DOI: 10.2507/34th.daaam.proceedings.xxx

SMART DESIGN OF CORE COMPONENTS IN ENGINEERING EDUCATION

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This Publication has to be referred as: Ronkova, V[ryarka] & Dobreva, A[ntoaneta] (2023). Smart Design of Core Components in Engineering Education, Proceedings of the 34th DAAAM International Symposium, pp.xxxx-xxxx, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-xx-x, ISSN 1726-9679, Vienna, Austria
DOI: 10.2507/34th.daaam.proceedings.xxx

Abstract

The paper presents an investigation concerning the specific features of academic training in fundamental engineering subjects in the field of Higher education. The main objective of the research presented is to ensure a smart design of core components in engineering education by implementing innovative practices and improvements in two of the main four components of the concept of Education 4.0: advanced educational teaching and learning models and instruments for increasing the competencies of future engineers. The statistical and experimental study has been carried out according to an advanced methodology containing six main stages. The target group of research consists of first-year students from 22 engineering Bachelor degree courses. Based upon the research results, a system of advanced educational models, methods and tools for increasing the competencies of future engineers aiming to increase the training quality in the Higher education has been suggested. Conclusions and recommendations have been made, the authors' vision for future work in the area investigated is presented.

Keywords: Engineering Education;, Smart Design of Educational Technologies; Competences; Learning methods.

1. Introduction

Technological progress has a great impact on the industrial sector and other important areas. In the field of education, the application of current and emerging technologies is combined with innovative pedagogical approaches and good practices. Four main components of education have been formulated, so that they can be used as benchmarks for designing new projects in the field of educational innovation: competences, learning methods, information and communication technologies, infrastructure, [1].

During the recent decades, the interest in engineering education and research has grown worldwide. During the same period, however, there is a constant shortage of students in technical bachelor degree courses in higher education institutions. For Bulgaria, this problem is particularly important for the field of mechanical and general engineering.

As it is known, adequate training of qualified engineering professionals is possible only in close cooperation between schools, universities and industry. University curricula are expected to meet the needs of enterprises developed in a particular region. In order to solve such a problem, the authors of [2] initiated a joint project with the participation of three universities in the Baltic region. The project described aims to develop a new approach to preparing pupils and students in choosing the right profession through the joint efforts of universities, schools and enterprises.

At the same time, global perspectives and experience indicate that engineering higher institutions will increasingly focus on the development of "skills for effectiveness in a global environment", i.e. they have to provide students with a range of opportunities to work in different counties and to adapt to different cultures making the role of educational technologies even more important and responsible, [3].

2. Theoretical analysis of the special features of the education in fundamental engineering subjects

Certain number of significant studies have investigated the importance of knowledge management concerning engineering higher education outcomes and innovations [4], [5], [6]. The authors of [5] emphasize the extremely important role of creating a sustainable functional and theoretical approach to teaching and learning through the application of a theoretical framework related to knowledge. According to the authors of [7], the correct decision-making in managing the knowledge flow and volume in fundamental engineering subjects involves a critical evaluation of proofs which requires time and efforts.

In [8], the importance of knowledge management, providing the link between universities and engineering practice, has been emphasized. Teaching Engineering Graphics as a fundamental subject creates important creative perceptions according to [9], which is related to introducing to the first year students the traditional ways of creating graphical presentations. The knowledge of geometry is very important for the engineering students' further education, because the understanding of geometry principles is a key feature of human intelligence. In addition, interactive work with 3D-models is important for clarifying spatial representations and relationships, especially if sufficient effort is implemented into combining graphical drawings, models and text descriptions, [9].

Based upon the theoretical analysis of the special features of education and training in fundamental engineering subjects, the research objective has been deduced: smart design of engineering education by applying innovative practices and improvements in two of the four core components of the concept of Education 4.0 (advanced educational teaching and learning models and tools to enhance the competencies of future engineers) has to be ensured.

