Journal of Sustainability Perspectives

journal homepage: https://ejournal2.undip.ac.id/index.php/jsp/

Innovative Approach to Training Sustainable Engineers

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Article Info

Received:
23 May 2023
Accepted:
4 November 2023
Published:
15 November 2023

DOI:
10.14710/jsp.2023.20785

Presented in the 9th International Workshop on UI GreenMetric World University Rankings (IWGM 2023)

Abstract. Oguz han Engineering and Technology University of Turkmenistan is a higher education institution, which specializes in training engineers with innovative views. Training of future professionals that "Engineer a Sustainable World" requires not only new competencies, including creative learning and thinking, complex problem-solving interdisciplinary and international cooperation, and a code of ethics, but also challenges a change in engineering education itself. In our approach, we suggest innovative ways to develop a deeper working knowledge of technical fundamentals while simultaneously learning personal and interpersonal skills, and product, process, and system building skills. For analysis of interrelated arrangement of modules for effective acquisition of knowledge, a supportive alignment of disciplinary courses was studied and a wide range of skills required in professional areas were mapped throughout the curriculum. Moreover, we created a new learning context that provides an opportunity to implement both theoretical and practical knowledge to conceive, design, implement and operate real-world systems and products. In this approach, we developed integrated methods of gaining active learning experience that forms a basis for carrying out challenging capstone projects. As a result, our innovative approach that focuses on modification of education and research improves all aspects of comprehensive training of sustainable engineers.

Keyword:
Sustainable Engineer, Active Learning, Design-Implement Experience, Effective Assessment.

1. Introduction

Oguz han Engineering and Technology University of Turkmenistan (ETUT) is a higher education institution, which is specialized in training engineers with innovative view in engineering areas such as Materials science and technology of new materials, Chemical engineering, Biotechnology, Genetics and bioengineering, Informatics and Computer engineering, Mobile and network engineering, Applied mathematics and informatics, Automation and control, Electronics and nanoelectronics, Mechatronics and robotics, Biomedical electronics and others [1].

Since engineering functions as the engine of economic development, it plays a vital role in addressing basic human needs, alleviating poverty, reconstructing infrastructure, promoting secure and sustainable development. In other words, engineering underpins all the 17 Sustainable Development Goals (SDGs), which are blueprint to achieve a better and more sustainable future for all [2].

Engineering is a problem-solving profession and requires a problem-based approach to learning. The goal of engineering education is to prepare students to become engineers who can use their skills and knowledge to solve real-world problems and develop sustainable technologies. Such an education is essential for achieving productivity, entrepreneurship, and excellence in an environment that is increasingly based on technological complex systems that must be sustainable. It is the task of engineering educators to continuously improve the quality of undergraduate engineering education in order to meet this objective [3].

Engineering education needs to move quickly to make progress, not least because it takes five years to train an engineer. Engineering students today will use their skills to solve problems beyond the scope of the current Sustainable Development Goals. Technology will become more complex, and engineering education must adapt by changing both the content and methods of teaching [3].

In our paper, we demonstrate explicit ways of improving the engineering education at Oguz han Engineering and Technology University of Turkmenistan in order to educate students to become sustainable engineers – able to conceive, design, implement, and operate sustainable systems, products, processes, and projects that can prevent and control a range of environmental risks, as well as restoring and even reversing environmental damage.

2. Methodology and Results

To identify ways of reforming engineering education, an explicit plan was made up and divided into six phases:

