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Formation of technical competencies of undergraduate students in higher education

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Abstract

This study explores how university students develop technical competence to meet societal and industry demands, with a particular emphasis on their ability to set goals, organize group work, and plan technical activities. A comprehensive model of students' technical competence is proposed, comprising three key components: technological, informational, and value-motivational. The research findings, illustrated through detailed tables and diagrams, reveal the varying levels of students' technical competence. The experiment confirmed the hypotheses about the necessity of developing technical competence and established a clear link between the effectiveness of training and the proposed criteria-based structure. Ongoing research is focused on designing a professionally oriented, pedagogical training framework to further enhance competence in this discipline.

Keywords: Diagnostics; profession; student; technical competencies; university.

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1. INTRODUCTION

From the perspective of the theory of personality development, personality-oriented, personality-activity, and competency-based approaches, social aspects of innovative activity, dynamic characteristics of educational technologies, and level of formation knowledge, skills, and abilities of future professional activity, the works of domestic and foreign scientists and educators reflect a wide range of ideas about the content and structure of technical training of specialists. Among these, the development of specialist competence is given a lot of attention, as it is essential to successful professional activity. It is also noted how vital it is for engineers to be able to successfully carry out their professional duties that specialists with the necessary technical competence be available.

Existing approaches to the formation and development of technical competencies (systemic, personal activity, competence) consider various models of their formation in the educational process of the university, (Rihter, 2016). In the present study, the researchers propose the use of professionally directed training, in which technical competencies are formed through the educational process, focused on the content of education and the organization of students' activities in the context of the professional tasks of the future graduate. In this case, the model of training students in the system of higher technical education will reflect the object of activity of the future graduate by the structure of the studied personality quality. In this regard, the object of research in our case is a professionally oriented educational process, and the subject is the formation of technical competencies of students.

Establishing an environment in which students can develop technical competence is therefore one of the main goals of higher education. The researchers previously came to the following conclusion after conducting a theoretical analysis of psychological and educational literature: technical competence is a complex of knowledge, skills, and personal attributes that determine the efficacy of engineering work based on the application of scientific and technical knowledge in production and intended to advance research and improve engineering objects (technical systems and technological processes) (Nauryzbayeva, Mazhitova, 2019; Nauryzbayeva, Mazhitova, 2018; Ageeva, 2004).

Furthermore, technical competence (TC) enables the establishment and management of group production and technical activities for the creation and upkeep of social-technical needs (demonstrating a proper attitude toward technology and the appropriate handling of tools, machinery, and materials; adhering to safety regulations; upholding order at work; exercising caution when using tools, machinery, and materials; adopting a thrifty approach to resources; and so forth) (Moore & Thaller 2023).

1.1. Literature review

According to a review of recent literature on national pedagogy, competence is defined as the integrity of one's knowledge, abilities, and acquired skills. Competence is also viewed as a component of an ideal entity. Several works address this subject. In the university's educational process, these works deal with the construction of the learning process and the definition of technology for the progressive formation of technical competencies (FTC).

As per the pedagogical encyclopedia, "competence" encompasses not only purely professional knowledge and skills but also an amalgam of interrelated personal qualities (knowledge, skills, and ways of doing things), specified about a specific circle of objects, processes, and necessary about them high-quality productive activity. These attributes include initiative, teamwork, learning, evaluating, rational thought, selecting, and applying information.

Arabadzhi (2010) and Zenani et al., (2023) claim that competence establishes the caliber and degree of professional preparedness for tasks, such as labor, and the capacity to solve problems logically in the face of a variety of challenges. The creation of the pedagogical foundation for students' competencies (FC) as an integral system in combination with skills in harmony with the educational and creative process is the focus of several dissertations (Atlyaguzova, 2011).

There are variations in how the phenomenon being studied is interpreted in the writings of foreign authors. For instance, Sanchez & Ruiz (2008) state that the term "competence" is frequently used to characterize human resources and to evaluate an individual's productivity. They define competencies as a collection of connected knowledge and abilities that influence work performance and are correlated with its effectiveness. In this instance, competence is defined as the ability to assign to the qualities that underpin the behavior and as the behavior that supports this field of activity.

