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The role of educational results in designing a model of pedagogical internship in engineering and technology

The problem of theoretical basis for designing the models of training teaching staff able to work in specialized engineering and technology classes has been relevant abroad for more than half a century. In our country the significance of its studying has increased again because of the state tasks of economic development based on the latest engineering and technological advances. The experience of training participants for Olympiads and contests of the National Technology Initiative shows high efficiency of the work done by professional engineers with students. The involvement of people with non-pedagogical engineering education in pedagogical activity requires the search for evidence-based forms of intensive training, among which the authors give priority to internship. The productivity of training such personnel depends on a theoretically based design of internship programs, where the selection of planned results plays a crucial role. The goal of the research is to determine the principles for selecting the perspective results of engineering-technology pedagogical internship.

Thorough theoretical analysis done on the basis of more than 150 texts including a cluster of professional standards of an engineering group, federal state educational standards of higher education for areas of engineering training implemented at universities of Krasnoyarsk region, professional standards "Teacher" and "Teacher of additional education for children and adults" made it possible to single out universal and professional competencies that were compared with the results of a study done by UNESCO and OECD on competencies of the XXI century, the syllabus of engineering training programs in the CDIO concept. Among the universal competencies teamwork and self-development are paid special attention to. Among professional competencies, pedagogical proper and engineering pedagogical ones are pointed out. On the basis of the analysis of foreign and local models of the pedagogical internship, such normative-based practices for achieving the planned results as a scientific and methodological seminar, independent work in the information-activity environment, internships, tutorial practice in engineering competitions, and demonstration exam are specified. They may have any technological (industrial) content and provide training for people with engineering education to work as educators.

Key words: pedagogical internship, continuing engineering education, educational programs designing, national technological initiative

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Introduction

According to the Strategy for Scientific and Technological Development of the Russian Federation, it is necessary to create appropriate conditions to ensure the leadership of Russian companies in new high-tech markets, that will influence the structure of the world economy in the next 15-20 years. Achieving these goals requires increasing the competitiveness of Russian education, which is also provided by new models of teacher training for specialized engineering and technological education of schoolchildren. Local engineering education is famous for its traditions and high quality recognized in the world. However, involving engineers into the educational process within the context of basic and additional education in particular is not conceptually grounded, does not take international experience into account and is characterized by having no system. Our country focuses on high-tech sectors of the economy and relies on various industrial enterprises (mainly engineering and technological ones) to provide its competitiveness in the world. As a result, universities target the applicants with high-quality fundamental knowledge, as well as having experience in design, research and development activities in engineering. This sets the task of searching adequate ways to train a teacher with a basic engineering education to accompany the design, research and development activities of a student with a strong motivation to receive engineering education in organizations of compulsory and additional education.

In foreign countries the problem of preparing teachers to accompany the design and development activities of schoolchildren finds expression in the area of research dealing with “pedagogical content knowledge of teachers” [1], which opposes both the purely objective and purely didactic paradigm in teacher training scientific and physical-mathematical profile, as well as in the study of the effectiveness of technologically and design-oriented models of integrated teacher training STEM (Science, Technology, Engineering and Mathematics), STEAM (Science, Technology, Engineering, Arts and Mathematics) [2; 3], CEEMS (Cincinnati Engineering Enhanced Math and Science Program) [4].

The project-oriented method of training in engineering education is reasonable in the research and practical activities of the international community in engineering pedagogy, the CDIO international initiative aimed at special organization of the educational process for training an engineer capable of carrying out a complete technological cycle [5, p. 64].

Special aspects of the teaching methods in specialized engineering and technology classes in local education in the context of the National Technological Initiative (NTI) are viewed in the works by D.R. Merzlyakova and A.A. Miroshnichenko. The authors offer to introduce new technologies to schoolchildren within the STI by creating individual educational paths with in-depth study of certain subjects (physics, mathematics, computer science, etc.). It is also necessary for pupils to participate in special clubs and profile olympiads in this area [6, p. 2015]. In the researches by N.V. Gafurova, S.S. Graskina, E.E. Graskina, V.I. Lyakh, S.I. Osipova, A.N. Solovieva, I.P. Chernova and others productive approaches and techniques of implementing specialized engineering training for students in the context of the integration of educational resources and social partnerships of universities, manufacturing companies and secondary schools are described [7; 8; 9].

