DEVELOPMENT AND IMPLIMENTATION OF THE CDIO APPROACH IN KUBAN STATE TECHNOLOGICAL UNIVERSITY

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ABSTRACT

The paper presents undergraduate, graduate and postgraduate engineering programs of the Kuban State Technological University redesigned as “engineering triads” based on the CDIO Standards, as well as on the FCDI and FFCD models, developed as a result of the CDIO approach evolution. The methodology for developing the FCDI and FFCD models is based on the specifics of engineering activities of the MSc and PhD program graduates. In the continuation and extension of the CDIO model mostly focused on complex engineering activity of the BEng program graduates, the FCDI and FFCD models consider innovative engineering activity and research engineering activity as priorities for MSc and PhD program graduates, respectively. The CDIO Standards and newly developed FCDI and FFCD Standards were used for the design of undergraduate, graduate and postgraduate engineering programs ensuring the consistency and continuity of the 3 cycles of graduate training for complex, innovative and research engineering activities.

KEYWORDS

Engineering programs, cycles, redesign, evolution, CDIO Standards: 1 – 12.

INTRODUCTION

Kuban State Technological University (KubSTU) is one of the largest research, educational and cultural centers in the South of Russia (http://kubstu.ru/en). The University trains engineers for high-tech industry and offers 31 undergraduate programs, 26 graduate programs and 56 postgraduate programs. In January 2018, at the CDIO European Regional Meeting KubSTU was presented as a potential collaborative member of the Worldwide CDIO Initiative.

One of the most important challenges for KubSTU in the near future is the modernization of undergraduate (BEng), graduate (MSc) and postgraduate (PhD) engineering programs based on the CDIO Standards, as well as on the FCDI (Forecast, Conceive, Design, Implement) and FFCD (Foresight, Forecast, Conceive, Design) models developed as a result of the CDIO approach evolution (Chuchalin, Daneikina and Fortin, 2016, Chuchalin, 2018).

The redesign of KubSTU engineering programs will be carried out in the conditions of bringing programs in line with the requirements of the new version of the Russian Federal State Educational Standards (FSES 3++) introduced in 2017 (http://fgosvo.ru/fgosvo/151/150/24). A peculiarity of the process is as follows: BEng, MSc and PhD engineering programs will be redesigned *simultaneously* as “*engineering triads*”.

The main idea is to ensure the *consistency* and *continuity* of training of graduates of programs of 3 cycles to *complex*, *innovative* and *research* engineering activities, respectively.

The process of modernization of KubSTU engineering programs will be carried out progressively. To start with, "engineering triad" in the field of Food Production Technologies is to be redesigned. Engineering programs leading to BEng, MSc and PhD degrees in "Technologies of food production from plant raw materials" (specialization: oil & fat, and perfume-cosmetic products) have been selected as pilot programs. The CDIO model is well known and widely used for the design of undergraduate engineering programs (Crawley et al., 2014). The FCDI and FFCD models were developed recently by analogy with CDIO model to ensure *better adaptation* of the CDIO approach to *graduate* and *postgraduate* engineering education (Chuchalin, 2018).

FCDI MODEL

The *FCDI (Forecast, Conceive, Design, Implement)* model was developed to design *graduate* (MSc) engineering programs. A FCDI program is based on the principle that *innovative* product, process, and system lifecycle design and development – Forecasting, Conceiving, Designing and Implementing is an adequate competence model. The "Forecast" stage includes analyzing the market trends; making predictions of future customer needs; estimating risk and uncertainty; determining the most demanded and competitive innovative products, processes, and systems. The "Conceive" stage includes feasibility study; modelling and simulation; development of advanced technique and technology; assessment of the economic impact of innovations; planning and creation of R&D resources for innovative product, process, or system design. The "Design" stage focuses on designing & developing of innovative product, process, or system taking into consideration severe limitations. The "Implement" stage mainly refers to the production management when implementing innovative projects, as well as controlling of advanced technology when manufacturing and coding. The absence of "Operate" stage in the FCDI model indicates that this kind of engineering activity (operation and maintenance of products, processes and systems) is not a priority for MSc program graduates.