Put another way, competence is the conduct that a person displays when performing production activities in a specific company. These characteristics are made feasible by maintaining a consistent code of conduct, course of action, and organizational structure for productive work. They are also causally related to the realization of particular results (successes) through particular activities. This indicates that there is proof that the efficiency of production activities is predetermined and influenced by the possession of specific competency traits (Boyatzis, 1982).

The researchers believe that the abilities required to get the intended outcome are the fundamental basis of behavior. Competence is what a person can show that they can be identified, assessed, and developed with. Using criteria and indicators, it is simple to identify and quantify some desired competency traits. Many scholars, though, consider this to be a challenge. Simultaneously, it is evident that certain professionals' actions are more successful than others. Through competency measurement, all the contributing elements to an expert's increased productivity can be identified and analyzed.

As a result, the word "competence" has multiple meanings and situations in foreign sources. Technical competencies are categorized into three groups in Byham's (1996) work: Characteristics that enable people to compete; The abilities and competencies an expert must possess to function well in carrying out official responsibilities and production tasks; Personal elements that allude to abilities, accomplishments, and outcomes of human endeavor.

Consequently, technical competence is defined by the authors as the integration of the individual specialist, his awareness, and his actions in relation to the communication and activity processes (Byham, 1996). Technical abilities are interpreted as follows in Borisova's (2006) work:

1. Acquiring the knowledge, abilities, and skills required for the work in the specialty; maintaining flexibility and autonomy in handling work-related issues; cultivating a professional interpersonal environment and collaborating with colleagues.

2. Creating standards, or "elements of competence," which comprise the following: - application area; - performance requirements (a metric of quality); - necessary knowledge.

3. The efficient application of skills that enable you to successfully complete professional tasks in accordance with workplace standards. The professional triangle of "knowledge-skills-skills" is thus only one aspect of competencies; the other includes formal and informal knowledge and know-how (behavior, fact analysis, decision-making, information processing, etc.).

According to Borisova's (2006) research, the term "technical competence of the student" refers to a complex integrated system of personal and professional qualities of a future specialist, characterizing the state of an individual's development (self-development), reflecting the synthesis of technical knowledge, skills, and intellectual abilities, as well as a set of value orientations, motives, and needs of a student's professional self-improvement.

After examining the methodological and axiological underpinnings of engineering, Ageeva (2004) concludes that technical competence refers to the talents, knowledge, and skills required for personnel to carry out their official responsibilities in an efficient manner. These competencies are distinct from others since they pertain to the specific knowledge and skill set. A person's knowledge must be applied to their talents and abilities in order for them to do their work effectively. Technical capabilities, meanwhile, are described as follows:

1. Application of the information and abilities required for productive work in a particular position or set of workspaces within an organization. They have a lot in common with the abilities and know-how required to be successful in particular fields.

2. Use to construct high-priority job profiles that emphasize the "soft skills" and "know-how" required for effective work, in addition to general or interpersonal competence.

3. The aptitude to differentiate between tasks within the functional domain (Aldous, 2000).

Thus, according to an analysis of psychological and pedagogical literature, technical competence is defined as an individual's knowledge, skills, and abilities that support them in acting appropriately in accordance with production activity requirements, solving professional tasks in the field of technical work in an organized manner, analyzing questions and problems independently of others, and being ready for their professional role in a particular area of technical labor. From a psychological perspective, being willing to engage in professional activities is defined as having specialized knowledge and abilities that enable one to perform tasks at the level required by contemporary science and technology.

Drawing from the analysis, the following conclusion may be made: Technical competence is an amalgamation of abilities, aptitudes, and character traits that establish the efficiency of engineering endeavors. It is focused on the development, exploration, and improvement of engineering objects, such as technological systems and processes, and is based on the application of scientific and technical knowledge. Technical competencies facilitate goal-setting and the coordination of group production and technical operations to meet the public's technical needs. According to Mukhalalati et al. (2024), these include maintaining workplace order, exhibiting the appropriate attitude toward technology, handling tools, equipment, and materials with care, abiding by safety regulations, allocating resources, and creating a secure and comfortable work environment.

Scientists' considerable interest in the technical competence issues that have surfaced in recent decades can be explained by the fact that human technological capacity has grown dramatically on a global scale as a result of the advancement of science and technology (Soliz, 2023). Technical advancement is increasingly playing a significant role in the socioeconomic growth of society due to the close relationship between technical competencies, and all other areas of human material production (Shi & Bangpan 2022).