Nowadays the scientists pay special attention to the study of new forms of engineering education for students of a comprehensive school - children's technology parks. The potential

of Quantoriums is studied in the system of additional engineering education of students and the conditions for its implementation [10; 11]. The analysis of teachers' qualifications - "STI experts" shows that the teachers in clubs who have engineering education demonstrate high level of efficiency preparing students for Olympiads and engineering competitions.

Currently solving the problems of engineering training for students of a comprehensive school is impossible without training them as teachers in an appropriate way. Scientists are looking for the implementation of such training in the system of pedagogical education, professional retraining and skill enhancement.

We consider the implementation of professional and pedagogical training in terms of the internship to be one of the possible ways to solve this problem. Models of pedagogical internship abroad (Germany, Great Britain, France, etc.) show effectiveness of accelerated teacher training at the workplace in solving urgent educational problems.

Pedagogical internship as a program to start the profession is valid in many countries of the world, such as Great Britain, Germany [12], Canada, USA [13], Finland, Japan. The majority of pedagogical internship programs abroad and the experience of some local universities in organizing postgraduate internship guided by university departments [14, 15] are models in terms of the so-called continual teacher training program. Teacher training in France [16] and the pedagogical internship models of some universities in Russia [17], including Krasnoyarsk State Pedagogical University named after V.P. Astafiev, can be characterized as parallel training.

The object of the article is to describe the principles of selecting educational results while designing the model of a pedagogical internship with an engineering and technology focus. Following the theory of interested parties by R. Freeman [18], we turn to the analysis of different texts (professional standards, educational standards, concepts, etc.) reflecting the interests of all subjects regarding the competency profile of a teacher with basic engineering education, ready to work with schoolchildren.

Materials and methods

The materials and research methods are selected according to the concept of R. Freeman's stakeholders and present the analysis of two groups of sources in relation to expected results indicated for them in engineering and technology teacher training internship programs. The first of them are presented by programmatic, regulatory documents and studies of domestic and foreign scientists on the implementation of continuous engineering training (including work on the career guidance of schoolchildren). The second group of sources includes research on the practice of pedagogical internship in Russia and abroad.

The initial idea for designing the model of pedagogical internship with an engineering and technology focus lies in the statement that it should be aimed at developing some universal and professional (pedagogical and engineering pedagogical) competencies of interns needed for their active professional activities and social life, regardless of further spheres of employment in various types of educational organizations.

In this regard, analytical work has been carried out to emphasize the general requirements for representatives of engineering and technological areas in professional activity both from employers' side and from the point of view of the system registering the results of mastering academic programs in professional engineering education. In this view, the Federal State Educational Standard of Higher Education for engineering

areas and specialties of training, mainly implemented by universities in Krasnoyarsk was analyzed, as well as professional standards for the relevant specialties and specialties that are in demand in the regional labor market.

Moreover, we have analyzed the documents of UNESCO [19] and OCED [20] concerning the selection of key competencies required for the life in modern society, as well as strategic documents of the Government of the Russian Federation and the Krasnoyarsk region concerning development prospects that directly or indirectly reveal requirements for a modern citizen of the Russian Federation. In total, about 150 documents have been analyzed.

The second idea concerned the selection of educational results, reflecting the willingness to perform labor activities according to the professional standard "Teacher" and "Teacher of additional education for children and adults", which ensure the implementation of professional pedagogical activities in the field of pre-specialized, specialized and additional education in the field of engineering. For this purpose, at the intersection of labor activities and the requirements of the international standard of engineering preparation CDIO [5], the corresponding pedagogical and engineering pedagogical competencies have been selected.