The FCDI Syllabus v1, as a result of the evolution of the list of learning outcomes (LOs) presented in the CDIO Syllabus v2 (Crawley et al., 2014), was developed recently (Chuchalin, 2018). It focuses the attention of the MSc engineering program designers on the need to provide Masters with a deeper interdisciplinary scientific and technical knowledge (i.e. in-depth knowledge of mathematics, natural and engineering sciences; methods of innovative activity), as well as professional competences to forecast customer needs in innovations and to conceive, design and implement new products, processes and systems (i.e. analytical study and solution of innovative problems; systematic innovative thinking; forecasting and innovation management; leadership in innovative technical enterprise; innovative technological entrepreneurship, etc.).

The FCDI Standards v1 were developed as a result of the evolution of the CDIO Standards (Chuchalin, 2018). In particular, they focus the attention of the MSc engineering program designers on integrated curriculum with mutually supporting interdisciplinary courses, innovation activity with an explicit plan of integration of personal and interpersonal skills, and innovative product, process, and system design and development skills based on forecasting the stakeholders' needs (Standard 3 FCDI). The essential elements of the curriculum should be an introductory workshop that provides the framework for engineering practice in innovative product, process and system design and development based on forecasting the needs of stakeholders (Standard 4 FCDI); innovation-design experiences (Standard 5 FCDI); teaching and learning based on active and innovative methods (Standard 8 FCDI).

FFCD MODEL

The *FFCD (Foresight, Forecast, Conceive, Design)* model was developed to design *postgraduate* (PhD) engineering programs. A FFCD program is based on the principle that *creation of scientific basis* for the development and design of innovative product, process, and system lifecycle – Foreseeing, Forecasting, Conceiving and Designing is an adequate competence model. The "Foresight" stage includes future study; long-term vision; analyses of the society needs; research & innovation planning; technological foresight; analyses of "critical" technology. The "Forecast" stage includes knowledge management; research and new knowledge generation; critical analyses of scientific data; assessment of knowledge-intensive technology needs. The "Conceive" stage includes creation of scientific basis for the development and design of innovative product, process, or system; development of new technique and technology based on up-to-date knowledge. The "Design" stage focuses on scientific support of knowledge-intensive innovative product, process, or system design and development. The absence of "Implement" stage in the FFCD model indicates that participation in the production of products, processes and systems is not a priority for PhD program graduates.

The FFCD Syllabus v1 was developed as a result of the evolution of the list of LOs presented in the FCDI Syllabus v1 (Chuchalin, 2018). It focuses the attention of the PhD engineering program designers on the need for PhD-holders to acquire new scientific and technical knowledge (basic and applied sciences; engineering and research methods), as well as professional competences to create scientific basis for the development and design of innovative product, process, and system (i.e. analytical study and solution of scientific problems; experimentation, research and generation of new knowledge; systematic scientific thinking; critical analysis of the existing scientific data and results of own research; foresight and research management; leadership in the research enterprise, as well as research entrepreneurship, etc.). The acquisition of pedagogical competences is also important for graduates of PhD programs.

The FFCD Standards v1 were developed as a result of the evolution of the FCDI Standards v1 (Chuchalin, 2018). In particular, they focus the attention of the PhD engineering program designers on integrated curriculum with mutually supporting transdisciplinary courses, research and pedagogic activities with an explicit plan of integration of personal and interpersonal skills, abilities to create scientific basis for innovative product, process, and system design and development using the methods of technological foresight (Standard 3 FFCD). The essential elements of the curriculum should be an introductory seminar that provides the framework for engineering practice in creation of scientific basis for innovative product, process, and system design and development (Standard 4 FFCD); research-design experiences (Standard 5 FFCD); teaching and learning based on active and research methods (Standard 8 FFCD).