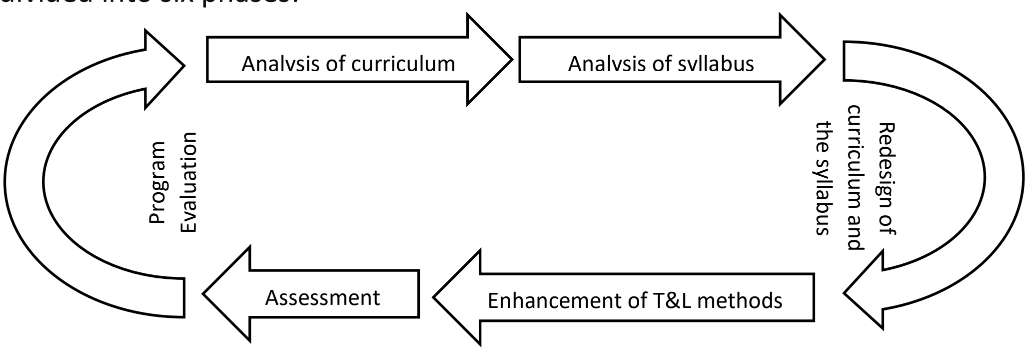

Figure 1. Plan of Reforming Engineering Education

2.1. Analysis of Curriculum.

Professional engineering skills are developed by combining and using knowledge and understanding of engineering concepts in real-world engineering work. In addition to applications of theory, professional engineering skills also develop the capacity for informed judgment and idea generation. This is achieved by development of an integrated curriculum which is characterized by a systematic approach to teaching professional skills, and product, process, and system building skills, integrated with engineering disciplinary fundamentals. Existing subjects in the curriculum have to be updated according to the progress within the discipline, and new fields of study need to be incorporated into the curriculum [4].

Accordingly, we began by examining the curriculum, since disciplinary courses are mutually supporting when they make explicit connections among related content and learning outcomes. Analysis of curriculum will help to identify the gaps in it and to map skills developed through the course.

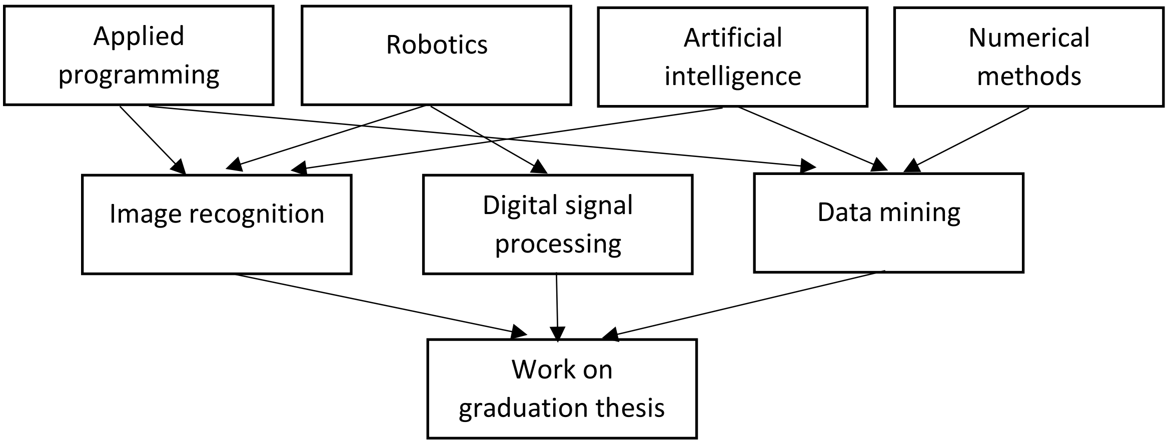

Figure 2. Analysis of the curriculum of Mechatronics and robotics major at ETUT

2.2. Module evaluation and syllabus analysis.

We have decided to analyze not only curriculum, but also syllabus of modules related to the major. When a sequence is appropriately established, the process of learning adheres to a pattern where each new experience builds upon and strengthens the ones that came before it. The evaluation and syllabus analysis process is demonstrated in Figure 3.

2.3. Redesign of curriculum and the syllabus.

After identification of the gaps in the curriculum and syllabus, we decided to redesign them to build structurally strong alignment of modules that gives to students the knowledge and skills needed in their future professional life.

