should be taken into account, for teaching programming using virtual laboratories (VL) are the following: Creating a new intellectual model in education that better than the existing and more beautiful that the imagined one; Constant gathering of knowledge and mastering the study material; Encouraging and guiding the students; Registration of student data and automatic evaluation; Possibility for constant update.

As an addition to these advantages of VLs, the following ones can also be added, which are provided in different articles and have been summarized by the following author (Shivacheva, 2016). We will list only those that relate to teaching programming: VLs are suitable for explanation of concepts (fundamental concepts and ideas); There are no restrictions such as time and place; They are economically viable; Once implemented they can be used repeatedly and by unlimited number of people; A simulation can be run as many times as necessary until the student understands and accepts the concept or algorithm, presented by it, when using a programming VL; The use of VLs allows for independent work at a pace that is typical for the student, without the need to comply with others; Enables the visualization, animation and simulation of abstract concepts that students perceive with difficulty, if provide and described only in a text (or
It helps for the easier understanding of some algorithms that can be followed step by step; it provides the means and methods for the step-by-step visual representation of the algorithm execution, and not just as rows of numbers and text, but also visually, with the help of geometric shapes (e.g., rectangles of varying heights proportional to the value of the number they figure), which enhances the visibility and reduces the abstraction of the algorithm. To fulfill its purpose, VLTP should include a theoretical part, a source code, and animations, simulations, and visualizations associated with the respective academic unit. In addition, it should include synchronous and asynchronous communication between the teacher and other students, and should also include the possibility for testing the gathered knowledge, and should also contain information about the learning level achieved using the VL.

For the purpose of our study, we took into account two classifications of teaching methods. The first classification we discuss is according to the mode of transmitting information from teacher to student. The methods are: verbal, visual and practical (Zhuzzhhalov, 2004).

According to V. Zhuzzhhalov while teaching programming to students, the lecturer can use both verbal (lecture presentations) and practical methods (implementing mandatory laboratories, workshops, problem-solving tasks). The practical work done (both real (hands-on) and mental tasks) is prevalent for the students, and a particular role is saved for independent thought processes, allowing for the implementation of selection of data and decision tasks (Zhuzzhhalov, 2004).

Verbal methods for teaching programming can be used both in the materials for e-learning, as well as the theoretical part of each interactive teaching units of the VLTP modules. The practical methods are implemented in the execution of simulations that use a student given data input when using VLTP. According to us, the lecturers can also use visual methods - flowcharts for describing and visualization of algorithms. During the lectures and the practical exercises some of the algorithms can be presented using short animations that visualize an analogical example in real life - such as the algorithm for changing the values of two variables as compared to the analogically equivalent changing of contents of two glasses using a third empty glass (i.e., the third auxiliary variable). In VLTP there is a distinct part of the learning resources that is used for visualization, animation and simulation of concepts, operators of program languages, algorithms and data structures, which are suitable for a presentation in this type of learning platform. This is done in order to lower the level of abstractness of information and to increase the level of visibility of information, to allow the easier perception of such concepts.

According to the classification of Oganessian (Oganessian, W.A. et al., 1980), methods of teaching are:
Explanatory-illustrative or Reproductive method (EIMd) is basically remembering the already thought material and its reproduction.

The method of programmed training (MdPgT) stems from the fact that the actions of the student are clear about what one should do and the sequence of actions following, i.e. they are programmed and planned in advance. After performing the first of these planned actions, the student goes onto the second part, then after its completion steps onto the third part and so on until producing the intended results.

If by using this method of programmed learning only the interim results are visible, but the method for achieving them is not clear, then one should use the Heuristic method of teaching (HMDT). This method of reaching the intended results is repeated at each intermediate level using a heuristic search.

When the intermediate results and the path for their achievement is known, it may lead to a conflict between the results that are important for solving the task and the outcomes that are needed. If this is the case, then this is called as problematic situation, i.e. the demand already has a complicated character and is called the Method of problem training (MdPrT).