BENG PROGRAM CURRICULUM DESIGN

The objectives of the BEng program “Technologies of food production from plant raw materials” based on the KubSTU mission and the CDIO Standards are as follows:
1. Graduates should have world-class competences and high civil responsibility necessary for *complex* engineering activity in the field of food production from plant raw materials.
2. Graduates should be able to solve *complex* engineering problems associated with food production to ensure the technological development of the Kuban Region and Russia.
3. Graduates should be able to conduct engineering activity at the stages of *conceiving, designing, implementing* and *operating* of food production technologies.
4. When *conceiving* graduates should be able to study the needs of consumers, assess the technological capabilities, determine the production strategy, carry out conceptual, technical and business planning.
5. When *designing* graduates should be able to take into account the needs of consumers and technological capabilities of production, create technological documentation, develop algorithms and product descriptions.
6. When *implementing* graduates should be able to use advanced materials and techniques, develop appropriate software, conduct testing and verification of products.
7. When *operating* graduates should be able to use modern food technologies, comply with the standards of health protection, environmental safety and provide recycling of products with the cessation of its harmful effects on the environment.

The diagram in the Figure 1 illustrates orientation of the 4-year (240 ECTS) BEng program LOs to C-D-I-O stages of complex engineering activity. It follows from the diagram that 15% of intended LOs (36 credits) will provide graduate competencies required for activity at the “Conceive” stage, and 25% of LOs (60 credits) are focused on the “Design” stage. The areas of priority for BEng graduates are “Implementation” (30% of LOs or 72 credits) and “Operation” (30% of LOs or 72 credits).

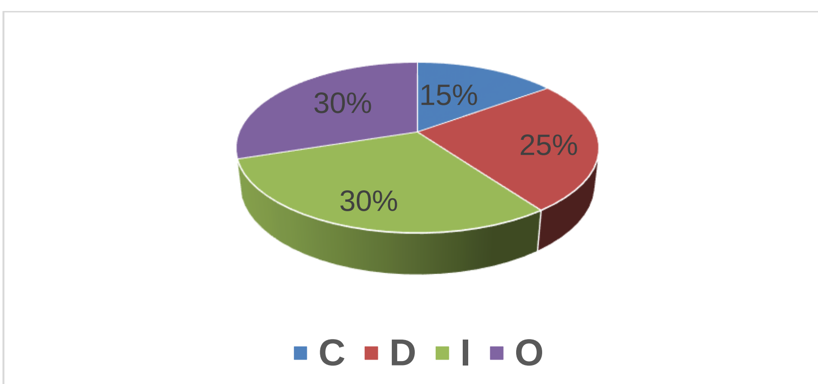

Figure 1. Orientation of BEng program intended LOs to C-D-I-O stages of complex engineering activity

The designers of BEng program have used the methodology developed within the framework of the implementation of the joint TPU-SKOLKOVO project of modernization of undergraduate engineering education on the basis of international standards (Chuchalin, 2013).

Table 1 shows the structure of BEng program corresponding to the C-D-I-O orientation (Figure 1) and meeting the FSES 3++ requirements. The program consists of three blocks of curriculum elements. Block 1 includes disciplinary (BEng1 – BEng3) and interdisciplinary

(BEng4 and BEng5) modules, Block 2 provides internship (BEng6), and Block 3 includes the final project, as well as the final examination (BEng7). The program is implemented in two phases. In the first phase (1^{st} and 2^{nd} years of study), mainly general scientific and general engineering training is provided. In the second phase (3^{rd} and 4^{th} years of study), professional training is provided, taking specialization into account.

Table 1. The structure of BEng program in ECTS credits

	Block 1					Block 2	Block 3
	Disciplinary modules			Interdisciplinary modules		Internship	Final project & exam
	BEng1	BEng2	BEng3	BEng4	BEng5	BEng6	BEng7
First phase of training	21	54	22	6	8	9	-
Second phase of training	9	6	3	20	58	15	9
BEng1 – module of social sciences & humanities BEng2 – module of natural sciences & mathematics BEng3 – module of basic engineering science BEng4 – module of mandatory courses BEng5 – module of variable courses							

The diagram in the Figure 2 shows the contribution of BEng program modules to LOs focused on C-D-I-O stages of complex engineering activity. It follows from the diagram that the greatest contribution to the preparation of graduates to activity at the “Conceive” and “Design” stages is made by module BEng2 (natural sciences & mathematics), followed by module BEng1 (social sciences & humanities) and module BEng3 (basic engineering science).