3. Research methods

In order to fulfil the objective of the research, an improved methodology has been developed. It consists of several stages:

1) Investigating the reasons for an inappropriate selection of a bachelor's major by some of the future students;

2) Specifying the consequences of the inappropriate choice made;

3) Selection of the target group of the research aiming to establish the challenges in the education of students from different secondary upper schools as future engineers;

4) Statistic and experimental research of the preliminary general technical training of future students taking into account the role of curricula in upper secondary schools in achieving their technical training and in the professional orientation of future students;

5) Analysis and discussion of research results;

6) Defining a system of teaching, learning methods and additional activities aiming to improve the quality of education in the higher education system based upon the results of the investigation. The authors' team outlines the following limitations: the methodology will be applied in the field of subjects with design engineering focus.

4. Reasons and consequences related to an inappropriate selection of Bachelor degree course

Future students do not always have a clear idea about the kind of specialists they want to be. Sometimes the selection of a Bachelor degree course when applying to a university is based upon the fashion trends in the surroundings of young people. The wishes of the future students are not always consistent with their capabilities, their knowledge and skills. These circumstances often lead to disappointments during the first year at the university.

The main reasons for the inappropriate selection of a Bachelor degree course are:

1) Some parents mislead their children when choosing a profession. Very often, the wishes of the parents do not coincide with the wishes of the children, which leads to negative results;

2) More than 10% of candidate – students from Eastern Europe leave their native country because they do not have complete information about the opportunities to study a given bachelor degree course in their own country [2]. Very often, the methods and technology of training are different from country to country. International students sometimes find it difficult to adapt to these new methods. Besides, another difficulty is that the training is not carried out in the native language.

A large part of the students abroad feel nostalgic for Bulgaria and for their relatives and friends. As a result of the circumstances listed, the training ends unsuccessfully, sometimes with health problems and/or with a negative attitude towards the receiving country.

The consequences of selecting an inappropriate Bachelor major are significant:

1) Students fail to manage with the study material, fail to pass the exams and this situation demotivates them. As a result of these difficulties, many students drop out after the first year;

2) The Bachelor degree course turns out not to be what the students imagined. Therefore, they look for an alternative to change their major degree during the next academic year. And they are again candidate students.

The challenge of retaining first-year students in the higher education system is becoming one of the most significant issues for the academic lecturers and for the management authorities of the universities in Bulgaria and in Eastern Europe. Several investigation studies have been done concerning the development of models to predict and represent the reasons for students' decline [9], [10], [11], [12], [13] & [14]. The research in the publications listed indicates useful algorithms aiming to help higher education institutions and faculties to provide necessary support for the first-year students in order to increase their academic success and their motivation to study and to learn at the earliest possible stage.

5. Selecting the target group

The target group of the study is determined. The investigation of the preliminary general technical training of future students has been made based upon a statistic research of the number of students and other indicators over the last 7 years. The students have been trained in engineering Bachelor degree course from the professional fields of "Mechanical Engineering" and "General Engineering".

When studying a certain subject from the area of Engineering graphics, it is necessary to examine the incoming knowledge of the students in order to be able to improve the methods and means of teaching in accordance with the modern trends in education and in engineering practice. The survey has been conducted for students of engineering bachelor degree courses studying a subject in the area of Engineering Graphics according to the type of upper secondary school completed. The target group of the research consists of first year students from 22 Bachelor degree course indicated in Table 1. Based upon the academic experience of the authors' team, it has been decided to determine what part of the engineering students, studying subjects in the area of "Engineering graphics", have prior technical training in similar topics.

No	Title of the Bachelor degree course
1	Automotive engineering
2	Agricultural engineering
3	Biotechnologies
4	Ecology and Technique for Environmental Protection
5	Electricity and Electrical Equipment
6	Electrical Engineering
7	Electronics
8	Agricultural Technique and Technologies
9	Industrial Management
10	Industrial Engineering
11	Air Conditioning, Hydraulics and Gasification
12	Computer Control and Automation
13	Materials Science and Technology
14	Mechanical Engineering
15	Management and Technical Service
16	Quality Management and Metrology
17	Industrial design
18	Civil Engineering
19	Technology and Transport Management
20	Food technology
21	Transport Equipment and Technologies
22	Chemical Technologies

Table 1. Bachelor degree courses at the University of Ruse delivering Engineering Graphics subjects

The objective of selecting a target group is to find out what percentage of students studying "Engineering Graphics" have learned subjects related to this one in their previous degree of education. This investigation provides extremely important information to the lecturers delivering these subjects concerning the preparation of the introductory teaching materials which depend on the entry level of the first year students. Therefore, this information assists the determination of the scope, contents, structure and topics of the subject.