In all these cases the student knows what the final results are. They can be reached using additional independent extracurricular assignments, special types of decision-making tasks and others. According to the level of understanding of a given task the student receives the results and compares them with the ones stipulated by him. If he has not reached the final results, he has to once again go through all the steps. This method is called Method of model made training (MdMT). Under certain conditions this method can be combined with the heuristic method.

3 Discussion and Results

The programming education at FTT - Yambol begins with mastering the basics of programming by studying C++ programming language, and algorithms and data structures. For better understanding of the new abstract concepts they are presented with both pseudo code and a C++ source code. At the next stage of learning, the students are introduced to the basics of object-oriented programming using Java, and after that with Internet programming using Java as well.

The created virtual lab for teaching in programming will cover only the basics of programming, and algorithms and data structures. Therefore, the matrix of the methods and forms of programming education in use at FTT - Yambol covers only these subjects in the education process. The specific character of the education here arises also from the goals that we have set for the education of engineering students, and this is also reflected in the scenarios included in VLTP and the characteristics of the VL as a learning tool. The matrix was developed taking into account the methods as given by Oganessian, but based on an analysis of the forms and methods that are in use at FTT - Yambol and the designed VLTP.
Teaching programming includes both mastering theoretical knowledge and gaining practical skills needed for describing algorithms and data structures using a specific programming language, and creating programming code.

The theoretical knowledge is related to basic concepts in the field of programming. Most of these concepts are abstract and understanding them is related to overcoming certain difficulties in perceiving them, and the need for understanding and comprehending them by the students. The practical skills for describing algorithms require the development of a new kind of thinking – algorithmic thinking. This kind of thinking allows for the description of the sequence of actions that will be implemented by a computer and therefore this sequence has to be extremely precise, clear and formal.

The reproductive or explanatory-illustrative method (EIMd) is achieved using the following forms of education: lectures, practical exercises and the VLTP.

The traditional form of teaching theory is the lecture. It may consist of a verbal presentation and writing on a board, or using some form of presentation. In FTT - Yambol the lecturer uses a computer-generated presentation for the material, while also using with additional explanations, sometimes associated with writing on a board or creating graphic images - for example, the term “variable” may be presented as a box with a label (name of the variable), and content (the value of a variable); some algorithms can be illustrated with the help of everyday life examples; or by using with specific values of the variables for testing of an algorithm which we have previously we verbally described; or by using a flowchart diagram.

The traditional form for the development of practical skills for description of algorithms and data structures through a specific programming language are the practical exercises. They are carried out in computer labs and the students input, compile and execute (test) different source code in the relevant programming environment. The practical exercises held at FTT - Yambol all contain the following steps:

- A brief reminder of the theoretical material from the lecture
- Assigning a specific task based on the current and previously thought theory
- Understanding the task and reaching an algorithm for its solution (in this step the Heuristic method of teaching is fulfilled)
- Discussion of the algorithms that provided by the students (if any) or of an algorithm, which is proposed by the lecturer
- Implementation of any of the selected algorithms
- Entering of the programming code in the programming language environment
- Compiling and testing of the source code with control examples (in this step the heuristic method is used in determining the appropriate input data for tracking all the typical cases and analysis of the baseline data)
- Discussion of the code operator after operator for the purpose of its perception by the students who have failed to implement it by themselves.

These steps are not always enough for contemplating and understanding of the respective algorithm that is implemented by the EP. Adding operators to exit the program and printing out of the intermediate results of each step of the algorithm can improve the understanding of the process. Another way is by using presentations, in which the lecture, given by teacher, is provided in the presentation, i.e. more of the human perception systems (organs) are involved in the understanding the subject. The presentation can also use images of objects or processes from the real world in order to illustrate the appropriate algorithm or data structure.

For example, for the easier perception of the program realization of the algorithm for adding a new element in the dynamic structure queue we can depict on the board how to change the structure for each operator.