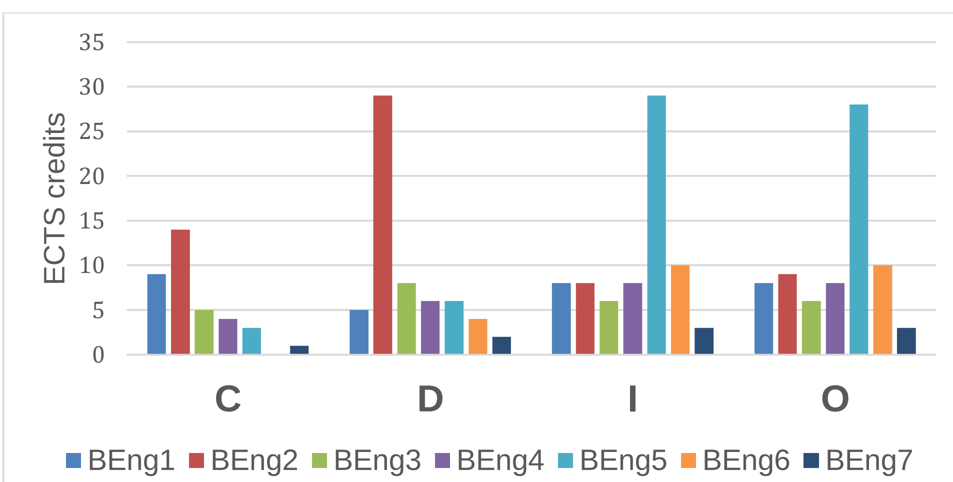

Figure 2. The contribution of BEng program modules to LOs focused on C-D-I-O stages of complex engineering activity

The greatest contribution to the preparation of graduates to activity at the “Implement” and “Operate” stages is made by module BEng5 (variable courses), followed by module BEng6 (Internship). At the same time, it follows from the diagram that each module of the integrated curriculum contributes to the preparation of BEng program graduates for complex engineering activity at all stages.

MSC PROGRAM CURRICULUM DESIGN

The objectives of the MSc program “Technologies of food production from plant raw materials” based on the KubSTU mission and the FCDI Standards are as follows:
1. Graduates should have world-class competences and high civil responsibility necessary for *innovative* engineering activity in the field of food production from plant raw materials.
2. Graduates should be able to solve *innovative* engineering problems associated with food production to ensure the technological development of the Kuban Region and Russia.
3. Graduates should be able to conduct engineering activity at the stages of *forecasting, conceiving, designing* and *implementing* of food production innovative technologies.
4. When *forecasting* graduates should be able to analyze trends in the market, investigate prospective customers' requests, assess risks and uncertainties, determine the most demanded and competitive products.
5. When *conceiving* graduates should be able to assess the high-tech capabilities, determine the innovative production strategy, create R&D resources for innovation design, assess economic impact of innovations.
6. When *designing* graduates should be able to focus on the consumer needs and high-tech capabilities, design and develop innovations taking into consideration severe limitations.
7. When *implementing* graduates should be able to manage production process and control advance technology.

The diagram in the Figure 3 illustrates orientation of the 2-year (120 ECTS) MSc program LOs to F-C-D-I stages of innovative engineering activity. It follows from the diagram that 20% of intended LOs (24 credits) will provide graduate with competencies required for activity at the “Conceive” stage, 25% of LOs (30 credits) are focused on the “Implement” stage and 25% of intended LOs (30 credits) are focused on the “Forecast” stage. The area of priority for MSc graduates is the “Design” stage (30% of LOs or 36 credits).

