Practice-oriented model of training students in physics at a technical university

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Abstract. The purpose of the report is to examine and justify the feasibility of practice-oriented teaching of physics in the training of engineers. A training model (at the level of physics), including such structural components as a model of a specialist’s activity, a model of practice-oriented learning, a structural model of cognitive activity and independence, the technology of their formation, the result of preparation lies in our research. This model is being tested at Almaty University of Power Engineering and Telecommunications for bachelors studying in telecommunications and energy.

1. Introduction

Practice-based educational research is increasingly gaining momentum in the field of education due to its clear intention to develop and contribute new trends in educational practice. Practical and theoretical researchers play an equality role in the process of sharing, constricting, and creating knowledge for the development of practice and theory. Unlike traditional or “theory-based learning” practical-based learning requires the students to learn and apply theory from the very beginning in a real work environment [1-3]. Modernization of Kazakhstan education should correspond to the world trend of professionalization of engineers' training which is aimed at strengthening the practical orientation of educational programs. A new directions in the technology of the educational process are very slowly implemented in practice in our country. The transformation of the university into a modern dual system is associated with a very low level of readiness of the majority of students to study in new conditions, especially those who have graduated from Kazakh schools. This provision determines the huge demand for the definition of new educational models for the development of an active and independent student already in junior courses, focused on mastering their practical skills in the subject being studied.

In order to prepare a successful technical specialist for areas of industry and the skillful use of competencies in a future career, it is necessary to determine the knowledge, technical and professional skills. Therefore, practice-oriented teaching of basic disciplines (in our case, physics course) is the main condition and environment, forming the main motives of students' independent cognitive activity (CA) [4-6]. The problem of increasing the learning and CA of students is addressed in many studies on pedagogy [7-10]. The implementation of the duality of training at junior (first and second) courses is complicated by the fact that students begin to acquire practical skills in the field of their specialty in production or in laboratories that are equipped with equipment after studying the subject of physics. Practice-based learning enables students to enhance their knowledge and skills but also adapt to an ever-changing
environment. At the same time, it is possible to make the transition to such training while using the principles of a personal activity, professionally directed training (PDT) and practice-oriented training (POT) in the context of a model of a specialist in technical profile (for example, the model of activity of power engineering, heat power engineering, in the field of telecommunications, etc.). In this article, we present a practice-oriented model of training in the preparation of engineers through a course in general physics. A learning experiment was conducted at Almaty University of Power Engineering and Telecommunications (AIPET). It should be noted that the University is one of the few universities in Kazakhstan that prepares highly qualified specialists in energy, telecommunications throughout the Central Asian region. Testing of the model was carried out in a group of students in the direction of Automation and Control (AuC). Questionnaire, observation, interviews and counseling were used to diagnose CA of students in accordance with the methodology for diagnosing CA. Diagnosis activated twice: during the development of a discipline at the level of input control and at the end of the semester of training. Practice-oriented model of training is a pedagogical approach where students study through a theoretical course while working on a more real problem and producing workable end results.

2. Generalized model of activity of a specialist in the field of energy and telecommunications

The construction of a practice-oriented learning process makes it possible to bring the content of preparation to their future profession as close as possible through a system of learning objectives, formulated in the language of typical tasks of the discipline, determined from the model of the specialist’s activities [11-12]. The developed model (Fig.1), as can be seen, consists of four blocks, reflecting respectively the object, fields of activity, types and generalized tasks of professional activity. We have previously developed and published common points of this model [13]. The model consists of four blocks, reflecting respectively the object, areas, types and generalized tasks of professional activity. We considered this model as an example of training students in the bachelor's degree in Automation and Control in the Fuel and Energy Complex. Next, consider these blocks in more detail.

As an object of activity of a bachelor, the following aspects were highlighted
a) The technological process of production and transmission of heat and electric energy, and reception, processing and storage of information,
b) Electric and heat power equipment of these systems,
c) Various types of information about these systems and their operating modes,
d) Information systems of automation and control in the fuel and energy complex.

The fields of activity are characterized by the commonality of the production functions of the cumulative bachelor of a given profile and determine his theoretic readiness and organizational field in
the production process. They constitute the functional component of the model, which includes the theoretical, research and organizational and managerial functions of the future graduate.