The model of the pedagogical internship based on educational results has been designed by analyzing internationally recognized effective educational practices of intensive training of teachers and engineers. The core idea of an open model of pedagogical internship is its focus on training teachers for engineering and technological education of schoolchildren (both within specialized engineering and technology classes and in additional education) who are ready to meet the requirements of the Federal State Educational Standards of General Education and Science and STI.

The results of the study

During the study the requirements for training and personal characteristics presented in each and all governing documents were specified. The requirements similar in meaning but formulated in a different way were united in single semantic groups. Then the clustering process was carried out, which means that more specific and narrow characteristics were combined into more generalized competencies (Table 1).

Table 1

Universal Competencies of an Internship Graduate and Indicators of their Achievement

Code and name of a universal competence	Code and name of the indicator of achievement of a universal competence	Basis
UC-1. Able to determine the tasks of professional and personal development, engage in self-education, consciously plan advanced training	(UC-1.1) Knows: the requirements of the Federal State Educational Standard of Higher Education and professional standards in terms of professional competencies and professionally important personal qualities; goals and final result of their professional growth and personal development. (UC-1.2) Able: to carry out a current analysis of their own capabilities, internal strengths, weaknesses, external threats; identify "points of success" and "points of growth"; set priorities in achieving the goals of their professional growth and personal development; establish the sequence and timing of the implementation of the tasks; make a selection of specific techniques, methods and types of activities for self-development. (UC-1.3) Masters: methods of setting goals and planning activities for their realization; skills in time management and organizing systematic activities focused on achieving professional and life goals.	Professional standards (engineering group), the Federal State Educational Standard of Higher Education, UNESCO materials

UC-2. Ready to work in a team	<p>(UC-2.1) Knows: basic norms of effective communication.</p> <p>(UC-2.2) Able: to make an adequate choice of the form of communication with a partner in a specific situation; to extract factual and evaluative information from oral speech (monologue, dialogue, discussion), defining the main topic, the assumptions, arguments, evidence, conclusions, assessments; to answer the questions aimed at clarifying facts, clarifying opinions; to ask questions aimed at clarifying factual information, developing a topic and / or discrediting a position; figure out and correlate points of views presented in a dialogue or a discussion; resolve conflicts in the team; create a good reputation of a team.</p> <p>(UC-2.3) Masters the skills to build relationships with communication partners based on collaboration; reasoned acceptance of the idea; maintaining a friendly atmosphere, good moral climate and a spirit of cooperation.</p>	Professional standards (engineering group), the Federal State Educational Standard of Higher Education, UNESCO materials
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As a result of the analysis of the Federal State Educational Standards of Higher Education in the sphere of ‘pedagogical education’, as well as professional standards “Teacher (pedagogical activity in the field of preschool, primary general, basic general, secondary general education) (educator, teacher)” and “Teacher of additional education for children and adults” the professional competencies of the internship graduate have been singled out. They allow to implement pedagogical, project and research types of professional activities of a teacher (Table 2).

Table 2

Pedagogical Competencies of an Internship Graduate and Indicators of their Achievement

Code and name of a universal competence	Code and name of the indicator of achievement of a universal competence	Basis
PC-1. Able to implement educational programs according to the requirements of federal state educational standards	<p>(PC-1.1) Knows: taught subject; psychological and pedagogical basis and modern educational techniques; features of the organization of the educational process in accordance with the requirements of educational standards.</p> <p>(PC-1.2) Able: to use pedagogically grounded forms, methods and techniques of organizing students' activities; apply modern educational technologies; create an educational environment helping to form students' educational results provided by the Federal State Educational Standard and (or) educational standards established by the educational organization, and (or) the educational program.</p> <p>(PC-1.3) Masters the skills of professional activities in the implementation of programs of academic disciplines.</p>	Professional standards “Teacher”, “Teacher of additional education for children and adults”
PC-2. Able to carry out the design of scientific and methodological and educational materials	<p>(PC-2.1) Knows: the requirements and approaches to the design and creation of scientific and methodological and educational materials; the procedure of the development and use of scientific, methodological and educational materials, exemplary or standard educational programs.</p> <p>(PC-2.2) Able: to develop new approaches and methodological solutions in the field of designing scientific, methodological and educational materials; to develop (update) exemplary or standard educational programs, exemplary work programs of training courses, disciplines (modules).</p> <p>(PC-2.3) Masters the skills to carry out activities for the design of scientific and methodological and educational materials in performing professional tasks.</p>	Professional standards “Teacher”, “Teacher of additional education for children and adults”
PC-3. Able to organize research activities of the students	<p>(PC-3.1) Knows: theoretical basis and techniques of organizing research and project activities.</p> <p>(PC-3.2) Able: to prepare design and research work taking into account regulatory requirements; offering students consultations at all stages of preparation and execution of project, research, scientific work.</p> <p>(PC-3.3) Masters the skills of organizing and conducting educational research, scientific-research, project and other activities in the course of performing professional functions</p>	Professional standards “Teacher”, “Teacher of additional education for children and adults”