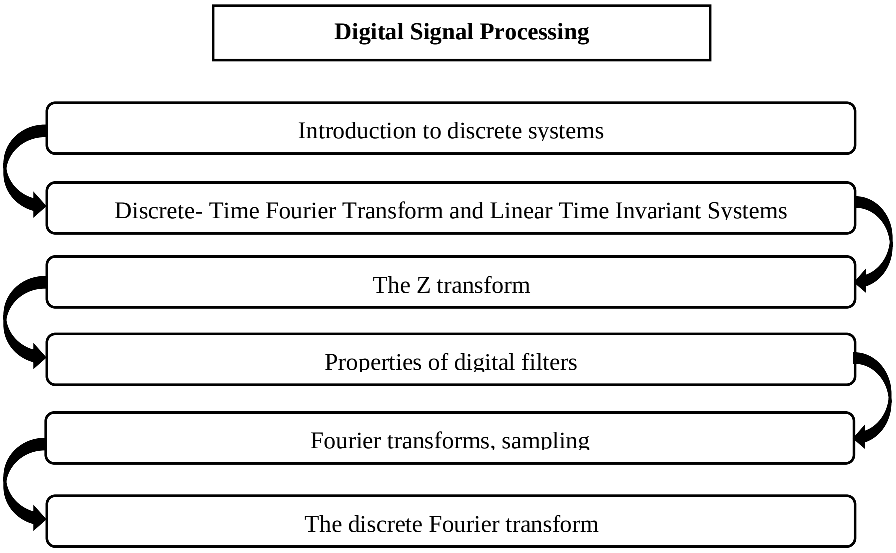

Figure 3. Module Evaluation and Analysis of The Syllabus of Digital Signal Processing Subject.