A joint examination of the subject and functional patterns of activity allows us to determine the main types of professional activities of the bachelor, and through them to identify generalized professional tasks. The main activities of a specialist in the field of Automation and Control in the fuel and energy complex include general culture, professional and special. Professional and special types of activities include service and maintenance, production and technology, design and experimental research.

Analysis of information on the activities of specialists in industry and academic institutes allowed us to single out the generalized tasks of professional activity in the field of Automation and Control in the Fuel and Energy Complex, the use of which is possible in teaching physics. We have chosen the most basic tasks. This is

- Identification and formulation of actual scientific problems,
- Diagnostics and control of physical processes and phenomena using instrumentation,
- Theoretical study of systems for the generation and conservation of energy,
- Creation of models for the description of physical phenomena,
- Identification of the essence of the design of devices with specified parameters,
- Experimentation,
- Search, collection, processing, analysis and systematization of information on the research topic,
- Preparation of reviews, reports and papers.

3. The scheme of interrelation of the components of the model of practice-oriented learning
The projection of the developed model onto the field of physic education made it possible to design a holistic educational process and build an appropriate generalized training scheme at the discipline level including such structural components as a specialist’s activity model, a model of PDT, a structural model of students’ cognitive activity, technology of POT and the result of training (Fig.2).

![Figure 2. The scheme of interrelation of the components of the model of POT](image)
Considerable attention is paid to PDT, the goals and objectives of which are determined from the model of a specialist, as shown in Figure 2. The content of training is determined, the teaching and learning activities of students are regulated, and the methods, forms and means of training are selected as ways of organizing the educational activities of students in accordance with the objectives of the PDT (Fig. 3) [13]. The content of the training is syllabus. Also, diagnosis and control of the model is carried out.

4. Methodology
The KASE (knowledge, abilities, skills and experience of practice-oriented educational activities) system is used with this approach, which is currently accepted in our country. The block of POT technology is presented (Fig. 2) in this regard. This block involves the implementation of the PDT model through its goals and objectives, the content and organizational and methodological support of the educational process, which is complemented by practice-oriented content when studying a physics course.

Figure 3. Scheme of the content and structure of POT physics

The construction of a physics course using training goals, obtained on the basis of knowledge of the professional tasks of the specialty, focuses the content and a teaching technology on future professional activities based on the idea of the unity of fundamental and applied knowledge, taking into account the role of physics in the development of automation and control of production processes. The content of lectures and practical classes, laboratory and independent work with practical content are used for this. An example is not only the selection of the content of the lecture material, but also the use of demonstration material in the form of computer presentations (slides, videos) reflecting the modern
application of certain laws and phenomena in energy production, automation and control of production processes in the heat and power complex. Moreover, presentations are prepared by students themselves on a given topic [14]. The problems in physics have practical content and are focused on the use of the laws of physics in various branches of the heat and power industry, for example, the tasks of obtaining thermal energy, converting it into electrical energy and distribution, conservation and possible losses.

We attract students to the scientific work of the department. Here they develop working schemes and installations, participate in conferences and exhibitions with independently manufactured installations in various areas of physics, but related to their practical application in automation and control systems of the fuel and energy complex, and modern science [15-16]. In addition, laboratories exist at the university, where students can receive working professions in the field of heat and electric power, and can view and work on the simplest schemes and installations that reflect the basic laws and phenomena of physics in practice [17-19]. This gives them the opportunity to participate in the famous WorldSkills championships in our country and abroad [20].

Cognitive activity of students was evaluated in the conditions of POT physics in order to diagnose changes in the quality characteristics of students' personalities, namely the occurrence, growth and development of GA formation levels [21]. In this regard, the level structure of GA was revealed on the basis of the following components.

- Needs, motives, interests make up the motivational component. This ensures that the student is included in the process of active learning throughout the educational activity.
- The cognitive activity component assumes the assimilation of knowledge and manifests itself in the independent realization of their capabilities, demonstrates qualities such as a steady interest in the profession, involvement in practice-oriented educational activities, perseverance and determination in achieving results.
- Evaluation component. The presence of this component is associated with the ability to adequately control, analyze and evaluate students the effectiveness of their activities.

Four activity levels were determined based on these components.

*The excellent level* of activity is characterized by the constancy of interests and the desire not only to penetrate deeply into the essence of physical phenomena and their interconnections, but also to find other ways of practical activity to achieve the goal.

