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INCLUSIVE DESIGN IN ENGINEERING EDUCATION

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Abstract

Various methods and approaches are to be applied in the University study process in order to activate new opportunities and potential for improving the quality of engineering education. The objective of the paper presented is to improve and adapt the established educational technology and to elaborate at a final stage a new educational methodology considering Machine Design subjects. The current study examines this methodology developed by the author's team aiming to ensure an inclusive design of Engineering Education. The inclusive design technology includes several stages: defining the problem of specifying the requirements for the "student - teacher - university environment" system; developing a system of solutions for creating personalized, tailor-made training and education, including preparation of special teaching materials containing sufficient information and literary sources that support the accelerated learning of the basic educational material; students' evaluation of the inclusive design educational technology suggested, in which important feedback comments are received on the efficiency of the new methodology applied. The results of the application of the inclusive design technology are presented and discussed. Conclusions are deduced.

Keywords: Inclusive Design; Innovative Training Technology; Machine Design subjects; Engineering Education.

1. Introduction

The contemporary level of industry development (Industry 4.0) calls for the integration of information and communication technologies with industrial achievements, aiming to transform production processes into more efficient and flexible ones. Employers from industry face barriers to implement this approach and the most significant of these barriers seems to be the lack of qualified staff. It is particularly important for the system of higher education that the qualifications of future university graduates, their competencies and professional skills, necessary to manage and control such modern industrial systems, have to be already achieved in the Bachelor and Master degree programs. Continuous monitoring of the academic and university environment is necessary in order to determine on time the necessary modernization of educational technology and curriculum contents that would ensure meeting the needs of modern industry [1].

It is expected that in Europe, during the next 10 years, there will be almost one million new jobs in industry and a significant part of them should be directed to professionals with new profiles. The main features of these profiles are: creativity, strategic and very good organizational abilities [1], [2]. Therefore, the universities have to play a key role in the training and educating of such future professionals.

The main competences, which have to be developed within undergraduate and graduate degrees should include interdisciplinary thinking, decision-making, problem-solving abilities, intercultural skills and willingness for lifelong learning [3].

2. Theoretical background

According to the authors of [4], the training of future engineers has to be modified so that they should be prepared to confront the rapid changes in technology and adapt to entire new types of jobs. Future specialists will have to develop new technologies, to collaborate with colleagues at an international level and deal with the main challenges facing society, such as global environmental problems, [5]. The authors of [6] emphasize that it is necessary for future engineers to be trained with appropriate pedagogical strategies which are based on experiment-based, research-based and active learning.

In addition to basic knowledge, skills and competencies in the field of innovation, the abilities to analyse data and solve problems play an increasingly important role. These abilities will allow the future graduates to analyze data sets from different sources, to optimize production processes and to make decisions in real time, [7].

The correct and appropriate application of educational technologies has the potential to enhance learning by maximizing the academic experience of students. Appropriate educational technology enables the delivery of face-to-face and/or distance education, improving learning outcomes by adapting assessment to learning style, facilitating access to up-to-date learning materials and to communication with famous experts in a certain scientific area, [8].

Based on the scientific literature sources analysed, the authors' team has focused on the following research objective: to improve, adapt and supplement the existing and established training technology and to create at a final stage a new educational methodology for inclusive design considering machine design subjects in engineering education. The methodology elaborated has been tested and validated in a real academic study process.

3. Research methods

The previous methodology according to the established curricula of the Machine design subjects, approved by the relevant Faculty Councils, includes two main stages. During the first stage, students receive assignments for course tasks and projects, consistent with the syllabus of the subject; lecturers control the current implementation of the assignments and deliver consultations, if necessary. At the end of the semester, the students fill out surveys about the quality of the study process.

A research methodology for ensuring an inclusive design of the educational technology in Machine design subjects within engineering training has been supplemented and improved. It should be characterized by the following features: education is carried out in both face-to-face and online mode; students are taught with a combination of such tools, methods, programs and aids, which are preferred, appropriate and most relevant for them; teaching and learning tools have to be adapted to each student's learning style and background; assessment is to be carried out on the basis of results, skills and competences achieved and less often – based on exams; information analysis and data interpretation represent a key competency that is additionally included in almost all Machine design subjects' syllabi according to the reccommendations of [8].

The methodology created by the author's team for ensuring an inclusive design of Engineering Education includes the following stages:

The first stage is related to defining the problem of specifying the requirements for the "student - teacher - university environment" system. Within this stage, the most important issue is the activity of the academic lecturer, who must identify the level of knowledge, skills and competences of each student, at the beginning of the semester, in order to prepare the corresponding personalized, tailor-made training.