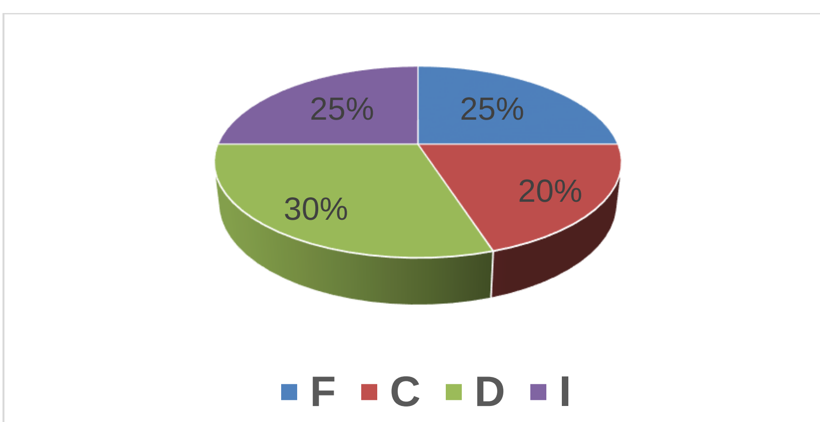

Figure 3. Orientation of MSc program intended LOs to F-C-D-I stages of innovative engineering activity

Table 2 shows the structure of MSc program corresponding to the F-C-D-I orientation (Figure 3) and meeting the FSES 3++ requirements. The program consists of three blocks of curriculum elements.

Table 2. The structure of MSc program in ECTS credits

	Block 1				Block 2	Block 3
	Disciplinary modules		Interdisciplinary modules		Internship & research	Final project & exam
	MSc1	MSc2	MSc3	MSc4	MSc5	MSc6
First phase of training	13	15	12	-	20	-
Second phase of training	2	-	8	8	33	9
MSc1 – module of fundamental sciences MSc2 – module of fundamental engineering MSc3 – module of mandatory courses MSc4 – module of variable courses						

Block 1 includes disciplinary (MSc1 and MSc2) and interdisciplinary (MSc3 and MSc4) modules, Block 2 provides internship & research (MSc5), and Block 3 includes the final project (thesis), as well as the final examination (MSc6). The program is implemented in two phases. In the first phase (1st year of study), mainly fundamental scientific and fundamental engineering training is provided. In the second phase (2nd year of study), professional training is provided, taking specialization into account. The diagram in the Figure 4 shows the contribution of MSc program modules to LOs focused on F-C-D-I stages of innovative engineering activity.

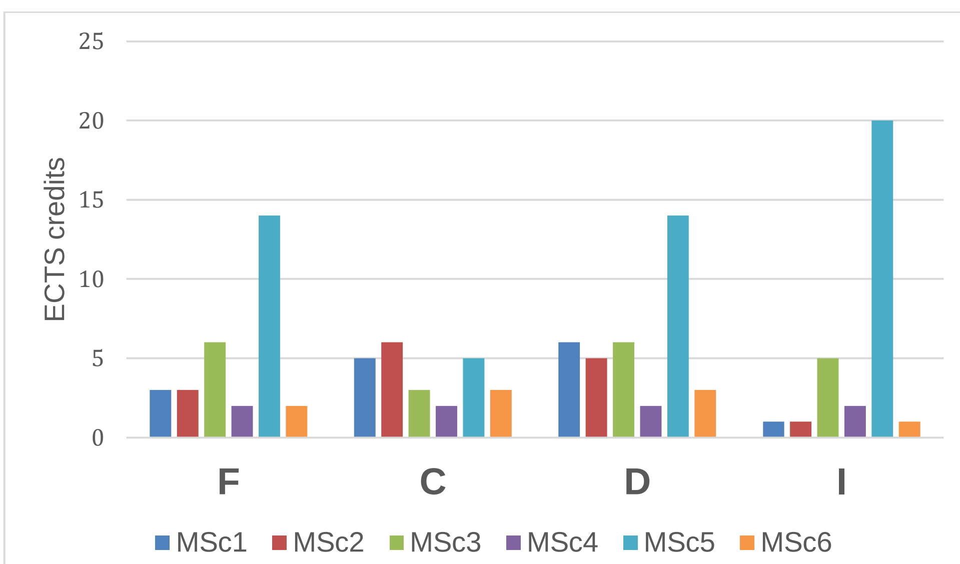

Figure 4. The contribution of MSc program modules to LOs focused on F-C-D-I stages of innovative engineering activity