*The good level* of activity is characterized by the desire of students to identify the meaning of physical laws, the desire to learn the connections between phenomena and processes, to master the ways of applying knowledge in new practical conditions. This level is characterized by the constancy of volitional efforts, the desire of students to achieve their goals when completing tasks.

*The satisfactory level* of activity is characterized by the desire of students to understand physical laws, the desire to learn and understand the relationship of discipline with future practical activities, but students lack the constancy of volitional efforts, the desire to achieve a higher level of assimilation and application of knowledge in practice.

*The critical level* of student activity is when they try only to remember and reproduce knowledge, apply it only according to the model, that is, they show a greater degree of reproductive activity. This level is characterized by the inconsistency of students' efforts, their lack of interest in deepening knowledge. Students are not interested in the relationship of physical phenomena with practice in life.

Knowledge of the level structure of cognitive activity made it possible to substantiate the methodology for diagnosing changes in the qualitative characteristics of the student’s personality in practice-oriented educational activities in the conditions of POT.

### 5. Results and discussion

Cognitive activity (CA) of students was assessed by us in quality characteristics in order to diagnose changes in their personality of students in POT conditions. The study was conducted in an experimental group on the basis of the Almaty University of Power Energy and Communications in 2017-2018, 2018-2019. The experimental group was trained in the direction of automation and control.

Diagnostics of students was carried out twice during the study of the general course of physics:
1) Starting diagnosis at the level of input control for the formation of CA;  
2) Final process diagnostics.  

Tables 1.1 and 1.2 show the distributions of students of the experimental 3 groups by CA levels (starting and final stages of diagnosis, respectively), and the corresponding diagram is presented in Figure 4.

The results appeared to confirm the assumption that the absence of a specially organized teaching technology in junior courses affects the formation of CA students. So, at the beginning, 58% of students showed a low level of activity, the middle level of activity was shown by 25% of students, the enough level is 10%, and the high level is only 8%.

These data led us to the conclusion about the need for special purposeful work in the conditions of a baccalaureate of a technical university for the formation of CA.

### Table 1.1. Starting diagnostics in the experimental group by CA levels.

| Classes   | low | middle | enough | high |
|-----------|-----|--------|--------|------|
| AuC-18-1 | 60  | 20     | 12     | 8    |
| AuC-18-2 | 59  | 25     | 8      | 8    |
| AuC-18-3 | 55  | 30     | 11     | 4    |
| The average | 58 | 25     | 10     | 7    |

### Table 1.2. Final diagnostics in the experimental group by CA levels.

| Classes   | low | middle | enough | high |
|-----------|-----|--------|--------|------|
| AuC-18-1 | 16  | 16     | 44     | 24   |
| AuC-18-2 | 20  | 13     | 50     | 17   |
| AuC-18-3 | 15  | 15     | 52     | 18   |
| The average | 17 | 14     | 49     | 20   |

**Figure 4.** The diagram of the distribution of students by levels of CA. Here, the vertical axis measures the number of students, in %, and the horizontal shows axis the levels of CA.
The success of the training was calculated through the total student rating, which was determined on the basis of summing up the grades given in percent using weighting coefficients. The value of the weight coefficient depends on the timeliness of the student passing the current control, laboratory and independent work, tasks of the midterm control and exam. The value, equal to the ratio of the total student rating to the maximum possible value, was used as an individual criterion for the overall success of this student. We divided the range of possible values (from 0.4 to 1) into four intervals and received four groups of students whose indicators correspond to the following levels of learning success in the context of POT: from 0.4 to 0.54 this is a critical level, from 0.55 to 0.69 is satisfactory, from 0.70 to 0.84 is good and 0.85 to 1 is an excellent level of learning success. Table 2 illustrates the distributions of students in the group by the success of training (starting and final stages of diagnosis), the corresponding diagram is shown in Figure 5.

Table 2. Students distribution by success rate.

| Classes  | critical | satisfactory | good | excellent |
|----------|----------|--------------|------|-----------|
|          | starting | final        | starting | final | starting | final |
| AuC-18-1 |  8       |   4          | 28     |   4     | 56       | 56    |
| AuC-18-2 | 17       |  12          | 46     |  21     | 29       | 42    | 8     |  36  |
| AuC-18-3 | 26       |  11          | 45     |  15     | 25       | 56    | 4     |  18  |
| The average | 17       |  9           | 39     | 13      | 37       | 51    | 7     |  26  |

Figure 5. Student distribution chart for student success. The vertical axis measures the number of students, in %, and the horizontal axis shows the levels of student success.