While acknowledging the scientific and practical significance of the results from the previously mentioned studies, it is crucial to emphasize that, despite the considerable interest expressed by scientists and the significance of the findings to date, the problem of students' acquisition of technical competencies during the learning process has not yet been sufficiently resolved. It is unclear how students can form technical competencies on natural science object matter based on the content types (generalized) tasks of future experts' professional work, as well as how to develop the essence and criterion-level structure of the phenomenon under study.

As for the junior course system currently in use for training future specialists, an examination of university experiences shows that it does not give special consideration to students' formation and development of technical competencies, and an examination of students' spontaneous formation within the parameters of the educational process shows that it falls short of modern standards.

The lack of theoretical and pedagogical foundations for students' technical competency formation, the absence of technology to track the quality of professional training received by students at technical universities, and a lack of basic understanding of how the establishment of technical competencies necessitates the use of specially designed measures to ascertain the educational conditions are some of the reasons, in our opinion, why there aren't any effective approaches to developing technical competencies in students. The analysis reveals that there is no systematic approach to the definitions of the terms "competence" and "competency" in the literature since there is no theory or practice of pedagogy of technologies and techniques of their production under the conditions of training technical specialists. It specifically relates to undergraduate student preparation for the teaching of natural science courses;

1. Each student is distinguished by the existence of his or her knowledge and abilities, by the personal traits that have been "honed" during training exercises, by their attitude toward the institution, by their leadership, and by their capacity to "fit in" with the university's environment. The idea of student competencies is made up of all these factors (Armstrong & Baron 2005).

Technical competence is highly relevant because it pertains to a student's or specialist's capacity to perform tasks and duties in both every day and professional contexts. It also involves the combination of particular personality traits and a high degree of technical preparedness for professional activities to enable successful interactions with educators and future colleagues.

As a result, one of the most crucial aspects of a student's personality is technical proficiency. Both substantive (knowledge) and procedural (skills) components make up competencies since a competent learner is able to solve an issue in practice in addition to comprehending its nature. According to research on cutting-edge technologies in higher education, TC students are critical to the success of their training and their subsequent professional endeavors (Mazhitova & Nauryzbayeva, 2010). For this reason, TC student formation must start at the undergraduate level in order to increase educational process quality and efficiency.

1.2. Purpose of study

The definition of technology for the gradual formation of technical competencies (FTC) in the university's educational process and the construction of the educational process is closely related to the diagnosis of the phenomenon under study and, as a result, the identification of the structure and formation levels of technical competencies of university students in undergraduate conditions. In this study, natural science subjects like physics can be used as an example to start the FTC process in elementary schools. One of the main goals of the study is to ascertain the standards and parameters for the development of technical competence, which is a top priority for students in higher education.

2. MATERIALS AND METHODS

The present study defined the working definition of the quality under study, technical competence, as the personality quality that refers to an individual's potential ability and willingness to handle professional tasks that arise in the course of work and form the basis of value attitude, by relying on the fundamental ideas of the theory of personality and activity (Aldous, 2000; Atlyaguzova, 2011).

The theory of the competency-based approach and professionally directed training (PDT) of bachelors served as the foundation for the development of the matrix model of technical competence (TC) of university students (Arabadzhi, 2010; Armstrong & Baron, 2005). This allowed us to add the value-motivational, substantive, and technological components as three parts of technical abilities.

The professional orientation of the personality, which reflects the value orientations of the personality, and the drive to complete professional and academic duties in line with the selected professional activity are how the value-motivational component of TC is expressed. Theoretical and empirical knowledge, or scientific theories, laws, and facts about natural processes and their properties, as well as information about the profession and the activities of a specialist in the creation and upkeep of energy objects and the standards for evaluating it, comprise the substantive part of technical communication.

2.1. Procedure

The technological component of technical competency calls for the capacity to apply newly learned knowledge to operational and practical actions for a given scenario pertaining to future labor activity as well as educational and cognitive activity during the training period. The researchers determined their criteria and indicators based on the examination of research on the development of technical competencies and the definition of what constitutes a technical competency (Borisova, 2006; Byham, 1996).