It follows from the diagram that the greatest contribution to the preparation of graduates to activity at the “Forecast”, “Design” and “Implement” stages is made by module MSc5 (internship & research), followed by module MSc3 (mandatory courses). The contribution of module MSc1 (fundamental science) and module MSc2 (fundamental engineering) is very important to the preparation of graduates to activity at the “Conceive” and “Design” stages. The diagram shows that all modules of MSc program integrated curriculum contribute to the preparation of graduates for innovative engineering activities at all stages.

PHD PROGRAM CURRICULUM DESIGN

The objectives of the PhD program “Technologies of food production from plant raw materials” based on the KubSTU mission and the FFCD Standards are as follows:
1. Graduates should have world-class competences and high civil responsibility necessary for *research* engineering activity in the field of food production from plant raw materials.
2. Graduates should be able to do engineering *research* associated with food production to ensure the technological development of the Kuban Region and Russia.
3. Graduates should be able to conduct engineering activity at the stages of *foreseeing, forecasting, conceiving* and *designing* of food production innovative technologies.
4. When *foreseeing* graduates should be able to carry out scientific foresight of the future of industrial food production and biotechnologies, analyze the society needs, plan research and innovations, implement a technological foresight and analyze "critical" technologies.
5. When *forecasting* graduates should be able to manage knowledge, do research and generate new knowledge, assess needs in knowledge-intensive technology for innovation development in food production.
6. When *conceiving* graduates should be able to create scientific basis for innovative food technology design, develop new technique and technology based on up-to-date knowledge in the area of food production.
7. When *designing* innovative technology of food production, graduates should be able to provide scientific support and expand technological capabilities of production.

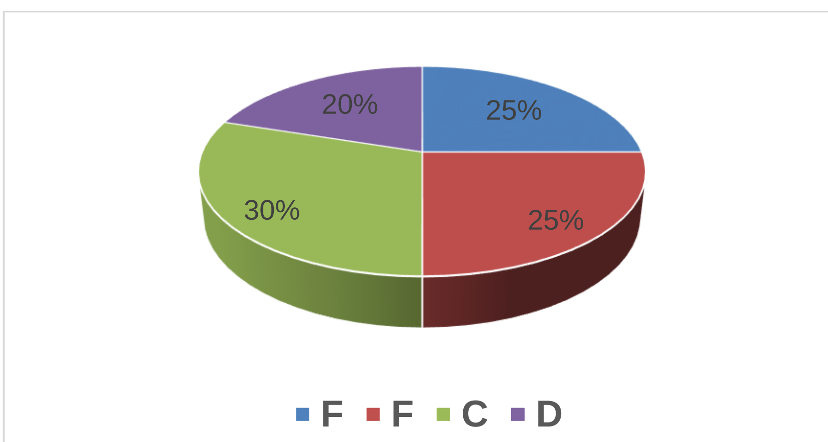

Figure 5. Orientation of PhD program intended LOs to F-F-C-D stages of research engineering activity

The diagram in the Figure 5 illustrates orientation of the 4-year (240 ECTS) PhD program LOs to F-F-C-D stages of research engineering activity. It follows from the diagram that 25% of intended LOs (60 credits) will provide graduate competencies required for activity at the “Foresight” stage, 25% of LOs (60 credits) are focused on the “Forecast” stage, and 20% of intended LOs (48 credits) are focused on the “Design” stage. The area of priority for PhD graduates is “Conceive” stage (30% of LOs or 72 credits).

Table 3 shows the structure of PhD program corresponding to the F-F-C-D orientation (Figure 5) and meeting the FSES 3+ requirements. The program consists of four blocks of curriculum elements. Block 1 includes disciplinary (PhD1 and PhD2) and transdisciplinary (PhD3 and PhD4) modules, Block 2 provides pedagogic internship (PhD5), Block 3 envisages research (PhD6), and Block 4 includes thesis preparation (PhD7). The program is implemented in two phases. In the first phase (1^{st} and 2^{nd} years of study), fundamental sciences and engineering sciences are studied, as well as transdisciplinary courses are mastered. At the same time, PhD students perform a large amount of research. The second phase of the program (3^{rd} and 4^{th} years of study) is mainly focused on research in the area of specialization.