Intermediate results were diagnosed in accordance with the goals for the entire semester. Transformations into the model of a specialist’s activity at the technology level are possible if the learning outcomes do not meet the training requirements (for example, low results by levels). Amendments to the model are envisaged in case of changes in the requirements on the part of customers (employers) to the personal qualities of graduates (levels of cognitive activity) or the conditions of activity of future specialists.

6. Conclusion
The presented technology of practice-oriented training of future specialists at the level of a general physics course showed good results. This can be seen from the dynamics in the levels of success of
training and levels of cognitive activity of students. We used the experimental methodology during 2017-2018 and 2018-2019, since the physics course at AIPET covers one academic year for two semesters. The first year was experimental for testing the methodology itself. As shown by the dynamics in the levels of learning success and levels of cognitive activity of students, the developed technology of practice-oriented training of future specialists can be used not only at the level of physics, but also at the level of methodology and technology in POT to other disciplines, taking into account the peculiarities of their content and organizational and methodological educational process support.

7. References
[1] Billett S 2010 Learning Through Practice. Models, Traditions, Orientations and Approaches (Springer Science+Business Media B.V.) p 288
[2] Chandler P. and Sweller J 1991 Cognition and Instruction 8 293
[3] Shukshina T I, Gorshenina S N, Buyanova I B and Neyasova I A 2016 Intern. J. of environm. & science educ. 11 9125
[4] Higgs J, Barnett R, Billett S, Hutchings M and Trede F (Eds.) 2012 Practice-Based Education (The Netherlands: Sense Publishers) p 26
[5] Pokholkov Yu P, Rozhkov S V, Tolkacheva K K 2013 Inter. Conf. on Interactive Collaborative Learning (IEEE Computer Society) p 619
[6] Yu Wang, Ying Yu, Nan Xie, Chun Xie, Xiao Feng 2012 Frontiers in Computer Education, AISC 33 (Berlin: Springer-Verlag Heidelberg) p 105
[7] Lajoie S P, Azevedo R, Fleiszer D M 1998 J Educ Comput Res. 18 205
[8] Bordovskaia N et al 2016 Procedia - Social and Behavioral Sciences 217 26
[9] Kameneva G A, Bondarenko T A 2018 Bulletin of the Novosibirsk State Pedag. Univ. 8 4 172 (in Russian)
[10] Andrews T M, Leonard M J, Colgrove C A, & Kalinowski S T 2011 CBE-Life Sciences Education, 10, 394
[11] Kale U, Selmer S 2014 The International Journal of Adult, Community, and Professional Learning 20 3 25
[12] Groothuijzen S E A, Bronkhorst L H, Prins G T. & Kuiper W 2019 Research Papers in Education DOI: 10.1080/02671522.2019.1633558
[13] Mazhitova L H, Salamatina A M, Binazarov C A and Nauryzbayeva G K 2017 Bulletin of AIPET 2 57 (in Russian)
[14] Mazhitova L H, Syzdykova R N 2018 Vestnik AUES 2 71
[15] Imanbayeva A K, Syzdykova R N and Temirbayev A A 2018 Journal of Physics: Conf. Series 1136 012029
[16] Imanbayeva A, Temirbayev A, Syzdykova R, and Saduev N 2018 Proc. of EDULEARN18 Conf. (Spain: IATED) p 9919
[17] Zhukeshov A M, Gabdullina A T, Amrenova A U, Moldabekov Zh, Fermakhan K 2016 J Lecture Notes in Computer Science 1 9254 475
[18] Gabdullina A, Zhukeshov A, Amrenova A, Adambek G, Mukhamedryskzyzy M, Fermakhan K, Yengay V 2018 Proc. of EDULEARN18 Conf. (Spain: IATED) p 2575
[19] Turekhanova K, Akimkhanova Zh, Gani J 2019 Recent Contributions to Physics 2 69 146
[20] https://worldskills.org/
[21] Mazhitova L H, Nauryzbayeva G K 2013 Bulletin of the Academy of Pedagogical Sciences of Kazakhstan 2 19