

Interdisciplinarity as a Key Component Contributing to Sustainable Development of Modern Engineering Education

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Abstract — Interdisciplinarity of higher education aims to improve such interdisciplinary skills as interdisciplinary thinking. Within the scope of this study, interdisciplinary thinking is defined as the ability to integrate the knowledge of two or more disciplines, improve the learning process, and produce results that would be difficult or unlikely to achieve when using a separate discipline. It is considered as a complex cognitive skill consisting of a number of sub-skills. The review showed that to date there is a small number of scientific studies focusing on the interdisciplinary approach to teaching and learning. The study further advanced the understanding of the necessary components of interdisciplinary thinking and the typical conditions that ensure its development. This understanding will provide a basis for further development of interdisciplinarity in higher education.

Keywords — *interdisciplinary thinking, interdisciplinary higher education, sub-skill, learning environment, learning process.*

I. INTRODUCTION

Information and its role in the development of the society have increased dramatically over the past decade. In such circumstances, it is impossible to maintain the old educational system when a teacher acts as a repeater of knowledge that is rapidly becoming obsolete. Therefore, the new paradigm of education is aimed not at the acquisition of a large amount of knowledge by a student, but at the formation of the ability to obtain new knowledge independently, which corresponds to the “life-long learning” concept. At the same time, the role of fundamental and interdisciplinary knowledge increases dramatically, allowing a university graduate to be more easily

oriented in related areas of professional activity and to build a non-linear model of his career development.

Compared to traditional higher education, which focuses on subject-matter knowledge and the development of general skills, interdisciplinary higher education aims to develop interdisciplinary skills. This, for example, includes the ability to change views, synthesize knowledge of different disciplines, and cope with difficulties. Unlike multidisciplinary, which is additive, interdisciplinarity is integrative: knowledge in different disciplines is contrasted and altered through integration. The interdisciplinary nature of education allows students to choose the right educational trajectory depending on objective and subjective factors.

II. PROBLEM STATEMENT

The interdisciplinary approach is a major opportunity to preserve knowledge and enhance its practical relevance. Interdisciplinary links allow compressing the educational process without overloading students and teachers. Besides, interdisciplinary links allow students mastering all-cultural and professional competencies in the integrated manner. The interdisciplinary links imply that a teacher gives new material to students based on the knowledge they have gained from previous courses. This method, on the one hand, ensures better memorization of the studied material, and on the other hand, gives students an opportunity to better understand and absorb new material that will be useful for studying subjects of the subsequent courses of study. The key factors in the organization of interdisciplinary links are as follows: 1. High qualification of a teacher. He shall have full knowledge of his

discipline and have good understanding of other disciplines provided for in the educational standard of the specialty; 2. Continuous work of teachers on mutual agreement of educational curricula. To ensure their interconnection, as well as to harmonize the schedule of teaching regarding courses taught in parallel [1].

Thus, it can be concluded that the formation of interdisciplinary links should be primarily based on cooperation and communication in the pedagogical community. In order to create the system knowledge and develop integrated courses there can be the following types of cross-disciplinary links: 1. Educational and cross-disciplinary direct links. They are formed if the assimilation of one discipline is based on the knowledge of another. The study determines the basic core of knowledge for each discipline, the structure of the relations of disciplines. For each discipline it is possible to develop a package of test tasks to check the input knowledge; adaptive automated learning programs to fill the basic knowledge gaps of learners; package of final control tasks for each discipline; a methodology for peer review and filling the knowledge gaps throughout the course. 2. Research and interdisciplinary links of a problematic nature. Occur when two (or more) disciplines share a common object of study or common problems, but are viewed from different disciplinary approaches, in different aspects. 3. Mental and mediated links that are developed when the same components, intellectual skills, necessary in professional activity are formed through different educational disciplines. Methods of analysis, system thinking, spatial imagination, image-intuitive thinking is used here. Mental and mediated links occur in the study of general engineering and professional disciplines. They relate to the procedural side of teaching, develop professional and intellectual skills. 4. Indirect applied links are formed when the concepts of one science are used to study the other [2].

The use of the principle of interdisciplinarity allows implementing the model of integrative learning (mastering of competences) and provides the synthesis of competences from already developed components. First of all, the principle of interdisciplinarity provides for the purposeful strengthening of interdisciplinary links thus preserving the theoretical and practical integrity of educational disciplines and sections of educational programs. At the same time, the integration of material study between different disciplines is important. The proposed disciplinary knowledge should be refracted through the lens of practical expediency, which is achieved through the synthesis of skills and abilities gained from the study of different disciplines. Interdisciplinary links, categorical and methodological unity of educational courses, latest achievements of modern science, integration of the information flow allows a student successfully mastering the general cultural competences and thinking deeply about the professional tasks that he is facing [3].