Finally, it is necessary to reflect the specific character of the profile of teachers-mentors in the content of educational results. As a result, we have singled out two engineering and pedagogical competencies that have indicators of achievement defined relying on the analysis of professional standards, as well as CDIO Syllabus [5] which represents the requirements of employers for engineering education in the world presented by the list of personal, interpersonal competencies and professional skills (Table 3).

Table 3

Engineering and Pedagogical Competencies of an Internship Graduate and Indicators of their Achievement

Code and name of a universal competence	Code and name of the indicator of achievement of a universal competence	Basis
EPC-1. Able to develop a program for monitoring the educational results of students of specialized classes (routes) of engineering and technological direction	(EPC -1.1) Knows: principles for constructing measurement scales in pedagogical applied research; requirements of FSES of general secondary education (compulsory education), standards of engineering education CDIO (EPC -1.2) Able: to use diagnostic pedagogical tools for assessing subject and meta-subject results, tracking the dynamics of students' personal results (EPC -1.3) Masters the skills of presenting monitoring results to the subjects of educational process	Professional standards "Teacher", "Teacher of additional education for children and adults", CDIO Syllabus
EPC -2. Ready for organizational and methodological support for student teams to participate in the Olympiads and engineering contests	(EPC - 2.1.) Knows: psychological features of creative activity, communication of teenagers, principles of working in a team (EPC - 2.2.) Able: to develop a series of tasks for teamwork in the field of engineering and technological creative work (EPC - 2.3.) Masters: methods of active learning (brainstorming, discussion, organizational-activity game).	Professional standards "Teacher", "Teacher of additional education for children and adults", CDIO Syllabus

The study of foreign and domestic experience in implementing intensive teacher training ordered by the municipality, pedagogical internship [21], as well as the experience of continuing engineering education in the world, allowed us to identify specific practices that can be implemented while preparing engineers for working with students of pre-specialized and specialized classes with engineering technological focus. We correlated the practices with competency indicators that can be used to estimate their effectiveness (Table 4).

Table 4

Practices of Pedagogical Internship in Engineering and Technology Sphere

Practices	Justification for the introduction (analogue, link to research)	Competency indicators
Research and methodological seminar in the profile departments of the university (mathematics, technology and entrepreneurial management, physics, etc.)	CDIO Syllabus , STI, referendariat	UC-1.1 UC-2.2 EPC - 2.1. EPC -1.3 PC-2.1 PC-2.2

Engineering hackfests, STEM games	STI circle movement, STI Olympiad (task analysis)	UC -2.3 EPC - 2.3 PC - 1.3 PC - 3.3
Self-guided work in the information and activity environment (collecting documents for portfolio)	Self-guided work at the Center of Pedagogical Documentation training teachers in France	UC -1.2 UC -2.1 PC 1.1. PC 1.2. PC -2.1 PC -3.1 PC -3.3 EPC -1.1
Practice under the supervision of a mentor	All types of pedagogical internship	UC -1.3 UC -2.3 EPC -1.2 PC -2.2 PC -3.2 PC -1.3
Demonstrational examination	Materials of Worldskills Russia championships in the field of Teaching Technology competency, competitive referendar's exam	UC -1.3 EPC -1.1 EPC -1.3 EPC - 2.2 EPC - 2.3 PC -1.3 PC -2.3