According to the researchers' methodological positions, "technical competencies" as a personality quality are formed in a single process of student personality formation, that is, in the holistic pedagogical process of technical college. Therefore, the criteria should reflect those ways of students' activity, mastery of which will allow them to effectively solve the problems of professional activity in the future. It should be noted once again that the researchers considered the possibility of forming a TC in a professionally oriented educational process using the example of the disciplines of the natural science cycle (physics).

Theoretical and empirical knowledge, or scientific theories, rules, and principles, as well as information about natural processes and their characteristics, about the profession, constitute the substantive part of TC. Therefore, the researchers identify the student's independence, activity, and drive for goal-achieving in all types of professionally directed training (PDT) as the first criterion. The attitude toward learning and future professional activities through PDT, as well as the knowledge and comprehension of the personal attributes required by the profession, are indicators of this.

The second requirement is knowledge of the role and importance of a specialist in the energy sector in the contemporary cooperative environment, as well as proficiency with self-educational activity techniques. The degree of awareness of the need to master the knowledge system for successful professional activities in the future, the emphasis on learning how to cooperate in the student group during the educational process, and staff practice in mastering self-educational and remedial activity techniques are the indicators of this criterion.

The third criterion pertains to an individual's self-perception regarding their future professional endeavors. Students gain theoretical knowledge in academic fields and develop a value-related attitude toward their eventual job as a result of professionally focused training. Additionally, students have the ability to assess and assess themselves. The following are indicators of this criterion: a drive for achievement; familiarity with the demands and traits of the field and one's own abilities; and an evaluation of one's own professional significance (Mazhitova & Nauryzbayeva, 2010; Zvezdova, 2012).

By the selected criteria, appropriate indicators were developed that can be presented in the form of a matrix model that reflects not only the qualitative characteristics of the phenomenon under study and its main forms of manifestation and significant quantitative characteristics (Table 1).

Table 1

Matrix model of technical competencies.

Indicators TC **Criteria in the formation of TC**	**Components**		
	Value-motivational	**Content**	**Technological**
Activity and independence in PDT and the desire to achieve the goals	Willingness to learn, understanding the need for volitional tension and personal development	The presence of knowledge, and skills in specialized disciplines.	Ability to translate subject knowledge into practical actions with a focus on future specialty
Awareness of the role, function, and significance of a specialist in the energy specialty in the modern world, mastering the methods of self-educational activity	A positive, interested attitude to the object of future professional activity, the attitude towards obtaining a modern technical education	Mastering the system of natural science knowledge in PDT for successful training in a specialty	The ability to systematize and structure knowledge gained during the search for information for self-education
Attitude to oneself as to the subject of future professional activity.	The desire and focus on achieving success, knowledge of their capabilities by the level of education	Mastering the methods of obtaining knowledge in the process of PDT and applying them in a future profession by the requirements	The ability to analyze and evaluate the results of educational and cognitive activities, to adjust and make changes; self-esteem

We identified four levels based on the idea we used to organize the TC of the students: high, sufficient, medium, and low.

The presence of a recognized need for professionally focused knowledge in the subject and a steady, positive attitude toward academic and future professional activities describe students with a high level of TC formation. At a high level, the student understands the value of collaboration and professional communication in their future professional endeavors and is already proficient in working in groups and pairs to conduct business with teachers and other students, effectively using knowledge to complete challenging cognitive and educational tasks. Being able to discriminate between one's ideal and actual self enables one to assess your potential to develop your inner world and enhance your attributes in an unbiased manner. Active, deliberate self-education is required for this. The student connects his life and career goals at a high level of TC.

A sustained high level of cognitive activity that contributes to the mastery of a normative given system of knowledge is indicative of an adequate level. An optimistic outlook on future professional endeavors and adequate preparation for training indicates that the student understands the significance of his chosen career path. Personality qualities affect how issues and circumstances are resolved in the future, successfully utilizing knowledge to complete the discipline's educational and cognitive tasks, though teacher assistance is necessary (Zheng et al., 2024). Capable of assessing the outcomes of their endeavors.

The willingness to master future professional activities is expressed situationally at the medium level and is driven by the desire to achieve an appropriate social status. It is typified by the presence of an overall positive attitude toward university studies and future professions.

