Teaching Programming to Schoolchildren in Gomel (Belarus)

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Abstract: - The author has been teaching programming to Gomel schoolchildren for more than four decades. For the last twenty-five years, training has been focused primarily on preparing for programming competitions from school to international competitions (IOI). Since 1997, 15 students of the author have won a total of 26 medals at IOI 1997 - 2023. The article contains a description of the teaching methods and tools used by the author. An essential technical basis for training is the instrumental distance learning system DL.GSU.BY, was created and developed under the leadership of the author from 1999 to the present time.

Key-Words: - computer science olympiads, instrumental system of distance learning, programming, DL.GSU.BY, primary school, secondary school, high school.

1 Introduction

Even a cursory analysis of the literature shows how relevant it is now to teach programming to schoolchildren from "Every student in every school should have the opportunity to study computer science" [1], to teaching schoolchildren such professional programming languages as Python [2], [3], [4], C++ [5], C# [6], Java [7], Javascript [8], HTML and CSS [9] . Particular importance is attached to gamification, [10], as a means of attracting the attention of schoolchildren to programming and automatic systems for checking programs, [11], to increase the speed and quality of programming learning. It is pointed out that programming competitions motivate schoolchildren to study programming, [12]. Recommendations are being developed for preparing for programming competitions, [13] and new approaches to teaching programming, for example, in [14], training is proposed according to the OBE (output-based education) principle. Proposals are also being made for the development of e-learning systems proper, [15]. There are examples of successful systems for teaching programming, [16]. Great attention is paid to the further development of teaching methods, in particular such aspects as integrated teaching of programming and mathematics [17], the development of effective learning without the direct use of computers (unplugged activities) [18], [19], the use of a balanced approach to simultaneous work on theory and practice, [20].

The role of the development of technological resources for learning is noted, [21]. Examples of successful technological resources are given, [22]. The future is seen in personalized learning systems, [23], [24], with the widespread use of educational video materials [25], mobile devices [26] and artificial intelligence [27], [28].

2 Problem Formulation

The author has been teaching programming to schoolchildren, [29], for several decades, and in this paper offers a description of his approach to teaching programming. Initially, the author was focused on teaching applied programming to schoolchildren. However, when only two out of ten well-motivated and well-prepared schoolchildren - programmers entered the university, it was decided to reorient themselves towards preparing for the Olympiads in Informatics, since obtaining a diploma from the Republican Olympiad for schoolchildren guarantees university admission.

3 Problem Solution

3.1 What to Teach?

Since 2010, the conditions of tasks for the Belarusian Republican and Regional Olympiads in Informatics have been prepared by a single scientific committee, and, in this way, the vector of

development of education is set - what topics and at what level of complexity are required to prepare schoolchildren for Olympiads in Informatics. Since that time, the author himself has been solving these problems in two directions:

A) Score enough points to pass from the Gomel region to the Belarusian Republican Olympiad and score enough points to receive a diploma from the Belarusian Republican Olympiad. As a rule, to achieve the desired result, it is enough to solve one or two problems completely in each round and make partial solutions for two or three problems in the round. Each round includes four tasks.

B) Solve completely thematically important problems that were not necessary to solve completely to get a diploma, but they are very useful for successful performance at international Olympiads. We are talking about tasks on the following topics: dynamic programming, complex data structures, graphs, and elements of number theory.

For all solved problems, the author writes his detailed descriptions of not only the ideas of the solution but also the details of the implementation of his solution. The description also includes the full text of the solution in Pascal. This is done so that the solutions can be understood by all students. Our training begins in Pascal, but from some point on, many Olympiad students switch to C++. If the jury's original decision uses advanced (compared to Pascal) C++ features, then it (together with the original description) is attached to the decision of the author of the article.