Results discussion

The analysis of two-phase teacher training programs in France and the referendariat in German Federal Republic allowed us to single out the most important organizational and regulatory mechanisms, such as practices for the internship model as a network program for entering the teaching profession (when interacting with basic schools):

- internship with a combination of teaching without assistance and conducting lessons under the supervision of a mentor;
- scientific, methodological and practical seminars, the content of which is based on such urgent problems of school life as issues of administration, education (basic seminar) and issues of planning, evaluation, methodology of the subject (subject seminar with practice);
- multi-subject assessment of interns' lessons by theoretical and methodological seminars and by mentors (without giving marks);
- classes at the Center of Pedagogical Documentation for mastering the skills of self-guided work with databases and the use of digital educational resources are the mandatory and significant part of the intern training;
- final qualification exam consisting of work written at home, an examination on the teaching methodology (sketch and the lesson itself), a colloquium on a topic chosen by the intern completes the studying process. We use the concept of a demonstration exam following the practice of Worldskills Russia, as the ability to work with technological equipment is important for an educator in engineering and technology profile. These practices form both pedagogical and universal competencies (primarily, self-development competency).

The analysis of research conducted in the field of continuing engineering education, a study of the types of tasks at the STI Olympiads suggests the high effectiveness of practices

in participating in STEM games, as well as tutoring practices in engineering and robotic hackathons for children and teenagers in terms of building competencies for diagnosing students' abilities, assessing and developing tasks of an engineering and technological profile, support of teamwork.

Conclusion

The solution of the problem concerning theoretical grounds for developing intensive training models of pedagogical personnel while working with students in specialized classes of engineering and technology orientation seems possible on the basis of a comparative analysis of domestic and foreign experience in modern pedagogical and engineering education, among which the authors give priority to models of pedagogical internship and the CDIO concept. The model of the pedagogical internship within engineering and pedagogical sphere is designed according to the educational results, developed on the basis of clustering high-demand competencies from the parties involved in the development of engineering and technology pre-profile and profile general and additional education of students by trained teachers. There are eight key competencies identified as educational results. Universal, pedagogical and engineering-pedagogical competencies are formed during intensive training in an internship through humanitarian practices implemented in network interaction with organizations of general or additional education of the municipality: from internships under the supervision of a mentor, through independent work in the information and activity environment of the internship, STEM games and tutoring practices in engineering hackathons, finally - to passing the demo (qualification) examination in front of prospective employers. The method of designing a network model of an engineering-technology pedagogical internship can be used in any applied study while training teachers for solving economic strategic tasks through education.

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REFERENCES

1. Neumann K., Kind V., Harms U. Probing the Amalgam: the Relationship between Science Teachers' Content, Pedagogical and Pedagogical Content Knowledge. *International Journal of Science Education*, 2019, vol. 41, no. 7, pp. 847–861.
2. Ruhf R.J., Jenness M., Oppliger D. Evaluating Impact of Student Team-Based STEM Projects and Research: Successes and challenges. *A Summary of a Panel Presentation at the American Evaluation Association Evaluation 2015 Annual Conference Chicago*, Illinois, November 2015. Available at: https://www.researchgate.net/publication/304325084_Evaluating_Impact_of_Student_Team-Based_STEM_Projects_and_Research_Successes_and_challenges (accessed 5 March 2020).
3. The STEM Education Coalition. Available at: <http://www.stemedcoalition.org/> (accessed 5 March 2020).
4. Kukreti A.R., Broering J. An Entrepreneurship Venture for Training K–12 Teachers to Use Engineering as a Context for Learning. *Education Sciences*, 2019, no. 9 (1). 54. Available at: <https://www.mdpi.com/2227-7102/9/1/54> (accessed 5 March 2020).
5. Crowley E., Malmqvist S., Broder D., Edstrom K. Rethinking Engineering Education. The CDIO Approach. Moscow, HSE Publishing House, 2015. 503 p.
6. Merzlyakova D.R., Miroshnichenko A.A. Development of Teaching Methods for Schoolchildren in Specialized Engineering and Technology Classes. *Modern High Technology*, 2018, no. 10, pp. 211–215.

