

Codeforces as an Educational Platform for Learning Programming in Digitalization

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Abstract. Digitalization imposes ways of development and influences the process of Codeforces development. Codeforces' infrastructure provides a solid open ecosystem for building a programming learning process. Functionality covers the entire process, from the Polygon system for devising problems to mashup contests and private groups on Codeforces. A beta test of the educational subsystem with a pilot educational course was launched. The paper describes all the aspects and relationships of the ecosystem, typical flows of use, examples of successful integration into educational processes in the age of digitalization.

Keywords: educational platforms, competitive programming platforms, sports programming, e-learning, Olympiads and hackathons in Informatics, education digitalization.

1. Introduction

Digitalization becomes possible when there is the development of digital infrastructures and communication standards, information security, the expansion of online learning (e-learning), access and ability to use online-services and a lot of qualified IT-specialists who can create and develop information technologies, on-line services and others. Nowadays there is a shortage of IT-specialists all over the world. Their need in Russian IT- industry is 62400 people and their need in other industries of Russia is 82600 people. Enrollment in higher education institutions for IT majors in 2024 in Russian universities should be 120 thousand applicants. To ensure this number, it is necessary to train, motivate and attract more schoolchildren interested in IT and reform educational system, making it possible to teach a vast number of students.

2. Codeforces as a Platform for Programming Contests

In the world there are several mostly used contest's platforms such as American Top-coder, Indian CodeChef, Japanese AtCoder, European CSAcademy and Russian Codeforces. Codeforces is an international platform that hosts the largest regular Internet programming and Informatics competitions (Olympiads and hackathons), posts articles in IT-field, organizes programming trainings, discusses competitions & training tasks, and various news from IT-community. This is the largest training resource in the world, which provides an open infrastructure for preparing and conducting programming competitions, as well as automation of programming training courses.

Codeforces provides a wide range of services for those who are interested in algorithmic tasks and programming competitions. The main goal of Codeforces as a platform for competitions is to provide an opportunity to unite all those interested in programming contests, providing a wide list of services for this area of interest. The platform supports Russian and English languages and most of the materials are presented in two languages.

For many years Codeforces has provided three services:

- Social network (with various classic social network services and some specialized solutions).
- Subsystem of the competitions.
- Subsystem of hosting trainings.

Since December 2019 Codeforces has become the educational platform as well.

2.1. Testlib

Testlib library for C++ has been developed since 2005 as a replacement for an outdated similar library for the Pascal language. Currently, Testlib for C++ includes significantly more functionality compared to Testlib for Pascal. The new library has become the de facto standard for developing C++ tasks and programming tasks.

The library is widely used in the jury's work of various Olympiads and competitions:

- All the stages of All-Russian Olympiad of schoolchildren in Informatics (computer science).
- All the stages of All-Russian Team Olympiad of schoolchildren in programming.
- Repeatedly used in the development of tasks for the International Olympiad in Informatics (IOI).
- Dozens of regional competitions of the world student programming championship (ICPC).
- Many University competitions in Russia and abroad.
- Most stages of training camps (schools) in Russia and abroad.
- All rounds of open Codeforces competitions.

2.2. Polygon System

Polygon is a system for developing problems (task). Work on the Polygon system was started in 2008. Since March 2009, the system has been available online for everyone. Polygon simplifies and unifies the work of authors of programming problems and jury members of computer science and programming Olympiads. This is the only system of its kind with advanced functionality and accessibility to a wide range of problem authors.

Key features of Polygon that are an advantage of using it over other ways of developing problems are below:

- The Polygon system protects against errors.
- A lot of automation and self-checking tools are built into the Polygon:
 - The system protects against typos in tests from the condition and from the fact that they are not updated after changing the tests, since tests from the condition are inserted automatically, and responses to them are generated by the system by the author's decision.
 - All source texts in the problem archive (solutions, generators, checker, validator, etc.) will be compiled and correspond to the current versions.
 - The system displays a warning that the first test is not a test from the condition.
 - If the system checks that the non-deterministic generator (which is initialized from the current system time) is not being used, it will run the generator twice at intervals of a second and make sure that the tests match.
- The Polygon system implements dozens of similar checks that effectively prevents errors or ignoring good practices in problem development.
- Archives (packages) of Polygon tasks are uniform and machine-readable.
- Polygon provides long-term storage and availability of issues and competitions.
- Polygon reduces the threshold for entering the task preparation process.
- The system helps you manage access.
- Polygon has built-in issue-tracking.
- Polygon provides easy integration with automated testing systems.
- There are no special software requirements for the task developer.
- Polygon is attentive to security issues and data leaks.
- Polygon has built-in tools for classifying, indexing, and searching for issues.