Table 3. The structure of PhD program in ECTS credits

	Block 1				Block 2	Block 3	Block 4
	Disciplinary modules		Transdisciplinary modules		Internship	Research	Thesis
	PhD1	PhD2	PhD3	PhD4	PhD5	PhD6	PhD7
First phase of training	9	7	8	6	-	90	-
Second phase of training	-	-	-	-	2	109	9
PhD1 – module of fundamental sciences PhD2 – module of fundamental engineering sciences PhD3 – module of mandatory transdisciplinary courses PhD4 – module of variable transdisciplinary courses							

The diagram in the Figure 6 shows the contribution of PhD program modules to LOs focused on F-F-C-D stages of research engineering activity. It follows from the diagram that the research (PhD6) is dominant in the preparation of graduates for activity at all stages. However, all modules of the PhD program curriculum contribute to integrated learning experience of PhD students. Modules of fundamental sciences (PhD1) and fundamental engineering sciences (PhD2) consist of the courses providing the necessary theoretical basis for further research in the area of specialization. Modules of mandatory (PhD3) and variable (PhD4) transdisciplinary courses deepen the knowledge necessary to achieve new scientific results in the research area. Pedagogical internship (PhD5) is an indispensable attribute of the PhD program mastering.

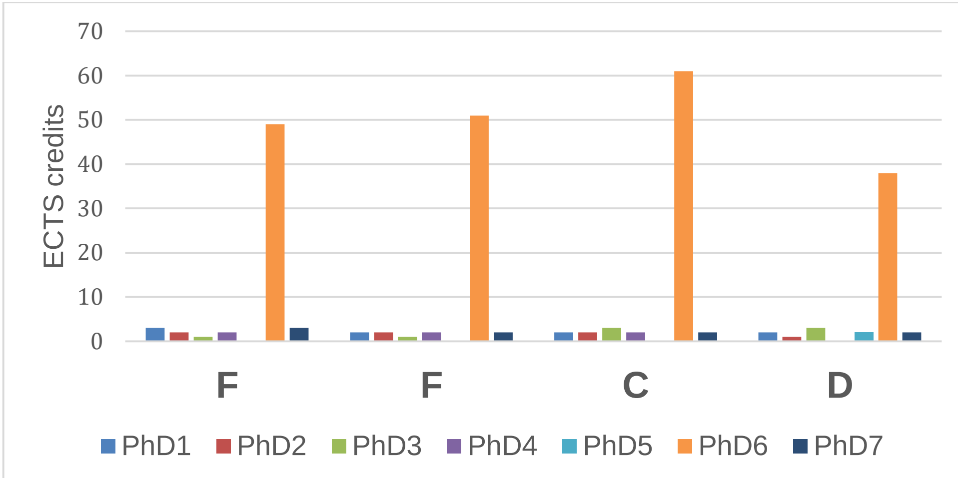

Figure 6. The contribution of PhD program modules to LOs focused on F-F-C-D stages of research engineering activity

CONCLUSION

Modernization of the engineering programs in the field of Food Production Technology simultaneously at 3 cycles of higher education (undergraduate, graduate and postgraduate) based on the CDIO, FCDI and FFCD models is the first experience of practical application of the FCDI Standards and FFCD Standards developed by analogy with CDIO Standards. The programs are being prepared for implementation at Kuban State Technological University in the next academic year. The results of the implementation of the programs redesigned as engineering "triads" will be discussed with the CDIO Worldwide Initiative community in the future. In the case of positive experiment results, the CDIO, FCDI and FFCD models will be used for modernization of the 3 – cycle academic programs in the field of electrical and power engineering, computer engineering, mechanical engineering, etc.

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BIOGRAPHICAL INFORMATION

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