The integration or synthesis of knowledge is seen as a defining feature of interdisciplinarity. As a consequence, the ability to synthesize or integrate is seen as a beneficial result of educational activities within interdisciplinary higher education. In this case, the learning outcome is called interdisciplinary understanding or interdisciplinary thinking. Veronica Boix Mansilla proposed the following definition of

interdisciplinary thinking: “The ability to integrate knowledge and ways of thinking in two or more disciplines or in certain areas of scientific interest to create cognitive perception, such as explaining a phenomenon, solving a problem, or creating a product that would be impossible or unlikely to be accomplished through the means of individual disciplines” [4].

According to this definition, interdisciplinary thinking can be seen as a complex cognitive skill that consists of a number of sub-skills, such as the possibility of changing disciplinary concepts and creating meaningful links between disciplines. Interdisciplinary thinking does not happen spontaneously; students may take a considerable amount of time to achieve a sufficient level of preparedness in their practice. Besides, students need a teacher to help them to be able to synthesize data from two or more disciplines. Too often, curricula are called interdisciplinary, in fact being multidisciplinary: multiple concepts are presented without the ability to integrate disciplinary knowledge throughout the curriculum [5].

The difficulty of teaching and learning interdisciplinary thinking results in interdisciplinary higher education facing the challenges of producing both broad and narrow interdisciplinary thinking by students. Achieving the desired learning outcomes requires a coherent and well-designed learning environment within a coherent and student-oriented curriculum. For this reason, curricula and course developers need a comprehensive understanding of the typical conditions underlying the development of interdisciplinary thinking. This requires, for example, information on the extent to which students should have knowledge of different disciplines as well as didactic means of integration [6].

III. RESULTS AND DISCUSSION

Interdisciplinarity involves much more than parallel knowledge about the second or third discipline (in Russia a few years ago there was a boom that the “techies” wanted to pursue the second education in economics). It is equally important to learn to think in a way that is different from how students are used to think in their discipline. The objectives of the review were to systematically identify, critically analyze and discuss scientific research on teaching and learning interdisciplinary thinking within interdisciplinary higher education. For this purpose, the Biggs theory was used as the basis. The author proposes a comprehensive model of teaching and learning in higher education. In particular, teaching and learning are seen as a systemic interaction of four components: student, learning environment, learning process and learning outcomes [7]. This model allows curriculum and interdisciplinary education professionals gaining a comprehensive understanding of teaching and developing interdisciplinary thinking. Besides, the model is based on the principle of equality meaning that teaching and learning are combined with desired learning outcomes. This principle leads to a result-oriented approach to teaching and learning, which facilitates the development of a coherent and pedagogically-based curriculum [8].

The main purpose of this review was to identify the sub-elements that serve as components of interdisciplinary thinking and typical conditions for the development of

interdisciplinary thinking both within the student component and in the learning environment, and throughout the learning process.

The analysis of existing literature on the study issue made it possible to identify the following criteria necessary for the implementation of the interdisciplinary approach in higher education (Table).

TABLE I. INTERDISCIPLINARITY IN HIGHER EDUCATION

Interdisciplinarity in higher education		
Components of the educational process	Category	Subcategory
Interdisciplinary thinking	Possession of knowledge	Disciplinary knowledge Knowledge of disciplinary paradigms Interdisciplinary knowledge
	Possession of skills	Higher level cognitive skills Communication skills
Students	Soft skills	Intellectual curiosity Respect Openheartedness Patience Studiousness Capacity for self-control
	Previous experience	Social Educational Balance between disciplinarity and interdisciplinarity
Educational environment	Curriculum	Balance between disciplinarity and interdisciplinarity
	Teacher	Disciplinary knowledge within and beyond interdisciplinary courses Intellectual community aimed at interdisciplinarity Expert potential of a teacher in interdisciplinarity Consensus on interdisciplinarity Team building Team learning
	Teaching strategies	Focus on interdisciplinarity Focus on active learning Focus on cooperation
	Assessment	Intellectual development of students Interdisciplinarity
Learning process	Model (structure)	Gradual progress Linear Iterative Progress check
	Learning activity	Focus on interdisciplinarity Focus on reflection

The table makes it possible to conclude that the four main components of the educational process, i.e. interdisciplinary thinking, a student, the educational environment and the learning process, are key concepts of the interdisciplinary approach in higher education. The five components, divided into two categories, are the most significant in the development of interdisciplinary thinking. The first category, knowledge possession, consists of three subcategories: knowledge of disciplines, knowledge of disciplinary paradigm, and interdisciplinary knowledge. These subskills imply the significance of declarative, procedural, and

paradigm knowledge of disciplines. The acquisition of this knowledge appears to be required to enable students to go beyond the theories and methods of each individual discipline, to establish interdisciplinary links and contradictions, and to consider the possibilities of meta-level integration [9].

