AC 2011-2314: PREPARATION OF CHEMICAL ENGINEERS IN THE MULTI-LEVEL CURRICULUM STRUCTURE

PhD Valeriy Solomonov, Lomonosov Moscow State Academy of Fine Chemical Technology (MITHT)
PhD Olga Belyaeva, Lomonosov Moscow State Academy of Fine Chemical Technology (MITHT)
Prof. Alla Frolkova, Lomonosov Moscow State Academy of Fine Chemical Technology (MITHT)

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Preparation of chemical engineers in the multi-level curriculum structure

The training of specialists in science-based technologies as the basis for stable social development

Modern society is based on innovations and public control over implementation of scientific results. One of the basic constituents of turning science into the source of innovations is the development of science-based sectors of industry: chemical, microbiological, computer industries, electronics, optics, etc. Competition leads to the creation of increasingly complex systems which is followed by the demand for their safety. The development of science-based or so called high technologies and industries leads to the greater demand for professionals and the need for training of increasing number of highly qualified specialists, including engineers.

Science-based technologies are characterized by intensive use of achievements in science and engineering. They presuppose deep scientific knowledge of physical and chemical laws, molecular and quantum chemistry, fine technologies, models based on types of interaction, thermodynamic, kinetic and mathematical regularities as well as on modern computer technologies and programs.

Multi-level structure of educational programs in Lomonosov Moscow State Academy of Fine Chemical Technology (MITHT)

The multi-level education system for chemical engineers has been tested and developed for 20 years since 1991 up to the present in Lomonosov Moscow State Academy of Fine Chemical Technology. The former system consisted in the linear professional curricula covering five and a half years. Such curricula were successfully realized in the former Soviet Union under conditions of a plan-based economy. The typical features of linear-structured curricula were as follows: forming curricula in accordance with the future professional activity of a student, levelled requirements to the quality of students’ knowledge, no possibility to choose courses and professional specialization.

The transfer to market economy introduced new requirements, including quick reaction to the changing conditions at the labour market. To meet these requirements the multi-level curriculum structure has been introduced. It includes Bachelor and Master programs, well integrated with one another and pre-university and postgraduate training. Basic scientific training courses similar for all specialties were placed in the first years, special training started to cover shorter period — 0.5-2 years and the set of specialties and specializations started to be permanently adjusted to the changing conditions of the labour market.

This curriculum structure is used for 15 years for approximately 3000 students per year. About ⅓ of those who enter MITHT later get Master Degree (about 250 students per year). Multi-level structure of professional training in science-based chemical engineering uses the following principles:

■ multi-level type of professional training;
■ matching curricula of subsequent levels;
■ flexibility in the choice of levels and stages of education suitable for particular student;
■ deep general scientific training;
■ individual choice of courses within special professional training.

By education level we mean a curriculum segment followed by competitive exams. This multi-level education system is presented in Figure 1.
Postgraduate study
(postgraduate education, 3-4 years)
Competitive examination to enter postgraduate level

Master's degree education
(special professional higher education, 1-2 years)
Competitive examination to enter Master of Science program

Bachelor's degree education
(basic higher education, 3-4 years)
Special professional education
(the fourth year)
Distribution of students into specialty groups on competitive basis

Basic professional education
(the third year)
Appointment of students to work with particular department on competitive basis

Basic professional education
(the second year)
Distribution of students into bachelor degree specialty types on competitive basis

Basic scientific training
(the first year, basic scientific courses, similar for all technical specialties)

Competitive examination to enter a university

Complete secondary school
(complete secondary education, 2-3 years)
Competitive examination

Basic secondary school

Figure 1. Multi-level curriculum structure.

At the first curriculum level students are getting accustomed to the university life, the knowledge of different students is uplifted to the more or less similar level, the personal choice of future curricula levels takes place.

The curriculum of the first year includes the same set of compulsory disciplines for students of all technical specialties of Bachelor degree program: higher mathematics, computer science, physics, engineering drawing, general and inorganic chemistry, foreign language, history, economy, special courses, selected by a student (elective disciplines).

Students, who have successfully passed the exams after the first year, are distributed on competitive basis into groups in accordance with the specialty in which they will receive their Bachelor Degree.

Lomonosov Moscow State Academy of Fine Chemical Technology offers at present 7 technical and scientific specialties: chemistry, chemical technology and biotechnology, material science and technology of advanced materials, meteorology and standardization, environmental protection, applied mathematics.

The specialty is chosen in accordance with the preferences of a student, his or her academic records and the quotas, regulating the number of state-financed and self-financed students for a given academic year. Those whose rating was not good enough to get state-financing can
study at the chosen department on their own finances or be financed by a particular company, or they may go on to a less popular department the state quotas of which are not yet filled. In the second and the third year students proceed to study basic disciplines in accordance with the chosen specialty, which includes basic courses in natural sciences, engineering and technology, economical and management courses. At the end of the second year examinations take place, the results of which influence the possibility to choose particular department in accordance with the future specialty. At the end of the third year after the introductory practice the direction and topic of qualification work of students is determined so that they could proceed education in accordance with the chosen specialization. For example, the Bachelor specialty Chemical Technology at MITHT includes further subdivisions such as Chemical Technology of Organic Substances, Chemical Technology of Synthetic Biologically Active Substances, Technology of Pharmaceutical Compounds and Cosmetics, Chemical Technology of Natural Energy Carriers and Carbon Materials, Chemical Technology of Polymer Composites. At the fourth year some students prepare themselves for the future study for the Master Degree, while others – to graduation from the university and meeting the requirements of the labour market. Within the Bachelor Degree curriculum 2 or 3 levels are singled out, which can be entered by a student only after competitive exams, which substantially stimulate the quality of study. Thus students go through competitive exams and academic records competitions along all their study for the Bachelor Degree, which considerably improves the quality of their academic work. Courses for the Master Degree normally depend on the future specialty of a student (engineer, designer, applied scientist, etc.).