According to Google Analytics, Codeforces is ahead of its competitors in terms of the number of competitions per month, the number of participants. Codeforces has an open registration system. The number of registered users is constantly growing. At the end of 2019, the main metrics according to web analytics system "Google Analytics" were:

- 472 158 users.
- 29 138 871 page views.
- Average session duration: 15 minutes.

Judging by the metrics Codeforces has a huge potential for creating on its basis an educational subsystem for participants of Olympiad programming.

3. Codeforces as a Platform for Education

3.1. The Concept of Educational Platforms

The debate rages in impact and effectiveness of e-learning, its benefits and drawbacks, motivations, performance and barriers (Alias *et al.*, 2012), (Zakariah, *et al.*, 2012), (Khan *et al.*, 2019), (Shapiro *et al.*, 2017), (Al-Rahm *et al.*, 2015) (Shoufan, 2019), (Shin *et al.*, 2019), (Magalhães *et al.*, 2020). This topic is becoming very actual in the time of Covid-19 pandemic. The significance of e-learning possibilities has changed and grown.

3.2. Existing Educational Solutions

Nowadays many online learning resources exist all over the world – Coursera, edX, YouTube, Udemy, Khan Academy. But only some of them have courses on competitive programming. The main metrics are presented in Table 1.

However existing educational platforms such as Coursera, Stepik, Universarium, EdX and others do not offer programming competitions. Moreover, the courses presented by these platforms do not meet the requirements of courses on Olympiad programming.

To conduct a comparative analysis of existing courses, the most closely related courses were selected, which are also considered the most popular in IT-community:

- The course “Sports programming” is available on the Stepik and Coursera platforms. It is the closest course in the subject <https://ru.coursera.org/learn/sportivnoe-programmirovanie>
- The course "How to Win Coding Competition: Secrets of Champions" on the Edx platform. It is a similar course in English <https://www.edx.org/course/how-to-win-coding-competitions-secrets-of-champions-4>
- The course "Algorithms and data structures" on the Stepik platform <https://stepik.org/course/63>

The comparison is shown below in Table 2.

Table 1
The main metrics of similar courses.

Platform	Stepik & Coursera	Edx	Stepik
Name of the course	Sports programming	How to Win Coding Competitions: Secrets of Champions	Algorithms and data structures
Metrics			
registered	2430	78015	16286
Issued certificates	129	191	542

Table 2
Comparison of algorithms and data structure courses

Platform	Stepik & Coursera	Edx	Stepik
Name of the course	“Sports programming”	“How to Win Coding Competitions: Secrets of Champions”	“Algorithms and data structures”
Course contents (main topics that should be covered in competitive programming)			
Backtracking	+		
Stack, queue		+	
Segment tree			+
Union-Find			+
Greedy algorithms	+		
Dynamic programming	+	+	
String algorithms			
DFS, Topological sorting		+	+
Shortest paths		+	+
Binary search		+	
Binary climbing			
Graph games			
Combinatorics			
Bitmasks	+		
Numbers theory algorithms			
Network flows			
Matchings			
Number and level of practical tasks in the form of problems			
Number of practical tasks in the form of problems on programming for each topic	not presented	on the average 10 problems for each topic	on the average 5 problems for each topic
Level of offered task in the form of problems on programming	not presented	mainly training problems + one-two problems similar to Olympiad problems	almost all the problems are training ones
Possibility to choose separate lectures, topics and problems	not presented	not presented	not presented
Access to the solutions of participants	not presented	not presented	not presented
Possibility to write comments	not presented	not presented	not presented
Availability of social networks for discussions	not presented	not presented	not presented
Possibility to get personal recommendations from teacher or coaches	not presented	not presented	not presented

Comparative analysis showed that the existing courses have a number of disadvantages, including:

- The material is presented in a difficult language, that is the material is intended for a more adult audience.