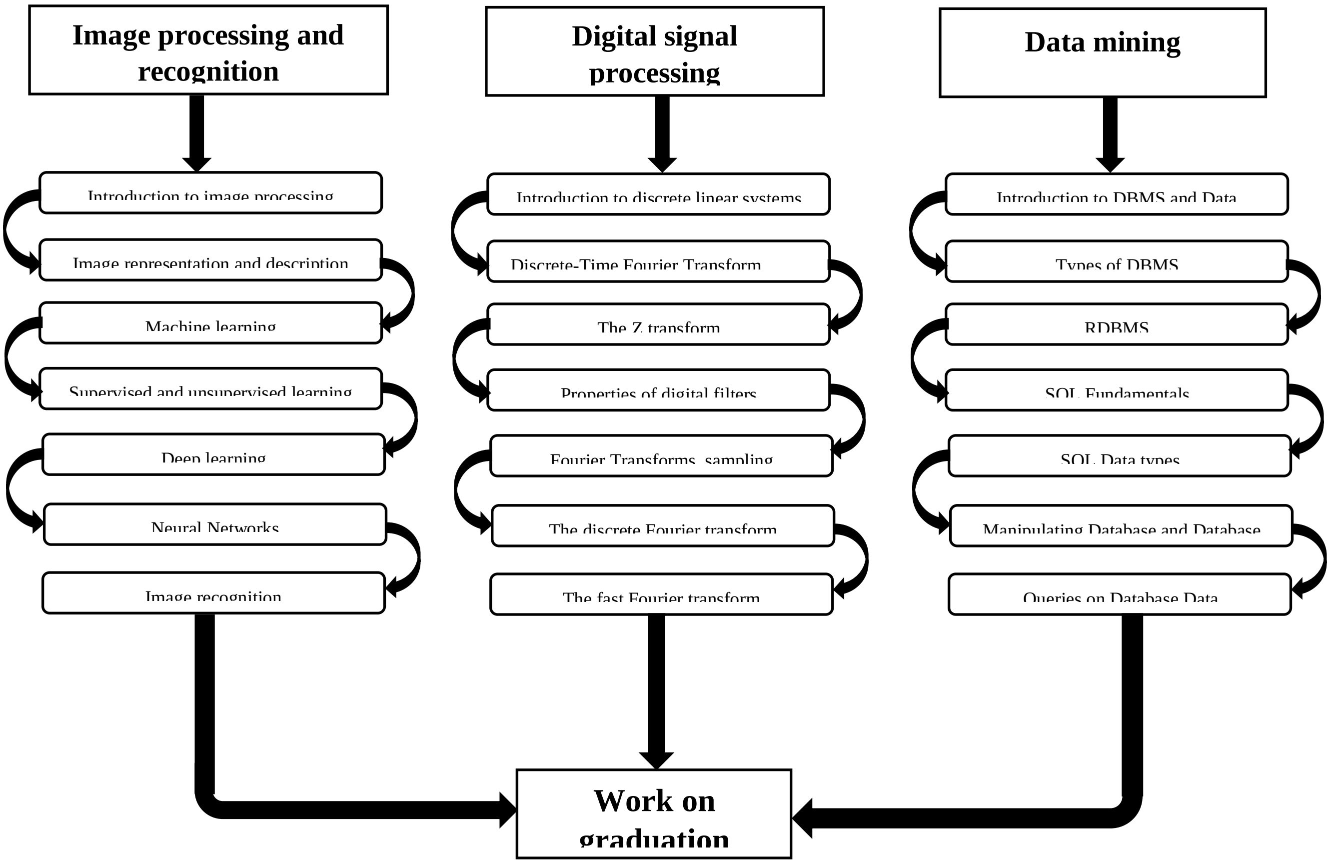

Figure 4. Re-Design of The Curriculum and Syllabuses of Subjects Taught in Mechatronics and Robotics Major at ETUT.

2.4. Enhancement of teaching and learning methods.

In order to achieve both disciplinary and skills learning, students must spend their time learning differently and teachers must use the best teaching and learning methods throughout the program. To address these learning needs, we did improvement in two basic areas: (1) an increase in active and experiential learning, and (2) the creation of integrated learning experiences that lead to the acquisition of both disciplinary knowledge, personal and interpersonal skills, and product, process, and system building skills [4].

Active learning approaches get students involved in their learning through activities that require them to think critically and solve problems. There is less emphasis on passive transmission of information and more emphasis on engaging students in manipulating, applying, analyzing, and evaluating ideas. Students learn more and better when they are actively engaged in thinking about concepts, especially new ideas, and when they are required to express their understanding in some way. Such metacognitive awareness supports students' motivation for the learning task at hand, and can also contribute to fostering habits of lifelong learning [5].

Educational research confirms that active learning techniques significantly improve student learning. Students learn actively when they engage with ideas in a meaningful way, such as by experimenting, solving problems, and reflecting on their learning. Active learning in lecture-based courses includes pauses for reflection, small group discussion, and real-time feedback from students about what they are learning. Active learning becomes experiential when students take on roles that simulate professional engineering practice, such as design-implement projects, simulations, and case studies. Emphasis on widespread use of active and experiential learning is a key element of the commitment to developing a deeper understanding of the technical fundamentals. The expected outcome is an understanding of the underlying technical concepts, as well as their application. This is understood to be a precursor to innovation [5].

Figure 5. Active learning method and design – implement experience at ETUT.

Integrated learning experiences are required to make more effective and efficient use of student learning time. Integrated learning refers to learning experiences that lead to the acquisition of disciplinary knowledge concurrently with personal and interpersonal skills, and product, process, and system building skills [7].

This gives the learning experiences dual impact. This learning certainly occurs in design-implement experiences, but is not limited to these experiences. One example of a critical ability in engineering is the competence to solve problems effectively. Disciplinary knowledge allows a student to solve the problem right, but an integration of broader skills is necessary to teach students to solve the right problem [7].

A modified problem-based learning format, with strong emphasis on the fundamentals, supports this type of integrated learning. However, we have many other opportunities to integrate learning, such as coupling communication or teamwork with an assignment, encouraging students to dig deeply into a topic and use specific research and inquiry methods, or discussing the ethical aspects of a technical problem concurrently with its technical aspects. An important subtle aspect of this integrated learning is that students see their role models - the engineering faculty, discussing this wider range of skills, signalling their importance to the profession [7].

