Applying a new teaching methodology to university programming language courses

Mikheil Kantaria[1*], Giorgi Basilaia[2], Marine Dgebuadze[3], Girshel Chokhonelidze[4]

[1] Business and Technology University,
82 I. Chavchavadze ave, 0162, Tbilisi, Georgia,
mikheil.kantaria@btu.edu.ge

[2]Business and Technology University,
82 I. Chavchavadze ave, 0162, Tbilisi, Georgia,
giorgi.basilaia@btu.edu.ge

[3]Business and Technology University,
82 I. Chavchavadze ave, 0162, Tbilisi, Georgia,
marine.dgebuadze@btu.edu.ge

[4]Business and Technology University,
82 I. Chavchavadze ave, 0162, Tbilisi, Georgia,
girshel.chokhonelidze@btu.edu.ge

***Corresponding Author**: Mikheil Kantaria, 82 I. Chavchavadze ave, 0162, Tbilisi, Georgia,
mikheil.kantaria@btu.edu.ge

Abstract: The article examines the challenges that are present in the Information Technologies education methodologies. Today's Information Technologies are vastly dynamic and change at an outstandingly fast pace. Consequently, the students wishing to be strong in a highly competitive job market need to update their knowledge constantly, but knowledge like this becomes quickly outdated. This requires developing optimal methodologies of learning for the above-mentioned field.

The article covers the methodology of learning the Python programming language. The methodology was developed by integrating the principals from the Management Theory. This led to establishing a consistent learning algorithm for the students. Except for the algorithm, the methodology describes control points that are enriching its functionality. The learning methodology presented in the article is based on the Management theory where the lecturer (Subject) has a direct influence on the students (Objects) and by monitoring their performance collects feedback in a predetermined environment (University, Python course).

The article further illustrates how the methodology applied improves students' learning curve and performance using the Python course as an example. The lecturer used the methodology on the students of the Python class and monitored their performance throughout the course. The methodology was tested and compared to the classical learning methodology applied for the IT subjects.

The results showed a 10-15% increase in student performance in programming with the Python course. The article argues this methodology is increasing performance and knowledge acquiring rates among students enrolled to learn the Python programming language

Keywords: ***Technological determinism, new literacies, social changes, new technologies, future learning, teaching methodology***

1. INTRODUCTION

The latest technological development cycles are much higher in modern life in comparison to the previous century. In the past a person could have learned one or several disciplines and use it through life but the situation has changed starting from 1914-39 years, where the cycle of generation change matched the technology change cycle.

Starting from this period mankind has encountered a situation where the technological development and frequency of technology changes got higher than the life cycle of a person.
This resulted in the human to learn more disciplines in life as the previous knowledge and skills started to become outdated faster.

As an example, old technologies like Horse-drawn carriage, bicycle or train, could have worked for tens of years without major advancement, but nowadays during the life of one person, many new technologies become available while recent ones become less used or useless (hybrid, electric bikes, cars, trucks, trains, buses, new computer parts, phones, and corresponding operating systems and software). The knowledge and skills gained especially in computer science and technologies are actual for 3-4 years, while the lifecycle of hardware devices and software is also the same period until it becomes outdated.

Let's focus more on computer science/ information technologies and one of its main directions – programming. A person representing this field has to work hard to stay competitive on the employment market as new programming languages, technologies and systems become available at very high speed and the previous technologies are becoming not so actual as before. They are only used as a part of old project/software support and maintenance before they are re-written to a new platform using modern programming languages and methods that are also actual for another 3-4 years only.

A person that is employed in the programming job has a constant problem to act in the optimal way to follow up the technology development while processing a set of very large

information and pick the right data in time and gain modern - up to date knowledge and skills that are currently in demand on the market.

The modern education system is built in the way that a student in this direction is getting stressed as a result of receiving huge information during the learning process, sometimes they do not understand the need of learning different subjects and courses because they think that it will quickly become outdated.

The fast growth of information technologies requires the development and implementation of new teaching methods. This paper aims to discuss a newly created teaching model that will be useful for the teaching/learning of existing or new programming languages.

Course "introduction to programming using python is a basic course where the main tools of python programming language are discussed, where the course called Programming with Python is based on more advance topics, such as object-oriented programing, web parsing, visual interface programming, web frameworks, and web applications.

The above-mentioned arguments lead to the idea to review the existing traditional teaching methods, especially the transfer and presentation of theories and facts to the students, remembering the facts even they represent the practical steps represents the wrong direction as the knowledge gained in this manner does not develop the practical skills and knowledge transfer does not happen. As a result, a student gets new skills, improves memory, trains the concentration, planning, adaptation, situation modeling and creative thinking skills, gains independent working ability.