7. Graskin S.S., Graskina E.E. A Conceptual Model of the System Matrix in Pre-profile Engineering Training for Schoolchildren. *Modeling and Design in the Educational Environment: Materials of the 4th All-Russian (with international participation) Scientific-practical, Methodological Conference for the Scientific and Pedagogical Community*, April 5, 2019, pp. 69-74.
8. Soloviev A.N. Preparing Students for Engineering Education in Moscow and the USA. *Automobile. Road. Infrastructure*, 2017, no. 1 (11). Available at: <https://www.adi-madi.ru/madi/article/view/347> (accessed 5 March 2020).
9. Chernova I.P., Osipova S.I., Gafurova N.V., Lyakh V.I. Innovative Practice of Specialized Education Focusing on the Needs of Corporations in the Region. *Higher Education Today*, 2012, no. 8, pp. 10-16.
10. Chayka A.N. Quantorium as a New Russian Means of Additional Engineering Education for Children. *Scientific and Methodological Journal "Science and Education: New Time"*, 2017, no. 3 (4), pp. 122-124.
11. Makhotin D.A. Engineering Training in Technological Education of Students. *Kazan Pedagogical Journal*, 2016, no. 2, vol. 2, pp. 301-305.
12. Gracheva E.Y., Luchkina T.V. The Role of a Teacher Education Center in Professional Activities of Novice Teachers in Germany. *Professional Education in Russia and Abroad. Scientific and Educational Journal*, 2014, no. 1 (13). Available at: [http://www.krirpo.ru/prof-obr/Archives/1\(13\)2014.pdf](http://www.krirpo.ru/prof-obr/Archives/1(13)2014.pdf) (accessed 5 March 2020).
13. Sidorkin A. Jessica will not be a Teacher. The American Teacher Training System has Improved Thanks to Advances in Science and Common Sense. *School Management. The First of September*, 2014, no. 4, pp. 50-51.
14. Zabrodin Y.M., Sergomanov P.A., Gayazova L.A., Leonova O.I. Development of the Differentiation System of Skill Levels in Teaching Professional Standards, 2015, vol. 20, no. 5, pp. 65-76.
15. Gevorkyan E.N., Savenkov A.I., Egorov I.V., Vachkova S.N. Internship as a Form of Organization of Post-graduation Practice in the System of Higher Professional Education. *Vestnik Moscow City Teacher Training University*, 2013, no. 2, pp. 32-43.
16. Semenova Y.I. Professional Teachers' Training System in France. *Higher Education in Russia*, 2009, no. 10, pp. 126-132.
17. Minyurova S.A., Leonenko N.Y. Pedagogical Internship: a University Innovative Project. *Higher Education in Russia*, 2015, no. 10, pp. 38-46.
18. Freeman, R. Edward and McVea, John, A Stakeholder Approach to Strategic Management (2001). Darden Business School Working Paper No. 01-02. Available at: <https://ssrn.com/abstract=263511> (accessed 5 March 2020).
19. Delors J. et al/ Learning, the treasure within: Report to UNESCO of the International Commission on Education for the twenty-first century. Paris: UNESCO Publishing, 1996. Available at: <http://www.unesco.org/delors/fourpil.html> (accessed 5 March 2020).
20. Trends Shaping Education 2019. OECD Publishing Paris: Available at: https://doi.org/10.1787/trends_edu-2019-en (accessed 5 March 2020).
21. Bocharova Y.Y., Lomasko P.S., Simonova A.L. A Content and implementation model of integrated training in digital pedagogical competences of teachers-mentors and students-interns. *Bulletin of Krasnoyarsk State Pedagogical University named after V.P. Astafiev*, 2018, no. 3 (45), pp. 6-19.

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