Changing Traditions of Mathematical Education: BSc Program in Mathematics at the National Research University Higher School of Economics

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HSE Faculty of Mathematics invited its first bachelor students in 2008. The program aims at providing a fundamental mathematical background as well as wide opportunities for its application: from physics, economics and computer science to actuary and financial analysis. Below we describe the problems encountered by the Faculty of Mathematics while building a new mathematical curriculum, and the solutions found. To this end, we first need to recap the principles of mathematical education in traditional Russian universities.

A typical faculty of mathematics in a Russian university follows Soviet tradition dating back to the 1920s–1930s. Students are offered a standard curriculum or a choice between its several standard variations. Each subject within the curriculum is taught in the form of lectures delivered to all students enrolled, and accompanied by recitation sessions conducted separately in smaller groups, which are similar to high-school classes. There are also special topics courses and seminars offered every semester. Individual interaction between students and professors happens mostly in the context of writing bachelor's thesis.

Details and advantages of this traditional framework are described in another text of this issue [1]. However, this scheme turned out to be inadequate for the objectives set by HSE Faculty of Mathematics for the following reasons:

- Study plans do not allow for much variation. Students inclined to pursue an industrial career have no time to specialize, and students planning to stay in the academy cannot intensify their training in fundamental mathematics.
- The mandatory part of the curriculum is hard to modify; it tends to be very conservative, not sensitive to contemporary trends in mathematics.
- Lack of contact between a freshman or a sophomore and a professor obstructs the development of key professional skills (e.g., scientific communication and self-study) and impedes comprehension of abstract ideas.

In order to partially compensate the negative effect of these drawbacks on the most motivated students, some non-government "elite" educational institutions in mathematics and computer sciences were created, including the Independent University of Moscow (IUM) [2], and the Yandex School of Data Analysis (SDA) [3]. These institutions played a decisive role in the foundation of two new faculties within Higher School of Economics: Faculty of Mathematics (FM) and Faculty of Computer Science. Educational programs offered by these faculties were meant to be free of the listed drawbacks.

FM has chosen a format that merges some traits of the Soviet tradition with those of the Anglo-Saxon tradition. This format looks as follows: the first two years of the 4-year BSc program consist of mandatory basic courses, including both those traditional for Soviet mathematical education and "innovative" ones (topology, representation theory, Galois theory). The mandatory curriculum of the last two years is limited to academic writing, history of mathematics, and probability theory. All the rest is an "individual study plan" chosen from a large pool of courses offered by FM, other HSE departments, or external programs (first of all, IUM and SDA).

Mandatory courses are conducted in the form of lectures, tutorials (more resembling the North-American rather than the Soviet ones) and "mathematical practicum" sessions. The latter are individual discussions of theoretical problems between students and instructors; this kind of educational activity follows the best practices of IUM and mathematically oriented high-schools [4]. Optional courses can be basic ("elective courses"), taught in the same format as mandatory courses, or advanced ("special topics courses"), taught in the form of lectures. Thus, there are two major differences that distinguish the new scheme from the traditional one:

- "Mathematical practicum" and coursework for freshmen and sophomores provide intensive student-faculty interaction;
- Juniors and seniors build their own study plans choosing from a large pool of elective courses [5] and adding non-mathematical courses from other departments if desired.
- These features create the following advantages:

- Students who are half-way through their BSc program and decide to concentrate on a particular applied subject may take non-mathematical courses in their chosen field complemented by relevant advanced mathematical courses; these students do not waste their time on mathematical background unnecessary for them personally;
- Students wishing to pursue an academic career may first specialize in their chosen research field, and then, parallel to their own research agenda, strengthen their background in other mathematical subjects;
- FM can dynamically adjust the range and contents of elective courses without touching the mandatory part;
- The range of advanced courses can be expanded without increasing the teaching load: some courses may be offered bi-annually, so that students can take them either in their 3rd or 4th year of study.

As was expected, the rigid, mandatory part of the curriculum turned out to be the most problematic. It was clear that this part should be created from scratch rather than based on the Soviet tradition. Firstly, we had to reduce the contents of a traditional 5-year program to basically a 2-year program while adding new subjects (e.g., topology and Galois theory). Secondly, we had to provide up-to-date teaching materials (most textbooks currently in use at Russian universities are reprints of 50-year-old editions, at best). We also had to deal with internal restrictions imposed by HSE. For example, classroom hours are restricted by HSE regulations, whereas our competitors pose a double or triple amount of classroom hours (compared to what we have at HSE) as their advantage.

For these reasons, it was decided not to fix the mandatory part of the curriculum at the beginning. At the start-up stage (first several years of the program), instructors of mandatory courses all together discussed the prerequisites, core material and its distribution between courses. Timing was favorable for this scheme, since the first students were few, and the first instructors were very experienced (the percentage of young faculty members reached its current record later).

In 2014, the "codification" of the mandatory curriculum began, based on the experience of the previous several years. Teaching materials created during this period are now being unified and rectified. This task is not yet complete but it is already clear that we have obtained satisfactory "experimental" solutions to most of the challenges. A principal — yet unsolved — problem is that of finding an optimal balance between algebra and analysis in the mandatory part of the curriculum. Whether to make certain topics mandatory is being vividly argued upon. As a drawback of HSE educational model (actually, of any "western-type" model), one can view the impossibility of using exams as tools for education rather than only for control. The Soviet tradition implemented this possibility, which, to a large extent, shaped the success of the Soviet mathematical school. For example, at HSE it is forbidden to retake an exam once a student has passed it.

The fine-tuning of the BSc program is close to its completion [6]. FM partially owes its success to its international advisory board (P. Deligne, S. Fomin, A. Okounkov, T. Miwa, S. Smirnov), whose members helped a lot with their expert advice. According to the 2013 report of the advisory board [7], our BSc program is at the level of the best mathematics undergraduate programs in the world (this does not yet apply to graduate programs), and our department is in the top-100 of mathematics departments worldwide (just to emphasize: this estimate is based on personal opinion of the advisory board members rather than on formal quantitative evaluations). On the other hand, members of the advisory board indicate the following issues: lack of small (up to 10 students) study groups, insufficient promotion of alumni's career prospects.

A group of several strong students suggested their own version of the mandatory curriculum. The great job done by these students has provided elegant solutions to many methodological and organizational problems. Either competition with HSE or independent innovation initiatives have led some other institutions of higher education to similar modifications of their undergraduate programs in mathematics. For example, an introductory topology course has been added to the mathematical curriculum at Moscow State University [8].

References

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