1. LITERATURE REVIEW

Many scientific articles are representing various methods of teaching programming Python.

For example, the authors Hans Fangohr et al., propose using "feedback" to achieve a better result, but the method is rather laborious for the teacher and contains elements of individual learning, which is problematic for the class (4).

There is the problem of effective programming training in Python is being investigated, at various universities. Quantitative research is being carried out and the quantitative data of the results of teaching different programming languages are being compared, as shown in the article by authors Jayal Ambikesh et al.

This article compares two different approaches to teaching introductory programming by quantifying student grades in a real classroom. Each approach was adopted during one academic year with first-year students. Then a quantitative analysis of students' grades for the first semester of each year was conducted. The results of the analysis suggest that a later approach leads to an in-depth study of introductory programming concepts by students. (Jayal, Ambikesh et al., 2011)

The obtained result also failed to be used in our case since the training of this subject is planned in the first year.

Some authors suggest researching to test different teaching methods. According to A. Ehlert and C.Schulte, (Ehlert., 2009), various pedagogical aspects complicate the analysis of various approaches to teaching programming. (Fangohr, H. & O'Brien et al.,2015) K. Bruce argues that there is a need for additional experimental research to explore different approaches to teaching programming. (Bruce.,2005).

The authors Kui, Xiaoyan & Liu, Weiguo et al. of the article argue that reform is needed in teaching the Python programming language. (Kui, Xiaoyan & Liu, Weiguo et al., 2018)

Training methods and assessment of the exam system is an urgent problem of the current reform of education in higher education. Python language is released against the background of computational ecology, which is concise, understandable, elegant and easy to learn. There are over

a thousand third-party software libraries. The rich resources of the open community also cause new problems, a large amount of information will require a lot of attention. (Kui, Xiaoyan & Liu, Weiguo et al., 2018)

In an article by Kui, Xiaoyan & Liu, Weiguo et al. a method of teaching the Python language based on minimal knowledge sets is proposed; the method can not only help students understand ideas and methods for solving practical problems, but also improve good computational thinking, innovative thinking and programming skills, and only after that can effectively improve the quality of education and promote the development of higher education.

The authors suggest a gradual transfer of knowledge, which in our case again complicated the task.

Based on the studied literature, it became necessary to find an unbiased teaching approach that would meet the needs of the Business and Technology University. That is why it became necessary to develop a teaching algorithm, taking into account the existing standard in teaching methods.

In the fifties of the last century, the professor of Chicago university Benjamin Samuel Bloom has introduced the theory called Bloom's taxonomy for education purposes. This theory is actively used these days in the education process. The research has shown, that 95% of quizzes did not require high or even middle intellectual activities from the students. In other words, the tests were checking only the knowledge of facts or their remembrance. Based on the research Bloom together with the group of experts of different disciplines, have developed the skills classification structure called Taxonomy. The learning aims were connected to the thinking skills, compiled from six levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. (Adams N. E., 2015)

It can be found that the Bloom's taxonomy theory and general control theories have cross points in three main components, where Bloom's theory's knowledge, comprehension, application are associated with the Information, Understanding, and execution.

Currently, the situation is the following:

1. A student can get any desired information from the lecturers, trainers, teachers or the internet. (Knowledge layer).
2. At the same time 10 percent of them have comprehension (layer) of the information.
3. Only 1 percent of the information and comprehension can be applied (application layer) in real practice.

Because of the above reasons, the main attention has to be paid to teach the usage of technologies based on different thinking algorithms and actions that can also be useful for students in other fields, meaning not the course "facts", but the "experience" learning.

The better results can be achieved where the student is given methods and instruments to work with facts and information flow, instead of the method where the student is given a large number of different facts that are hardly interconnected, forcing a person to remember the information and quickly forget it after exams. The student gains knowledge from the different sources, then a lecturer helps a student to understand the information, create a model and realize the knowledge in practice. (Chandio et al., 2017)

To receive high-quality education these steps cannot be ignored. In today's education system mostly the second step of comprehension is neglected and teaching/learning is based on a combination of two: giving information and practice, so the knowledge is used in practice without understanding, not realizing the processes hidden in the back of the knowledge, causing that the

student loses the understanding, of course, main concepts. This causes a situation, where the students becoming non-professionals, who instinctively do the job - without understanding the issue.

In the General control theory, there is a process control general algorithm, that represents a powerful tool to control different processes. It is possible to reassemble this algorithm to the teaching instructions and present it the method to the students in a conceptual way. Based on the new concept a student will be able to learn and use new technologies independently, point out, establish and solve the different tasks.