First, we make a schematic representation of the queue, for example with three elements.
Then we begin to illustrate the code consistently operator after operator.

```c
pq*p=new(pq);
```

```c
p->i=x;
```

```c
p->next=NULL;
```

```c
if(top==NULL)top=p; else bottom->next=p;
```

```c
bottom=p;
```
The virtual laboratory, is a non-traditional form of teaching programming, related to theoretical knowledge and practical skills. The explanatory-illustrative method is implemented through training modules when using the VLTP. The theoretical part includes verbal description and relevant illustrations of examples of life, which are analogical to the concept, operator or data structure. And using through educational materials provide further clarification to the simulation, to which they are related.

In the lectures we apply the method of programmed learning the following way -the students are given the opportunity to test for themselves an algorithm with a specific input data or to write a program code and test it in the relevant programming environment. In the practical exercises the lecturers use a multimedia projector to present a programming code, that, using joint efforts (through discussion between the lecturer and the students) is modified according to the terms of the new task and then it is tested in the relevant programming environment. Another traditional form related to the expansion of theoretical knowledge and improvement of the practical skills is the independent extracurricular work. The student can read and analyze the materials found in the corresponding e-learning course, or can use other sources of information, and solve problems to test the gained knowledge.

The method of programmed learning is achieve du sing different modules, arranged in two levels in the VLTP, which present interactive teaching units.

The heuristic method of teaching is implemented in the practical exercises in which the students have to modify the code, presented in the presentation. Another traditional form related to the improvement of the practical skills is the coursework. To solve it, the student uses the theoretical knowledge acquired from the lectures and the practical skills gained from the exercises solved.

The students have to get to the idea which algorithms are suitable for solving the task by themselves and they have to select the operators which are to be implemented in the relevant source code. The analysis of available materials and solving the exercise problems that are part of independent extracurricular work also apply the heuristic method of teaching. This is achieved by selecting input data to perform simulations in order to cover various typical cases for the algorithm in question and also analysis of the results of its implementation using the VLTP.

The problematic method is applied in a lecture to justify the need for the introduction of interchangeable operator or another data structure. The lecturer provides the problem to be solved and ways for solving it, using the up-to-date knowledge, are sought. For example - the need to structure an array can be reached by giving a task that requires double-scan series of numbers and therefore cannot be achieved with a simple variable. The necessity to save the values of the elements in the series arises it this is done by using an array. The coursework is a problem for which the student himself must find a solution using the knowledge and skills acquired, during the lectures, laboratories, and from materials like the e-learning platform and other sources. The independent extracurricular work is similar to the coursework in the way the gathered knowledge gathered is applied to solve problems. The problematic method in the VLTP is used in predicting the intermediate and output results from the simulation of an algorithm with a pre-selected input from the student.

The method of model training is implemented in the coursework using a predefined condition and solution of a sample task, which is used as a benchmark. During the independent extracurricular work, the student solves problems that are based on the provided materials on the subject and the knowledge and programming skills acquired up to that point. The method of model training while using the VLTP is achieved by going through all of the education stages in the laboratory - reading theory, case studies, examining algorithm code, data input, performing a simulation, solving a test and obtain a score. If the end result does not satisfy the student, he or she may again repeat some of the stages.
4 Conclusion

The verbal, visual and practical methods are appropriate in teaching programming. The first two methods are suitable for the presentation of the theoretical material. The visual and practical methods are suitable for the gaining practical skills for description of algorithms and data structures using specific program languages.

The methods of education, according to the classification of Oganessian (Explanatory-illustrative or Reproductive method, Method of programmed learning, Heuristic method of teaching, Method of problem training and Method of problem training) can be applied in teaching programming, not only using the traditional forms of education (lectures, practical exercises, coursework, independent extracurricular work), but also the VLTP. The VLTP may be used as an addition to e-learning, or can be used on its own as a form of distance learning.

References


Huda Mohammad Babateen, (2011): The role of Virtual Laboratories in Science Education, 5th International Conference on Distance Learning and Education IPCSIT vol.12 (2011) IACSIT Press, Singapore