Engineers design and implement products, processes, and systems. Repeated opportunities to design and implement systems help students develop a deep understanding of the basics and the skills to create new systems. Because engineers need to work in design teams, design-implement projects are a good way to teach students personal and interpersonal skills, as well as product, process, and system building skills. Students gain hands-on experience in every stage of engineering, from conception to operation, especially in the introductory and culminating projects. The concluding project course is re-tasked into one that is closely linked to one or more disciplines and engages students in designing, implementing, and operating a sustainable product, process, or system. Aligning theory development with practical implementation gives students opportunities to learn both the applicability and limitations of theory [3].

It was decided to re-task existing laboratory space by building modern engineering workspaces that are supportive of, and organized around, conceiving—designing—implementing—operating. Conceive spaces have been designed to encourage people to interact and to understand the needs of others and to provide a venue that encourages reflection and conceptual development. They are largely technology-free zones. Design and Implement facilities help students learn how to use digital tools to work together on design projects, and how to build and integrate modern hardware and software. In operate workspaces, students learn how to operate their own and faculty-assigned experiments. Simulations of real operations, as well as electronic links to real operations environments do supplement the direct student experience. In addition, workspaces also support other modes of active and hands-on learning, including experimentation, disciplinary laboratories, and social interaction. The space facilitates and encourages team building and team activities.

2.5. Development of effective assessment methods.

Educational reform needs to be guided by rigorous assessment and evaluation to ensure that it is effective. Effective learning assessment measures how well students have achieved the specific knowledge, skills, and attitudes that they are expected to learn as a result of their education. Student learning assessment measures the extent to which each student achieves specified learning outcomes [4].

Effective assessment is learner-centred, that is, it is aligned with teaching and learning outcomes, uses multiple methods to gather evidence of achievement, and promotes learning in a supportive, collaborative environment [4]. At this stage, we improved the assessment methods at our university by creating new effective rubrics such as awareness about sustainability [6].

Table 1. Rubrics for Effective Assessment

	Written and Oral questions	Performance Ratings	Project Reviews	Self-Report Instruments
Conceptual understanding	X			
Problem solving	X		X	
Knowledge creation and synthesis		X		
Skills and processes				X
Attitudes		X	X	X
Sustainability			X	

2.6. Program evaluation.

In the end of our program, we need to evaluate the overall quality and the entire educational program in order to judge effectiveness of the program based on evidence of progress toward attaining the goals of our innovative approach to training sustainable engineers. Acquired results will lead to enhancing the methods in further improvement of the approach.

3. Conclusion

In our approach, we suggest innovative ways to develop a deeper working knowledge of technical fundamentals while simultaneously learning personal and interpersonal skills, and product, process, and system building skills. For analysis of interrelated arrangement of modules for effective acquisition of knowledge, we studied a supportive alignment of disciplinary courses and mapped a wide range of skills required in professional areas throughout the curriculum. Moreover, we developed a learning context that provides an opportunity to implement both theoretical and practical knowledge to conceive, design, implement and operate sustainable systems and products, and integrated methods of gaining active learning experience that forms a basis for carrying out challenging capstone projects. As a result, our innovative approach that focuses on modification of education and research improves all aspects of comprehensive training of sustainable engineers.

References

[1] University website etut.edu.tm
[2] UNESCO. *Engineering for Sustainable Development* (2021).
[3] Edward F. Crawley · Johan Malmqvist Sören Östlund · Doris R. Brodeur Kristina Edström. *Rethinking Engineering Education* (2014).
[4] Biggs, J. *Teaching for Quality Learning at University* (2003).
[5] Bransford, J. Brown, A., and Cocking, R. How people Learn (2000).
[6] UI_Greenmetric_Guideline_2022.
[7] Cristian Cardenas, Claudia Martinez, Marcia Munoz. *Bringing active learning into engineering curricula: creating a teaching community* (2013).