Bloom's taxonomy is difficult to apply sequentially for evaluation problems in introductory programming courses. Bloom's taxonomy is a valuable tool that can enable analysis and discussion of program evaluation if it can be interpreted sequentially. We will look at the learning algorithm using Bloom classifications and provide a consistent interpretation with specific examples that will enable computer science teachers to use Bloom's taxonomy to evaluate programs. Using Bloom's taxonomy for training planning can significantly improve the quality of knowledge in programming courses. (Thompson, E. et al., 2008)

Besides, teachers need to think about how to increase the effectiveness of informational knowledge.

2. METHODOLOGY

The environment of the new methodology

Based on the analysis of different approaches, discussed above the methodology was applied to the two courses: Introduction to programming using Python and Programming with Python courses at the Information Technologies BSc program, Methods were applied to 12 classes, where each of them consisted of 25 students. The total number of students was 300.

In the theory of general control, questions of optimal control and algorithms are given that allow the manager to control the process with great success in almost any field. The main aspect of the general theory of control is the function of total control, which is a set of step-by-step instructions of the manager for optimal and current process control.

Algorithm of the total control function is the following:

1. Determination of actual problem or trend: what do we deal with? What is popular or mandatory these days? What will be demanded in the nearest future?
2. Forming the stereotype for the problem or trend for the future: If the same problem will be raised in the future, we will already have the experience (maybe the solution as well), so the solution will be driven to the template for the future;
3. Formation of goal vector to the determined problem or trend: what do we need? what do we need to achieve the determined problem/trend? Formation of goals and determination of priorities;
4. Formation of the action concept for the determined goals: How can we reach the desired goals? Thinking of the ways/algorithms of the goal-reaching.
5. Formation of the structure according to the developed concept: who or what will fulfill the goals of concept?
6. Control of the process (in our case the development of a student): The obligatory feedback for successful control of the process and real perception of the situation.
7. Improvement and optimization of existing actions: nothing is static, the plan that was

determined yesterday might not be valid today, so the above-determined algorithm should be constantly improved in time.

This algorithm was used to study a programming course in Python language

3. DISCUSSION OF THE RESEARCH

Several problems were defined before applying the new methodology to the courses:
First – the students were learning using the traditional methodology, so the theoretical part was given first about a topic during the first hour and then they were starting to write a code on the next hour. This was resulting in the realization of code in a kind of automatic flow, where they just typed some commands and data in, causing that this kind of knowledge later could not be applied to other problems. The problem was that they were getting and remembering the information only as a fact, without getting the methodology to use this knowledge.

The second problem was determined on the stage of giving a problem to the students. For example, students were used to that the lecturer would give them the tasks, but in the real-life where there are real programming projects such ready-type given tasks are very rare. Usually the programmers have to define the tasks and later modify them several times during the project execution. Nowadays the traditional teaching does not take into consideration the stages of independent task defilement and strategy planning and proposes the student the ready tasks and projects to write the solving code directly.

The third problem is caused by the two previous: companies on the market are forced to re-train the graduates on their premises on topics that they will encounter in the real-life tasks and projects, as most newcomers do not appear to have the ability and skills to define the problem, create a correct task and solve it in the different real projects. Mainly the graduates would fulfill the third task only: resolve the problems that are already defined.

The final problem is that the programming belongs to the technology field that is being developed and changed very quickly. Student faces the problem of dealing with the huge amount of information. Based on the traditional pedagogic methodology, that uses only 2 steps of information gaining and practice dealing with that amount of data is very hard or impossible, so a student needs the third component – an adequate methodology for dealing with and managing these information streams.

Tasks and aims for solving of the defined problems

1. Deliver the learning algorithm – instruction in step by step to the students
2. The methodological algorithm should be described and the problem should be shown using visual block schemas, accompanied by the visual interpretation and intense discussion, where the student will get the thinking skills. At this stage the student should understand the problem and realize what is he dealing with and start not just execution but do the programming.
3. As soon as the student goes through the first two stages, we have to teach a way to define the aims correctly corresponding to the problems. A vector organization with corresponding priorities has to be done.
4. Lecturer and the student should write the physical realization of the aims by defining the

appropriate instruments, choosing the right ones, comparing and using them for programming.

5. Discussion of the written program running results and corrections in case of need.
6. Giving the tasks to improve the built program if necessary.
7. Increasing the medium grading rate of the students.

Described aims/steps will give the students the stage of comprehension that is not possible in traditional pedagogy.