- Theoretical orientation (not practical).
- Basic (not advanced) level.
- They cover only a small part of the topics required for successful participation in computer science and programming Olympiads.

The authors of the paper claim that similar courses have three significant drawbacks:

- They are isolated from the competitors' community on third-party educational platforms.
- The presence of a community on Codeforces not only provides a database of participants interested in the course, but also creates a social environment for participant's communication, discussion, mutual assistance, etc.
- They use an insufficiently developed testing automation infrastructure. Support for programming tasks even of the largest educational platforms lags far behind the support for similar tasks on Codeforces.

3.3. Codeforces – a Platform for Education

Codeforces is well-known all over the world as a platform for contests, but lately Codeforces became the educational platform as well. The edu system has been running for three months. During this time three lessons were introduced to the users. Each lesson consists of 4-5 steps, each step includes:

- Lecture video of the algorithm (whiteboard or presentation).
- Lecture text notes.
- Coding video, explaining how to implement the algorithm.
- Programming tasks for practice.

These elements can be used in any order and independently as well as the lessons themselves. Everything is at the discretion of the learner – the pace, the order, the speed of the video, the number of problems.

The lessons were studied by approximately 3000 users. Three-month experience shows that e-learning is of great demand and the combination of platform for contests and education is very popular with IT-community. Especially it is popular with undergraduate students and schoolchildren – future IT-specialists. One can participate in co-decups, learn and have talks with like-minded people at one place which is comfortable and convenient. 47 users left the feedback about edu system on Codeforces and it turned out to be highly positive. The feedback is presented in Table 3.

The feedback shows that users themselves like the idea of the educational project on the contest platform and edu project is in great demand among teens who are interested in hi-tech, Informatics and programming.

Table 3
How students express their praise or critics in relation to a new format

Aspect	Users' feedback
Praise from users	
	<p>Cool! Continue to do such courses! Helps a lot.</p> <p>COOL!!! Good Job and Good Luck. Thanks for such an opportunity!!!</p> <p>This can help us to improve our programming skills and our knowledge. Good Job!</p> <p>Yeah that is right ! thanks a lot.</p> <p>Super! Thank you for such excellent courses! This helps not only beginners, but also advanced users. Excellent lectures, theory and practice! By the way, you are very cool to explain!) P.S. I would Really like more of these courses)</p> <p>Keep doing this great job! Thanks a lot!</p> <p>Interesting form of presentation. This option must clearly exist! Thank you for the quality courses!</p> <p>Good new system. It would be great to study more different strong algorithms.</p> <p>I have always dreamed of such a course, thank you very much!</p> <p>Just what was missing!!! Well done!!</p> <p>It is very cool in codeforces not only to solve problems but also to learn. It has become the main advantage of the platform and soon everything will be better</p> <p>Thank you so. Please don't stop. Your lectures are very useful and I really want to watch that more.</p>
Critics and Recommendations from users	
	<p>It would have been good to see solutions of other users if you solved the problem yourself.</p> <p>Thanks! The only thing I would like is open tests for detecting errors.</p> <p>I suggest increasing the scale of the lecturer by 2-2.5 times.</p> <p>It would be cool if you added moving (rewinding) through the video with the help of the keyboard (the same arrows)</p> <p>Can you make so that the video continues where it is left off after you switch to practice?</p> <p>Good lectures. The problems are interesting. It may be worth making the player's buttons bigger so that you could watch it via smartphones.</p> <p>A good course, and most importantly in demand. It is definitely worth developing further. I didn't find any special disadvantages for myself, so continue in the same way!</p> <p>When will be the continuation?</p>

4. Conclusion

The development of a new format opens up a number of opportunities and has a huge practical significance. The combination of platform for contests and education give possibility to train and study at one place. Distant format provides teens with the possibility to learn for those who live in remote regions where there are no teachers and possibility for children and teenagers with a disability. Learning and contest participation is highly beneficial pastime especially during epidemics. Such approach can be used as a supplementary means in teaching because such platforms attract young people to competitions and in-depth programming studies, they facilitate to cover a wide range of topics and enlarge the number of learners, helping to nurture and form intellectual capital of any country.

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