The tasks of item A are collected in a special package of tasks "Belarusian Olympiads - Diploma Minimum" in order of increasing complexity of topics and tasks within topics in the course "Basic Programming". At the moment, this task package contains problems of the Belarusian Republican and Regional Olympiads 2010-2023, grouped by topics: one-dimensional array, two-dimensional array, geometry, strings, enumeration, greedy algorithm, dichotomy, trichotomy, elements of number theory (modular arithmetic, divisors, greatest common divisor, sieve of Eratosthenes, number systems, bit processing), recursion, dynamic programming, graphs (recursion, disjoint set system), C++ goodies (multiset, map), partial solutions, also grouped by topic: one-dimensional array, two-dimensional array, strings, enumeration, elements of number theory (divisors, sieve of Eratosthenes, greatest common divisor, number systems, bit processing), greedy algorithm, queue, recursion, dynamic programming (prefix sums,

knapsack, largest increasing subsequence, partitioning an array into subarrays); graphs (queue, recursion, Prim's minimum spanning tree algorithm), C++ goodies (map)).

The tasks of point B are collected in separate task packages inside the "Belarusian Olympiads" folder on the following topics: dynamic programming (one-dimensional, two-dimensional, three-dimensional, on an array of strings, on a tree, by number, by bit number, inclusion-exclusion method); complex data structures: trie on (string, bit), segment tree (without modification, single increment-sum, single assignment-minimum, and number, increment on segment-lazy propagation-minimum); C++ goodies (vector+sort, map, multimap, upper/lower bound, ordered set); graphs (tree diameter, response dichotomy, Kruskal's algorithm, least common ancestor, centroid decomposition); elements of number theory (greatest common divisor, sieve of Eratosthenes, Euler function, bit processing (cycle over all submasks)).

The author does not always manage to solve the problem on his own, in this case, original analyses and solutions come to the rescue.

3.2 How to Teach?

Over the decades of teaching programming to schoolchildren, the following general principles of the author's teaching methodology have been formed:
- teach everyone who comes, without dropping out by age and/or level of training
- in every lesson, every student works every minute, and not because he is forced, but because he is interested
- personalized adaptive learning
- many individual educational trajectories
- a reasonable combination of individual and group lessons.

The effective implementation of these principles became possible thanks to the development of the leadership of the author of the DL.GSU.BY instrumental system of distance learning and its continuous development and filling with educational materials, starting from September 1999. The main capabilities of DL.GSU.BY is presented in the author's paper [5]. The following describes other features of the author's approach to teaching programming.

Automatic formation of the table of Codeforces-ratings of schoolchildren in Gomel and the Gomel region. All schoolchildren who aim to participate in the regional Olympiad in Informatics

and beyond are strongly recommended to register on the Codeforces.com website and solve rounds there at least once a month. As a result, a table [30] is automatically formed, that contains the columns "Rating", "City", "Surname", "Name", "Grade", "School", "Last Date", and "Number of Rounds". The top 15 rows of the table shown above represent the 15 most likely candidates for the next Belarusian Republican Olympiad as part of the Gomel Region team. As the statistics of the last 6 years show, at least 11 of them (in 2023 - 14) will take diplomas of the Belarusian Republican Olympiad. The top 25 lines of the table show the most likely graduates of the nearest Gomel Oblast Olympiad in Informatics. The 25 best in the table for Gomel show the most likely current participants in the nearest Gomel Oblast Olympiad from the city of Gomel.

Thus, each of the students can constantly understand their place in the regional / city hierarchy, monitor the effectiveness of their training, set themselves, and solve tasks to rise to the planned level. Columns "Date" (last participation) and "Number of rounds" (in which the student took part) show the seriousness of the student's intentions. It is also important to note that solving Codeforces rounds allows you to track trends in the development of Olympiad programming, learn new algorithms that are useful for learning, and conduct psychological and tactical training for Olympiad participants.

Weekly Sunday Olympiads. For the most advanced children of Gomel, based on the informatics cabinet of secondary school 27, training olympiads are held weekly on Sundays based on the materials of the olympiads USACO (USA), COCI (Croatia), Russian final, regional, and Internet olympiads. After the standard 5-hour solution, the participants of the Olympiads analyze the problems. Since olympiads are always taken, for which author's analyses are posted, they can also be used when resolving these olympiads.