6. Analysis of results and discussion

An appropriate understanding and assessment of skills and qualifications is essential for achieving a better compliance between students' skills obtained and labour market needs. It is considered possible to support some of the students to

acquire skills and update them throughout their lives by moving through different types and levels of education or through education and employment [15], [16] and [17].

The number of students in Engineering Bachelor degree courses, in which subjects from the area of "Engineering graphics" are studied, is presented in Fig. 1. It shows the distribution of engineering students in different years. The investigation has been carried out for the period from 2016 to 2022. Table 2 presents the percentage of first year students according to the type of school of completed prior education: Upper secondary school or Vocational upper school.

Vocational upper schools are divided into non-technically oriented and technical schools. This division in two categories has been made due to the fact that at the technically oriented vocational upper schools the subject "Technical drawing" or a related technical subject has been studied. Therefore, it can be determined what part of first year students have knowledge and prior training in the field of engineering graphics. Based upon the research done, it was found out that 29.8% of the students graduated from Upper secondary school, i.e. graduates have not studied Technical Drawing or a related subject. About 25.9% of the engineering students graduated from Vocational upper schools which are not technically oriented and they have not studied Technical Drawing as well.

On the other side, the remaining 44.3% of the first year engineering students have knowledge of in the area of Technical Drawing. Besides, it becomes clear that the knowledge of each student within these 44.3% (who graduated from Vocational upper school with the study of Technical Drawing) is at a different level. For some of the students, the studies during their upper secondary education have been more thoroughly in this type of subjects due to the contents of the study curricula and syllabi for the relevant profile of the school they graduated from.