The low level is characterized by the presence of a vaguely shaped positive desire for learning, the student understands the importance of having technical competencies, but there are significant difficulties in achieving them, therefore, student activity in making decisions to carry out self-assessment of their capabilities is rarely manifested.

Thus, by the criterion-level structure of students' TC, not only the indicators of their formation, which are presented in Table 1 but also TC levels are determined. The TC model of technical university students that we developed allows us to consider the mechanism of development of the phenomenon under study. Knowledge of this mechanism makes it possible to identify methods, means, and forms of the phased formation of TC in the educational process of the university in undergraduate conditions and use it to improve the quality of training of specialists in the system of technical education.

3. RESULTS

In this sense, the researchers created the technology that will enable students in junior courses at a technical university to effectively form their technical competencies based on professionally directed education, orienting all training components toward the acquisition of the competencies required of the future specialist to perform professional activities. Technical competencies, on the other hand, are a collection of interconnected knowledge, abilities, methods of operation, and character traits that establish how well problems are solved during the course of productive work. Competence is also a set of guidelines that specify exactly what a student must have in order to plan their professional actions going forward. By using this technology, a student who is placed in a new learning environment can successfully adjust to it and integrate professional knowledge, skills, and abilities if their university activities help them become ready to meet the requirements of the university. In other words, it should be done in a way that specifically creates pedagogical conditions for the development of technical competencies that help them achieve this.

The present study's approach to developing technical competencies is centered on using professionally led training that is targeted toward the area in which an expert will be working in the future. With the use of this technology, educational settings are created that facilitate students' convergence of their cognitive and academic activities with those of their future profession, which serves as the foundation for the construction of the TC. If the teaching techniques and material are based on the competence-based approach to professional training, which is based on the model of the specialist's work, then the construction of the TC in the circumstances of the preparation of university students can be efficiently executed.

The competence approach in pedagogy is evident in scientific works (Armstrong & Baron 2005). By simulating learning processes, one can establish a methodological foundation for vocationally-directed physics learning, which effectively helps to resolve the conflicts arising from physics' dual position in a technical university. When the professional orientation of physics instruction is addressed, it refers to how the subject matter is organized and how learning is accomplished in ways that match the methodical logic of designing a physics course and mimic the practical and cognitive tasks of a specialist's future work.

A study based on Almaty University of Power Engineering and Telecommunication (AUPET), which trains qualified specialists primarily in three areas electric power engineering, heat power engineering, and telecommunications was carried out in the second semester of the 2018–2019 academic year. The incredibly fast changes occurring in all fields of modern science, engineering, and technology are one reason why TC students need to be formed among students. As a result, there was experimental work done on the creation of student TCs in the training groups of the institutes of information technology, control systems, heat power and heat engineering, and electric power and electrical engineering. We conducted an initial experiment and looked at the prospects of organizing TCs from university students in the areas of automation and control, the heat power industry, and the electric power industry. The ascertaining experiment's objectives were to determine the students' TC formation levels and to investigate the viability of utilizing the indicators and suitable diagnostic instruments that were chosen for our model. A number of intricate techniques were employed in the experiment, such as testing, observation, and questionnaires.

The results of the determination of the student's TC levels are shown in Table 2.

This study's hypothesis that the lack of a specifically designed teaching methodology in junior courses influences the development of students' TCs was supported by the initial ascertaining experiment results: for instance, 62.3% of students at the Institute of Electrical and Power Engineering (IEPE), 54.1% of students at the Institute of Heat Power Engineering and Heat Engineering (IHPEHE), and 51.6% of students at the Institute of Control Systems and Information Technologies (ICSIT) demonstrated low levels of TC, with average levels of 32.4%, 39.7%, and 35.6%, respectively. Based on these findings, the researchers concluded that the institution needed to make specific, intentional efforts in the creation of the TC. Our additional research is to define its forms, procedures, and substance.

Table 2

Determination of students' TC levels.