Regional Olympiads in programming are described in the author's paper [4].

Weekly training olympiads. They are held on the tasks of regional olympiads of past years in two divisions 1-4 cells, 5-11 cells. Tasks open on Thursday morning and close on Wednesday evening of the following week. Thus, each student has at his disposal a whole week to find time to solve this Olympiad. The thematic format of the Olympiads allows the student and his teacher to constantly see the quality of the assimilation of the topics covered, as well as the topics to be studied.

Season Cups. For additional motivation for classes, quantitative results of training are summed up on a quarterly basis (who solved the problems most for Autumn, Winter, Spring, and Summer) in four nominations "Professional programming" (without age restrictions), "Basic programming" (for students 1-8 grades), "Informatics" (for students in grades 1-4), "Mathematics" (for students in grades 1-8). In the last three nominations, the results of the "Person of the Year" contest are also summed up. Valuable gifts are awarded by the OpenMyGame company, founded by the author's students.

Progress Cups. Awarded to one student in the courses "Basic Programming" and "Informatics" who has achieved the greatest progress. Valuable gifts are awarded by the DL Club (St. Petersburg).

The author's paper [4], contains a detailed description of such questions as t**eaching programming in middle and high school** as well as **teaching text programming (in Pascal) in elementary school** and a**utomation of learning in arbitrary programming languages**.

4 Teach to Learn

The author believes that the first and most important thing he should teach his students is to "teach to learn". Since a specialist in information technology will have to do this almost throughout his professional career. This study begins "from a small point" - to start a notebook on the subject, keep reasonable notes, and behave correctly in the classroom (do not be distracted by yourself and do not interfere with learning by others). The next level of "learning to learn" is to listen to the teacher's explanations, try to understand what you hear, and think about what you are learning all the time. Next comes the ability to understand the task, highlight the important, discard the unimportant, develop an algorithm, and debug a program written according to it. Then comes the formation of teamwork skills - listening carefully, concisely, and clearly expressing one's thoughts, behave correctly during discussions and dispute resolution. And, finally, the formation of the ability to obtain information from the Internet - the main source of knowledge today.

5 Teach Professions

Historically, it so happened that the author spends most of his time working with schoolchildren on teaching Olympiad programming. This is largely

because the diploma of the Republican Olympiad in Informatics (which is a programming Olympiad) makes it possible to enter any university in Belarus without exams. In addition, Belarusians can participate in Russian Olympiads, which give similar rights for admission to Russian universities. Winners of international Olympiads have certain benefits when entering universities in other countries.

At the same time, there are periodically schoolchildren who want to switch to applied professional programming, for example, after they took a diploma at the Republican Olympiad at the end of March and secured admission to a university and "free time" before starting their studies at a university in September.

Such guys are attracted to work on the development of DL.GSU.BY. What has been done to facilitate their transition to professional programming?

1) a DL virtual machine has been created, which allows you to install a website on your computer and learn "by trial and error" without threatening the operation of the combat DL.

2) a video tutorial was created on installing this DL virtual machine, modifying programs on the virtual machine, and transferring verified modifications to the "combat DL".

3) Professional programmers (the author's students) provide advice to beginners and exercise strict control over the code changed by beginners.

4) For professional communication of developers, a special DL documentation site is maintained, including a section of questions and answers

5) A special course "WEB-technologies for beginners" has been created - with automatic verification of solutions.

6 Conclusion

This work describes methods, tools, and technologies for teaching programming to schoolchildren. The effectiveness of the work is confirmed by dozens of medals from Gomel residents at the International Olympiads for School Students in Informatics (IOI) and hundreds of diplomas from Gomel residents at the Belarusian Republican School Olympiads in Informatics from 1997 to 2023.

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The author contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Conflict of Interest
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