Another category, possession of skills, consists of higher level cognitive and communication skills. Cognitive skills of higher level mean such a style of thought, in which a student is able to find the necessary information, analyze and synthesize it, draw logical conclusions, build evidence, critically process facts, properly present the results of the performed study, i.e. it includes different types of thinking: analytical, directed, creative, evaluation, constructive, purposeful. The soft skills of learners also have a direct impact on interdisciplinary thinking in the context of interdisciplinarity of higher education [10].

The eight criteria, which can be divided into two categories, have proved to be relevant for the development of interdisciplinary thinking. The first criterion, soft skills, includes six items. Its three components – intellectual curiosity, respect and openheartedness – point to the necessary positive attitude towards various disciplines, another three – patience, studiousness and self-control – relate to the characteristics necessary for the development of cognitive thinking. The second category, previous experience, includes social and educational experience implying, for example, ways of thinking, learning styles and beliefs about the nature of knowledge and learning [11].

The next twelve conditions that make up the learning environment and belong to the four categories are essential for the development of the interdisciplinary approach in learning. The first category – curriculum – is the balance between disciplinarity, interdisciplinarity and discipline knowledge within or beyond the interdisciplinary courses. The second category – teacher – implies five criteria: intellectual community aimed at interdisciplinarity, expert potential of a teacher in interdisciplinarity, consensus on interdisciplinarity, team building and team learning [12].

The third category – pedagogical technologies – includes three conditions: pedagogical technologies aimed at interdisciplinarity, pedagogical technologies aimed at active learning and pedagogical technologies aimed at cooperation. It is assumed that these conditions indicate the need to set targets that encourage students to actively apply knowledge rather than simply remember the facts of different disciplines [13]. Besides, such learning tasks should provide students with the opportunity to gain a typical interdisciplinary experience of search and research activities. The fourth category – evaluation – includes assessment of students' intellectual status, as well as the assessment of their interdisciplinary status. Both conditions offer assessment tools that include a combined perspective of development and efficiency to help a teacher and students analyze the development of interdisciplinary thinking [14].

The six conditions that make up the learning process have proved to be the most relevant for the interdisciplinarity approach. The first category – the learning model – contains four criteria: gradual, progressive learning, linear learning,

iterative learning, and progress check. These criteria appear to indicate the need for gradual, linear, phased model coupled with the achievement of intended learning outcomes that serve as benchmarks for each phase in which students are constantly forced to resort to interdisciplinary thinking. The second category – learning activities – includes educational conditions aimed at interdisciplinarity and educational activities aimed at reflection. Both conditions refer to the need for learning activities aimed at acquiring interdisciplinary thinking skills. In particular, creating the situation of contradiction within individual disciplines combined with critical thinking is necessary to encourage students to abandon the concept of absolute knowledge [15]. Publications on the relations between a student, a learning environment, learning conditions, and interdisciplinary thinking do not provide empirical research. However, the criteria presented in the table provide an opportunity to identify hypothetical relations between the identified criteria and the development of interdisciplinary thinking. For example, it can be assumed that student's intellectual curiosity and team learning positively influence the development of interdisciplinary thinking. Besides, gradual progressive advancement appears to be a desirable condition of the learning process, and has a positive impact on interdisciplinary thinking and learning outcomes [16].

IV. CONCLUSION

In summary, despite the fact that interdisciplinarity in higher education is welcomed and widely practiced nowadays, this issue is not enough studied. The concept of modern engineering education should be based on the principles of individualization, self-development and self-organization, the foundations of which include fundamentality and interdisciplinarity of education.

This paper presents an attempt to analyze this approach in learning to create a platform, which the theory of the interdisciplinarity of higher education can be based on, which will promote further empirical research thus leading to the development of a structure of the interdisciplinary approach in higher education and deepen the understanding of the nature of learning in interdisciplinary thinking.

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