The second stage involves developing a system of solutions defined by the student's entry level. For students with very good basic training, creative assignments and projects in the field of Machine elements, Machine Science and Engineering Design are prepared and delivered. If some of these students manage to cope excellently with the organization and timing during elaboration of these assignments, it is recommended to switch to the mode of Independent research work, which ends with a scientific publication or a case study necessary for an industry enterprise.

The second group of students receives assignments for coursework and projects, consistent with the syllabus of the subject. The lecturer monitors and/or corrects the current performance of assignments by supervising some of the students (if necessary) in face-to-face or online mode.

In some cases, a third group of students with a lower level of creative activity and prior technical training literacy emerges. Specialized learning and learning materials containing sufficient information, equations, standards and literature sources have been prepared for this part of the students, which support the accelerated study of the mandatory, basic study material. Concerning the preparation of drawings, face-to-face and/or online additional classes are provided, within which the lecturer delivers consultations concerning the preparation of drawings for each calculation, layout and design stage. Students from all groups are given the opportunity to participate in the "SMART in CAD" professional club, which is delivered every semester.

During the third stage, an evaluation of the inclusive design methods is implemented and feedback is received from the students concerning the efficiency and the quality of the new inclusive design educational technology applied.

The development approach of the new methododlogy presented takes into account several important limitations considering the research objective. The research has been implemented with students from engineering bachelor degree courses within the subjects from the area of Machine Elements, Design Projects, Machine Science and Engineering Design. These limitations have been defined by the authors' team due to the specific features of the subjects mentioned. They require relatively good prior education and training with STEM components (Science, Technology, Engineering and Mathematics). Besides, the machine design subjects require intensive work and efforts on behalf of the lecturers in order to facilitate and improve the students' creative activity and skills.

This new methodology of study process focused on Machine design subjects, has been applied within four semesters in a certain number of Engineering bachelor degree courses at the University of Ruse, Bulgaria. During this period of time, the previous, established methodology (currently approved by the relevant Faculty Councils) has been applied in the rest of the Engineering bachelor degree courses at the University of Ruse.

4. Research results and discussion

The period of implementation and validation of the newly created methodology for inclusive design continued four semesters. During that period, the following additional activities have been carried out:

A total number of eight scientific and methodological seminars have been organized on different topics, such as "Investigation of the possibilities of control and management of the work of technical systems and devices"; "Structure and organization of creating a scientific publication". Lecturers, Bachelor, PhD students and Incoming students from the Erasmus+ program participated in these seminars. Specialists from the industry also took part in some of the seminars as guest lecturers. The topics of the seminars have been determined by the academic staff of the Department of "Machine Science, Machine elements, Engineering Graphics and Physics" with the Transport Faculty at the University of Ruse and by the students according to their interests established during the first stage of the new methodology applied.

A total number of 12 questionnaires have been conducted among the bachelor degree students, concerning the feedback and assessment of the new educational technology applied. The students gave their opinion about the quality of lectures, tutorials, supervisors' consultations and additional activities. The contents of these questionnaires is elaborated by the academic staff of the Department of "Machine Science, Machine elements, Engineering Graphics and Physics".

Conducting this type of follow-up survey is an essential component of the feedback achieved. By expressing their opinion, the students have the opportunity to participate in the organization, management and control of the study process. The students evaluate this option extremely positively. Part of the results achieved concerning the diagnosis of the quality of the educational process are described and analyzed in [9], [10].

In order to facilitate this part of the students, who have a lower level of creative activity and prior technical literacy, two new special study teaching materals have been prepared, containing sufficient information and equations supporting the accelerated acquisition and assimilation of the obligatory, basic study material, [11], [12].