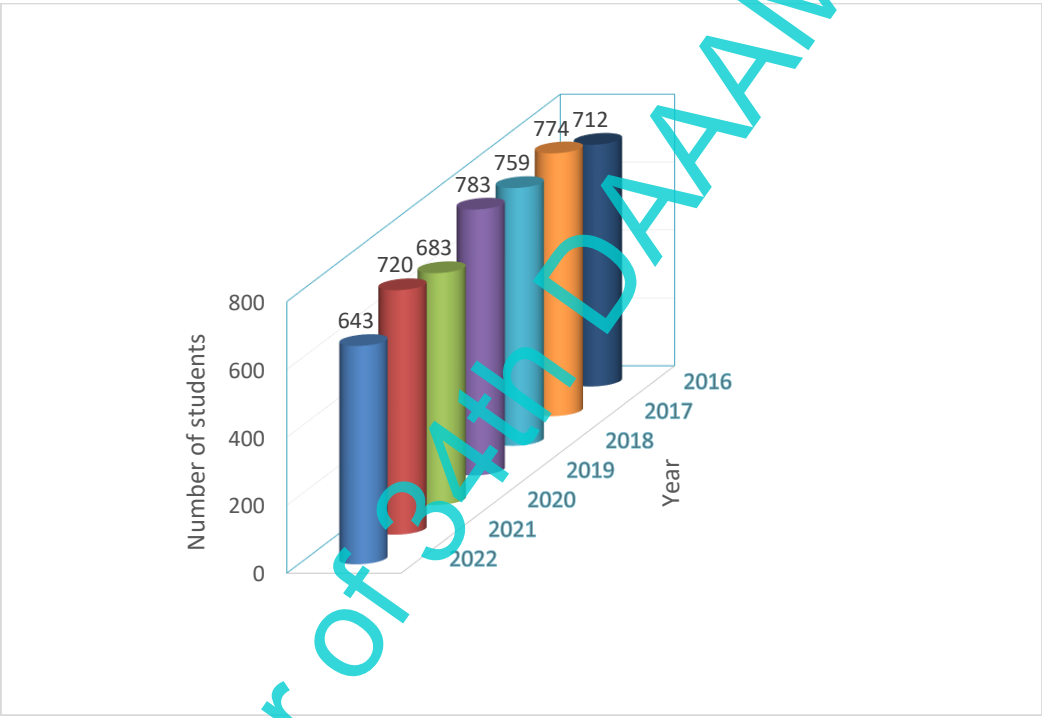

Fig. 1. Number of students in Engineering Bachelor degree courses

Besides, not all upper vocational upper school courses require basic study of Technical Drawing. In some cases, only a section necessary for training in the given course is studied in the Technical Drawing subject. In such specialized classes, only main topics the subject are covered, and in other classes such topics are only mentioned.

Another survey has been carried out concerning engineering students for the period 2016-2022: regarding the time of graduating the upper secondary school. This investigation has been implemented for vocational upper schools which deliver the subject “Technical Drawing”.

The students' sample investigated has been divided into three groups in the following way: the first group includes students who graduated from secondary education in the year of admission at the University of Ruse; the second group - students who graduated from upper secondary schools during the last 5 years prior to the year of admission at the University of Ruse; the third group – students who graduated from upper secondary schools 6 or more years before the year of admission at to the University of Ruse. The study is presented graphically in Fig. 2.

From the first group, 41% of the students graduated in the year of enrolment at the University of Ruse. In the second group, 17% of them graduated within the last 5 years of the year of enrolment and in the third group - those who graduated 6 or more years before admission - 42%, Fig. 2.

The first group (graduated from Vocational upper schools studying Technical Drawing or a related subject and graduated during the year of enrolment at the University of Ruse) are 17.9% of the total number of students studying Engineering Graphics.

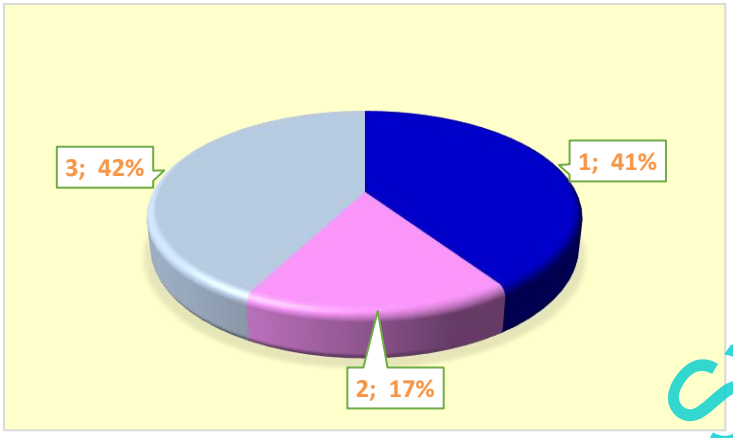

Fig. 2. Distribution (on an average value) of engineering students graduated at Vocational upper schools with "Technical Drawing" depending on the year of graduation (1 – First group; 2 – Second group; 3 – Third group)

The investigation shows that as a matter of fact about 55-60% of first year engineering students do not have basic knowledge of Engineering Graphics. About 20-25% have knowledge in the field but a certain period of time has passed from the completion of secondary education to their enrolment in the next educational level.

Enrolment Year	Upper secondary school	Non-technical vocational upper school	Technical vocational upper school
2016	28,1%	25,8%	46,1%
2017	25,6%	26,8%	47,6%
2018	26,6%	31,1%	42,3%
2019	32,6%	13,2%	54,2%
2020	31,6%	27%	41,4%
2021	34,6%	30%	35,4%
2022	30,2%	28,7%	41,1%
Average value	29,8%	25,9%	44,3%

Table 2. Distribution of first year students according to the type of their prior education

It can be summarised that the training in the area of engineering graphics should be complete and thorough, covering all the basic concepts and elements in order to enable the first year students to continue to a higher level of acquiring knowledge and skills. This makes it necessary to include additional study materials related to basic concepts in the areas of knowledge of Geometry and Design of drawing documentation when developing and up-grating university curricula and syllabi.