Realization of the defined tasks and aims based on Python programming courses at the university

The students of the two python courses were introduced to the methodology that was going to use for the teaching. The intense discussion was started to clearly define the problem as much as possible, where the definition of the real problems was the main task. Students had to do the main analytics independently and the lecturer was only correcting the problems and tasks time by time.
The same approach was used with the base python course. The small difference was that the intro course has small tools and fundamental programming instruments, while the base course has a real-world mini-projects realization. (fig. 1)

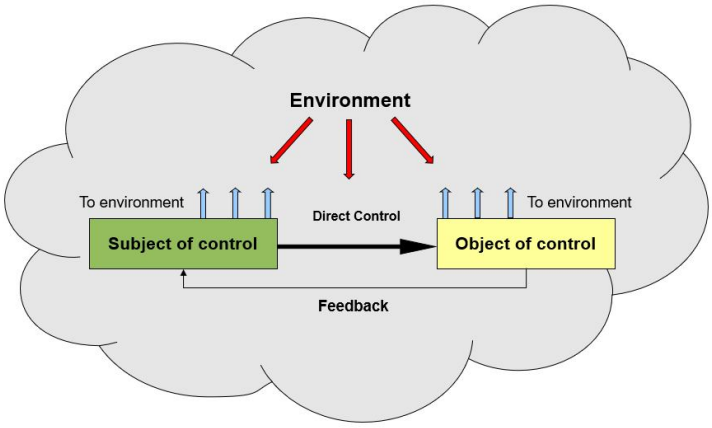

Fig. 1 Classical schema of process controlling

The teaching process was held based on the following classic schema, where the elements of control theory were used.

At the first stage of the use of the schema the lecturer was using the main control function – **control subject** in correspondence to the student that was acting as a **control object**. The lecturer has positively impacted the control object (student) during the lecture hours, in particular the teaching methodology algorithm was applied in practice.

Regardless of how the students (objects) were dealing with the defined aims and tasks, the lecturer was constantly controlling the process using the feedback. The feedback was realized in the way where the lecturer was not only checking the student's progress in the practical realization of the given tasks but the lecturer was checking the action of the students on the dramatically different problems, how the provided action algorithm would be used by the student.

During the teaching process, the additional control mechanism was used – the influence level on the environment from the side of student and lecturer was permanently measured. In this case, the university, companies from the labor market are meant as the environment, because no any process, including the teaching, cannot be discussed without taking into consideration the external factors. For this reason there was constant cooperation with the business sector representatives to

update the course materials and corresponding changes were made in the syllabus at the beginning of each semester based on the received feedback.

During the teaching process, the lecturer has used the following management approaches structured, nonstructured and combined control.

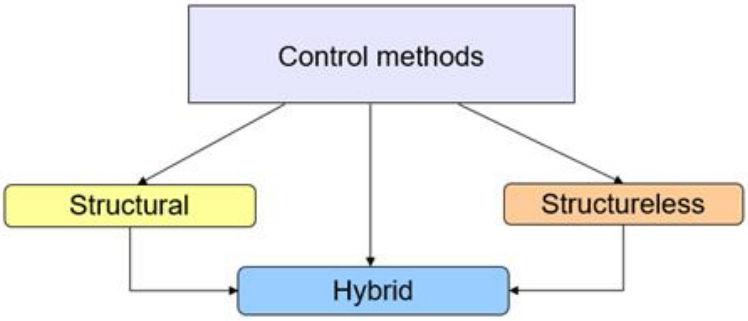

Fig. 2 Different types of control methods

When using the structured control, the lecturer has explained the students the algorithm of how to deal with the large information flow by giving the appropriate tasks, cases and directives. For Unstructured control, the lecturer was playing the role of a learning process controller. Students were independently were processing the received information using the provided algorithm, resulting in the training of comprehension.

As the learning process was continuous and permanent, the activities were done in a combined control method, where the structured directives from the lecturers and nonstructured load of the students were following each other.
The definition of the goals vector was done based on schema presented in task/project control style by the students, where the priority goals were taking the top position and the fewer priority goals were falling on the bottom of the list or table. (fig. 3).