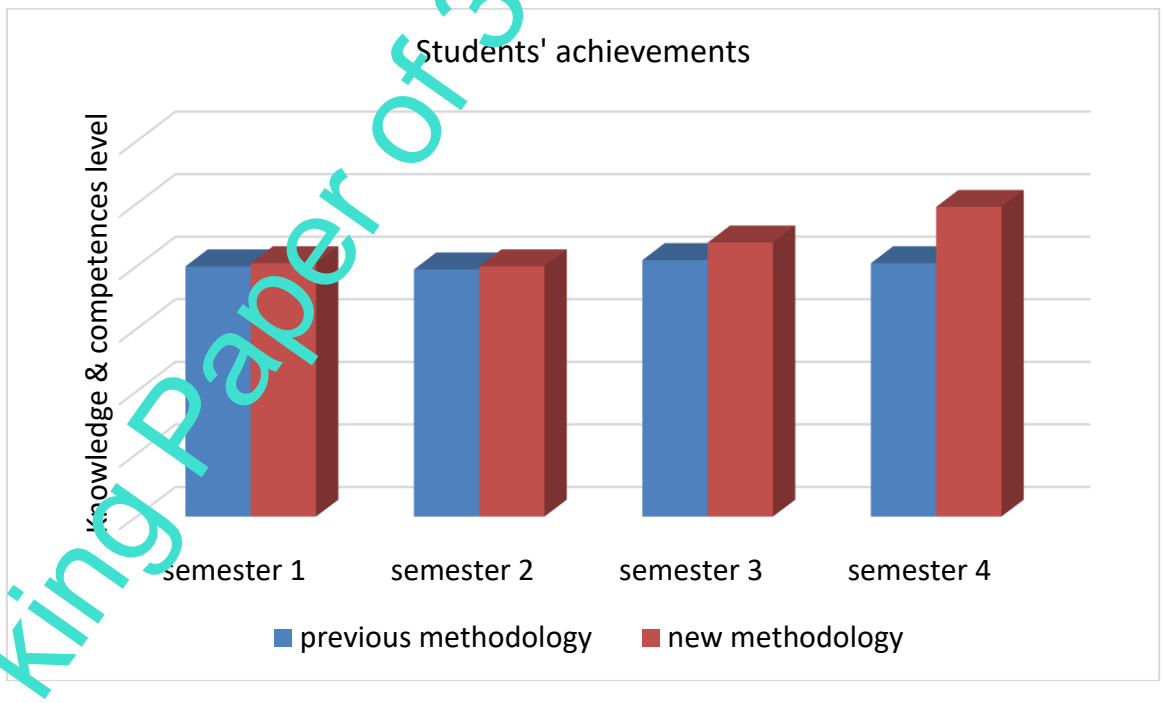

Fig. 1. Results of the tested and investigated new methodology for inclusive design example

The contributions of the department mentioned to delivering theoretical knowledge and practical skills in the field of computer-aided design are particularly significant. This addutional activity supports the work of bachelor, master and PhD students, who are members of the professional club "SMARTinCAD" headed by PhD Yuliyan Dimitrov. The achievements and results of this very important activity of this professional club have been described in details in [13], [14].

Considering that the authors‘ team and the academic staff of the Department of "Machine Science, Machine elements, Engineering Graphics and Physics" supervised more than 10 PhD students during the period of the research, the academic staff of the department has contributed significantly to the development of the creative thinking and the scientific skills of the students through several scientific activities. The most important of them are the active international activity improving the educational and internship opportunities of the students and the supervision of their relatively independent research work, [15], [16], [17], [18].

The main expected consequences of the new approach are directed towards the possibility that the methodology described can be applied by lecturers in other subjects in the same bachelor degree course through achieving horizontal and vertical integration. Horizontal integration can be achieved through active interaction between lecturers responsible for different subjects who could give joint independent assignments and projects (mainly for the students from the first and second groups described in research methods) within the same semester. Vertical integration can be realized if the academic staff responsible for the subjects during the last one or two academic years apply this new methodology and give students the opportunity to work on a topic of interest to them by setting new tasks and projects that deepen the knowledge and improve the skills of the students in the relevant professional area.

After applying the new methodology for inclusive design as educational technology, several very important groups of results have been obtained. The most important result is the significant increase of the level of knowledge and competences of students as is shown in Fig. 1. The students appreciated the tailor-made education technology and improved their interest in the study process and in the process of acquiring new knowledge and skills on their own. During each subsequent semester within the framework of the scientific research the scientific and publication activity of the students increased by about 50 %. Some additional negative limitations are expected. Due to the relatively great work load of some lecturers, it is possible that they will not be able to apply the new methodology in its full scope.

5. Conclusions

The study presented examines the methodology developed by the author's team aiming to ensure an inclusive design of Engineering Education. Based upon the research implemented, several conclusions can be deduced.

In the process of applying the new methodology the level of knowledge, skills and competences increased significantly. Due to the introducing of this technology the students' interest in the study process has increased. The students have begun to initiate their independent work to acquire new knowledge and technical skills.

The new methodology has also created prerequisites for achieving horizontal and vertical integration in the engineering training and education. This specific implication can be achieved through active interaction between lecturers in different subjects and giving the students joint and/or interdisciplinary tasks and projects. Some of these additional academic assignments can extend over more than one semester and deepen students' knowledge and skills in the relevant professional area.

The application of this methodology has created prerequisites for increasing students' motivation to participate actively in the study process and to improve the distribution of time necessary for preparing assignments and projects on their own. Based upon the conclusions deduced, it becomes clear that the objective of the research has been achieved. The students' motivation for learning has increased and the quality of the study process in Machine design subjects has been improved.

Future research plans include further development of inclusive design methodology. Enhanced work with companies based upon existing and new contacts with industry is envisaged.

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