Depending on the specific features of the professional field, the degree of specialization in Engineering Graphics is different for each Bachelor degree course. The subjects in Engineering Graphics are delivered for one or two semesters, which is to be determined through the study curriculum of the relevant Bachelor major. The level of knowledge and the duration of different course units in Engineering Graphics depend on the relevant qualification requirements for the future engineering professionals. The authors' team has been implemented several studies for the past few years. A comparative analysis of number of enrolled students in engineering bachelor degree courses has been made. Based upon these studies, it was found the number of students enrolled in the first year of engineering majors is decreasing compared to the total number of accepted students, [18] and [19]. It has been established that the research question is answered completely and the investigation made provides strategy guidelines for orientation of applicants towards engineering bachelor degree courses.

7. System of additional methods and tools aiming to improve the quality of university education

Based upon the research results, additional methods, models and tools have been determined in order to improve the quality of education in the higher education system. It is possible to provide new and upgraded knowledge using interdisciplinary methods in upper secondary schools. Priority is to be given to these schools in which already STEM teaching laboratories exist.

In order to improve the study motivation of first year students and to reduce their retention as university students, it is necessary: to ensure a systematic and sustainable control and distribution of different additional activities within the

semester by implementing an appropriate knowledge management system using good practices and opportunities for adapting the teaching methods to the relevant level of knowledge for each student; to structure appropriately the necessary knowledge volume and study contents according to the established entry level of the first-year students; to create opportunities for enterprise visits, through which a realistic idea of the future students' profession will be created; to strengthen the implementing of short term internships and long practice periods in the native country and abroad, which will facilitate the transition between academic environment and industry for future engineers.

The authors' team does not consider that students with good study motivation will receive less consultations and fewer topics for extracurricular work. Different types of additional training and intensive internship programs have been described in details in previous works of the authors. These publications are based mainly on the current achievements of scientific research in the field of STEM, [20], [21], [22], [23] & [24].

The specific characteristics of the intensive internship programs facilitate the achievement of the following results: highly qualified scientific and research human resources with skills to carry out theoretical and experimental activities; providing opportunities to create new scientific products and achieve significant scientific results; building up-to-date theoretical and practical knowledge and skills for carrying out independent research activities; providing opportunities for successful teamwork. The practice of participation of Bachelor, Master and PhD students in Scientific Conferences continues as a result of scientific collaboration between academic community and enterprises.

8. Future work

The following components of future work on the research problem are envisaged: establishment of closer cooperation between the University of Ruse and upper secondary schools; creating programs and practices with these schools initiating discussion about the needs of the surrounding environment and explaining that the world needs hard-working, smart and talented specialists; implementing even more intensive activities related to familiarizing the students with the university buildings, laboratories and with the opportunities that the university education would give them; elaboration of joint projects between upper secondary schools, companies and universities aiming to achieve greater commitment to the young people, for their future professional training and development.

In order to achieve these objectives, it is necessary to develop comprehensive approaches, combining established and new teaching and learning models in interactive way, which will support the final result - improving the quality of study process in the Higher education system.

9. Conclusions

The current challenges in higher education are not limited to training technologies and social issues. They are also problems caused by rapid technological progress and the need to develop basic competencies in pupils and students, encouraging them to develop themselves technically, technologically, analytically and with the ability to think critically. In order to achieve this objective new programs and products are required taking into account the necessary components in higher education. The authors suggest innovations and improvements in two of the four main components that determine the concept and the vision of Education 4.0: advanced educational models – learning methods and tools for increasing the competencies of future engineers.

10. Acknowledgements

The authors would like to express appreciation for the support of the Scientific Research Funds of the University of Ruse, Bulgaria. The research work done is realized in framework of several scientific seminars at the Department of "Machine Science, Machine elements, Engineering Graphics and Physics" at the Transport Faculty at the University of Ruse. The support is gratefully acknowledged.

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