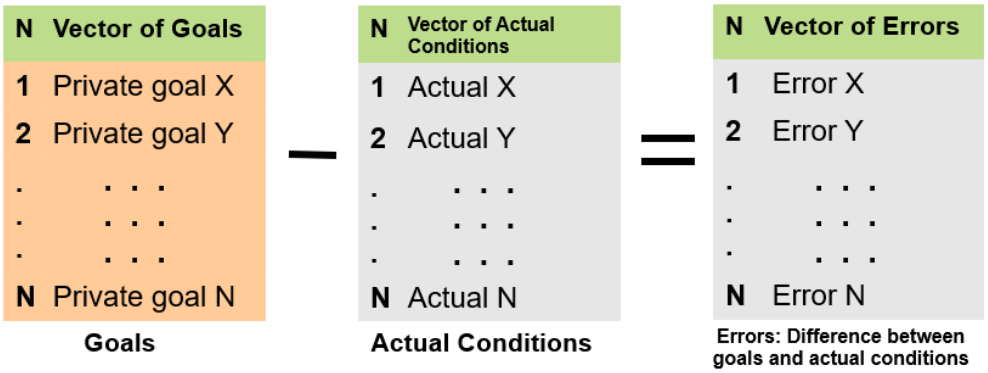

Fig. 3 Calculation of the quality of the educational process

Based on the schema student was controlling the process of the task/project fulfillment by three vector indicator: defining the goal vectors, estimating the current state of the project and by determining the difference between the defined goals and current state was getting the control error

or uncertainty in dynamic of how the one or another goal (problem/task/project) is reached or solved. The formula looks this way: **Goal vector – State vector = error vector**

Control of python programming language and establishment of "Programmer's thinking"

Control of the undergoing process by the lecturer plays a very important role during the implementation and realization of the teaching method.

During the implementation of the described methodology in the Python programming courses at the university, the following key issues were monitored by the lecturer to assure the "formation of the programmer's thinking":

1. During the programming of the pre-defined problems, the python instruments, characteristics, and attributes were sharply divided from each other. The strength of different programming instruments or ways were described in details for the given problem. The lecturer was checking the fact, how the student differs the various instruments from each other and which instrument is more preferable to use to program the given problem, by giving the thematic questions and specific tasks to do. This way was used to analyze the usage of python language instruments;
2. after defining the correct instruments by the students, the lecturer was checking on how can a student use the selected tools in a combination, create an orchestra as a whole system. Depending on the way the student was doing the given task the lecturer had been showing the optimal coding advice. The different selected instruments were synthesized in a single python project.
3. For each defined problem, frequently two alternative programming codes were realized. In such cases the particular indicators were calculated and defined (for example the code, algorithm execution time, code complexity, mobility and so on). These actions were used to compare two or more solutions and establish the comparing skills in the students and in future assignments the strengthening of this skill was done.
4. During the realization of certain problems, where the paradigm of object-oriented programming was used, the project planning skills had been checked by the lecturer. For example the students had to independently define the OOP classes, the dependence between the classes and other characteristics. This gave the students the skill of programming the things that are close to each other by means.
5. During the project realization, where the code syntax was built by the students, the frequent logic mistakes were appearing. These kinds of mistakes are very hard to find in the code, as the program is executed, but the program is not working as intended. The lecturer was controlling the skill of students on how well they could define the main concept and ignore less important events and processes. As a result the abstraction skills were developed within the students.
6. The experience gained during the course was monitored by the lecturer. In particular how they can systemize the problem resolution skills and ways. The skill of categorization and classification of the algorithmic processes was checked.

4. RESULTS AND DISCUSSION

The actions described in the methodology have shown the qualitative and statistical increase in the student's grades in the two courses of python programming language if compared with the previous

year's results. The groups with the same quantity of 300 students had shown an increase of 10-15% in grading. The students of the introductory course were showing the skills of systematic thinking in next semester's advanced python course that was significantly increasing their project quality and decreasing the time needed.

As the described method has shown the increase in the python programming language course learning, it is desirable to use it for the teaching of programming languages. Besides, as a universal teaching algorithm, it can also work in the teaching of other computer science courses, such as computer architecture, operating systems, computer networks, databases, algorithms and data structures, machine learning, cloud systems and more.

Method implementation steps:

1) The first lecture of the course should provide students with a detailed introduction of the algorithm of this method;
2) For students to understand the content of each method work, they should break down into small practical examples, depending on the subject of the course;
3) During the course, the lecturer should, together with the students, disseminate syllabus-based topics and make them practical according to the algorithm of the method described in the article (7-point plan);
4) The lecturer should hold the position of "Control subject" during the course and control the "control objects" - Students
5) When teaching the subject, the lecturer should change the management according to the students' preferences: "structured", "unstructured", or organize the "combined management" teaching process;
6) The lecturer should also monitor the performance of students during the course and compare the results obtained with the previous ones if statistics are available - thus providing dynamic feedback during the process;

It should be noted, however, that the method described above should not be used wholly in the teaching of other technical subjects. A thoughtful approach and small, thematic adjustments in teaching the relevant subject are required

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