The important peculiarities of the given type of multi-level higher technical education are:

- broad education in the first year;
- singling out curriculum levels within the Bachelor Degree program;
- requirements to students, increasing from level to level;
- competitive exams or rating competition to enter every next level;
- moving the main part of special professional courses on to the 4-6 years;
- individual curriculum adjustment in accordance with student’s choice and the requirements of the future employer.

Estimating the student’s knowledge

The introduction of the multi-level curriculum structure required working out the rating criteria for estimation of students. It was important that the rating system would stimulate the students not for just getting the maximum number of points, but mainly to deeper mastering the knowledge.

A scale of marks has been introduced, which is presented in Figure 2. The scale is structured so as to stimulate the students to master the information at the level of “good” (covers 10 points) and “excellent” (covers 20 points), “excellent” being also of two types – “excellent” and “outstanding”. To put a mark “outstanding” a teacher should provide a student with more difficult questions and tasks, requiring deep knowledge and analytical skills. The marks “satisfactory” and “below average” mean mastering the knowledge just enough to merely reproduce it, while “good” and “excellent” presuppose analytical approach. The same scale is used for examination marks. The subtypes within “unsatisfactory” mark facilitate the individual approach to those who fall behind. “Insufficient” means that a student can complete the course in the next semester, while “unacceptable” presupposes that the course should be fully repeated or the student should leave MITHT.
At the beginning of a semester students are provided with the schedule for every course, which shows the dates of tests and the weighting coefficient of each test. Every test results in a mark and a number of points corresponding to it. Different indexes of student rating are based on all marks during semester as well as examination marks. The quality of student’s knowledge in particular subject is shown by the so called Cumulative Mark (CM). CM is calculated by the teacher on the basis of the results of Intermediate Evaluation Tests (IET), which include written tests, colloquia, etc. Cumulative mark is determined in the following way:

\[
CM = \frac{\sum k_i N_i}{\sum k_i}
\]

*CM* – cumulative mark of a student;  
\(k_i\) – weighting coefficient of the intermediate evaluation test \(i\) determined by particular department;  
\(N_i\) – mark for the intermediate evaluation test \(i\).

For a positive cumulative mark a student should fully master the course materials, pass all intermediate evaluation tests and get not less than 15 at each of them. Some courses are followed by the exams. Therefore the final marks for a course consist of a cumulative mark and examination results. Different parameters of student’s study rating are calculated on the basis of cumulative mark and examination results. For example, the index of semester study rating is calculated as a value-weighted mark:

\[
R = \frac{\sum N_i}{n}
\]

*R* – index of a semester study rating of a student;  
\(n\) – a number of cumulative and examination marks received by a student within a semester;  
\(N_i\) – a mark (cumulative or examination mark) received by a student for a course \(i\).

Individual curriculum adjustment

The introduction of multi-level curriculum structure helps a student to adjust the education to his needs. The students choose whether to proceed to the next level or to graduate from the university and he also chooses special disciplines at a particular level. During one year a student normally studies within the same group. When passing on to the next curriculum level the groups are normally reformatted. For example, after the first year the new groups are formed in accordance with the Bachelor Degree specialties. Some students prefer to work along their personal curriculum because of certain life circumstances: falling behind because of an illness or the necessity to combine study and
work, a desire to change specialty, get extra qualification or the second education. Therefore
about $\frac{1}{4}$ to $\frac{1}{3}$ of students turns to individual curricula.
This helps graduates of Lomonosov Moscow State Academy of Fine Chemical Technology,
if necessary, to easily acquire another professional education in the related field, get
additional qualifications, proceed with their education during their professional career.

The results of work on multi-level curricula

1. The multi-level curriculum structure for professional education is developed, the levels and
their sequence are worked out on the basis of the appropriate teaching methods, content and
time schedule of each level, as well as coordination of programs at different levels within the
continuous study process are achieved.
2. The techniques of curriculum adjustment for personal needs of a student with compulsory
taking into account the student rating has been implemented. An effective system of forming
and developing the creative potential and capabilities of every student, increasing motivation
for study on the basis of intermediate and final competitive tests has been formed.
3. A full set of documents, following the teaching, applying teaching methods and
organization and management of multi-level curriculum structure has been worked out.
4. The multi-level curriculum structure and the underlying teaching methods and practical
recommendations have been tested for 15 year and their practical effectiveness has been
shown.

Conclusions

The multi-level curriculum structure turns out to be more effective than the linear one. The
main advantages of the multi-level structure are as follows:

- Quick reaction at the changes in student demands and labour market requirements. It takes
  only 1-3 years to introduce a new curriculum at particular level as it can rely upon the
  curricula of other levels.
- The possibility for a student to master two different Bachelor Degree programs: the main,
  normally technical one and the additional, normally social and economical or that in
  Humanities. This helps to attract students to some less demanded technical specializations.
- Additional convenience for having programs together with other secondary and higher
  school institutions.
- Permanent stimulation of student studies by the introduction of student rating and
  competition in getting to the most demanded groups of a subsequent educational level.
  Competition and the permanent necessity to choose the preferable courses and levels develop
  student's individuality and form them into grown-up people which helps them to show their
  potential at the labour market later to the best advantage.
- Increase in the quality of education: curriculum for the first years has become more stable,
  the number of simultaneously studied courses decreased, the logical sequence of disciplines
  improved.
- Increase of the demand for graduates at the labour market because of well specialized
  education.