Institute name	Results of a starting experiment by levels, %			
	low	medium	sufficient	high
IEPE	62,3	32,4	4,4	-
IHPEHE	54,1	39,7	8,1	-
ICSIT	51,6	35,6	9,6	-

The effectiveness of student learning is a key determinant of the validity of the suggested FTC approach. The researchers thought about considering the overall student rating in this regard. Thus, the registrar's office (RO) staff computes the so-called total student rating twice a year after the exam session ends in compliance with AUPET policy. The examination grades, which are expressed in percentage terms using weighting factors, are added up for this computation. The disciplinary cycle, the student's timely completion of the graphic and settlement work, the exam or defense, and the laboratory work all affect the weight coefficient's value. The researchers suggest utilizing a particular student's total rating as a measure of their overall success, calculated as the ratio of that student's rating to its maximum value at that point. The criterion in question is deemed fully compliant with the requirements, as it utilizes objective diagnostic methods to assess all potential types of current, midterm, and final controls. These results are somehow reflected in the examination assessment. Additionally, even though the criterion does not cover every aspect of the student's characteristics, it is still highly informative. Exam results also take into account the organization of a student's cognitive and educational activities in addition to his artistic pursuits. Because of this, this criterion can serve as a somewhat accurate indicator of a student's accomplishment. The researchers can determine four student performance groups by dividing the possible value range (from 0.4 to 1) into four equal intervals: critical performance, which falls between 0.4 and 0.54, satisfactory performance, which falls between 0.55 and 0.69, good performance, which falls between 0.70 and 0.84, and excellent performance, which falls between 0.85 and 1.

Table 3 shows the distribution of students by levels of TC and learning success.

Table 3

Distribution of students by the levels of TC and learning success.

Levels TC	Learning success levels				Total	
	critical	satisfactory	good	excellent	students	in %
low	8	8	1	-	17	16,4
medium	2	28	10	-	40	38,79
sufficient	-	1	18	22	41	39,8
high	-	-	-	5	5	4,91
Total	10	37	29	27	103	100

Figure 1

Three-dimensional diagram of student's distribution by TC levels and learning success.

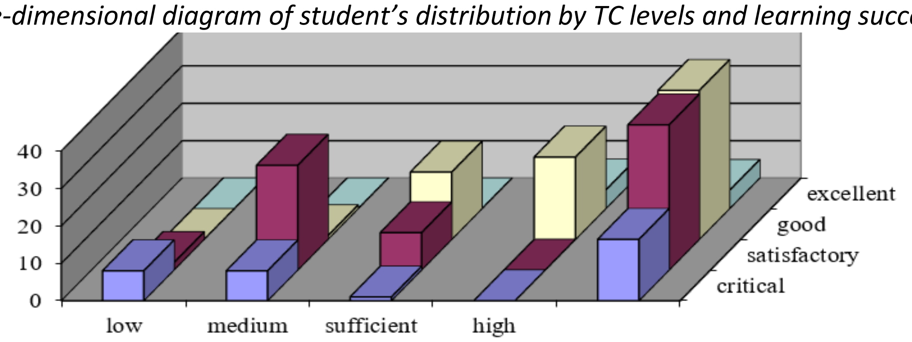

Figure 1 shows a three-dimensional diagram, from which it can be seen that students with a low level of TC show a low level of success in learning, and vice versa, students with sufficient and high levels of this quality achieve correspondingly higher rates of success in learning. This result is also confirmed by the calculation of the Pearson correlation coefficient for the entire sample (volume 110), which turned out to be +0.65, which indicates the presence of a strong direct relationship between the two given characteristics.

4. CONCLUSIONS

The study defined the term "technical competencies" based on a theoretical analysis of psychological and pedagogical literature. A preliminary student survey revealed that students' technical competencies can and should be developed in junior university courses as they study natural science disciplines (in our case, physics as an example). In this sense, we support the creation of technology that fosters the development of technical competencies in a learning environment under professional guidance. So, in order to ascertain the objectives of training in the language of professional duties in production, teachers must create a model of future bachelor's activities. Training objectives will be able to diagnose the development of technical competencies by identifying the content, organizational and methodological support, and criterion-level structure of the educational process for the formation of technical competences.

Thus, the results of the analysis of literary sources on the studied phenomenon and ascertaining experiment showed the validity of the researchers' assumptions regarding the need to form technical competencies and proved the existence of a connection between the criteria-level structure of TC presented by the researchers, and the success of the training. Analysis of the correlation coefficient indicated a strong direct relationship between the level of technical competencies and rates of success in learning.

Further studies should be devoted to the development of a training model in the above discipline based on professionally oriented training.

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