Journal of Engineering Education Transformations ,
Volume 37 , No. 4 , April 2024 , ISSN 2349-2473, eISSN 2394-1707

10.16920/jeet/2024/v37i4/24159

Studying the Impact of the "Undergraduate Research Projects" Course in Mechatronics Engineering on the Professional Career Development of Engineers

Zühal Erden
Department of Mechatronics Engineering, Atilim University, Ankara Turkey
zuhal.erden@atilim.edu.tr

Abstract : Undergraduate research (UR) in engineering education is an important active learning strategy, and it is widely used through various implementation styles. Several studies have been conducted to assess the contribution of UR experience in the career path of alumni from an academic point of view and based on graduate studies. This paper is focused on the assessment of UR experience gained through a two-semester long "Undergraduate Research Projects" course sequence, on the professional career of mechatronics engineering alumni. The results of a survey-based investigation show that such UR experience is considered beneficial by the alumni in three main aspects: employment, entrepreneurship and the effect of the obtained knowledge and skills on the professional career. The feedback from the alumni has revealed that this experience contributes significantly to the development of their research abilities. In addition, many graduates emphasized that the UR experience is beneficial for employment as well as for their academic and professional development. The suggestions from the alumni concerning collaboration with the industry, course methodology, and selection of project topics form a basis for systematic UR model development by faculties in the future.

Keywords : Undergraduate research; engineering education; mechatronics; professional career; assessment

Zühal Erden
Department of Mechatronics Engineering,
Atilim University, Ankara Turkey
zuhal.erden@atilim.edu.tr

1. Introduction

Pioneered by MIT in the late 1960s, the concept of undergraduate research (UR) has been integrated into engineering curricula in various ways, especially at research-intensive universities in the U.S. With positive results obtained, UR has been strongly recommended, particularly since the 2000s, and the "research experience for undergraduate students" has been embedded in engineering curricula in many universities worldwide ever since. (Shettar & Mudenagudiemail, 2015)

The contributions of the UR experience to the career goals of the alumni have been studied mostly in terms of the potential graduate research and publication (Youngblood et al., 2018). Undoubtedly, such UR studies in engineering education have left a positive mark in this sense; however, most engineering graduates prefer to participate directly in the industry rather than have an academic/research-

oriented career. For this reason, in addition to the graduate research performance of the alumni, it is important to measure and evaluate the contribution of the "UR" experience to them while on their path to the professional engineering career. Such evaluations can be useful in updating the undergraduate engineering programs since the UR experience provides students with research culture and methods, not to mention other potential benefits such as communication skills, teamwork, leadership qualities, ethical standards, and project management. In addition, UR studies improve the students' problem-solving and critical thinking skills, which are considered among the key abilities for professional life in the 21st Century (González-Pérez & Ramírez-Montoya, 2022). The UR experience also creates an important environment for engineering students to engage in interdisciplinary and multidisciplinary teamwork, which is another important qualification sought by the industry (Carter et al., 2016).

Rigorous studies are needed to identify ways of designing research experiences for undergraduate students. It is further important for such studies to have assessments that can document the students' progress based on research experience, as well as help to distinguish between the effective and ineffective aspects of the UR experience. These types of studies provide an important basis for creating systematic and sustainable research experiences for undergraduate students. (Linn et al., 2015).

Mechatronics engineering is considered as a research-oriented engineering discipline due to the interdisciplinary nature and innovative engineering systems involved in it. Therefore, UR has a special importance in this field. Parallel to the developments in the world, mechatronics engineering education also began in Turkey in the late 1990s, and this education gained its formal and standard structure in the early 2000s. One of the very first mechatronics engineering undergraduate programs in Turkey was established by Atilim University in 2002. At this university, engineering design with research for technology development and learning through hands-on experience in laboratories are highly encouraged at the Department of Mechatronics Engineering (Akpinar, 2006). With the contribution of this laboratory infrastructure, UR has been systematically included in the curriculum since the establishment of the department. The senior-level course titles are “MECE 407 Undergraduate Research Projects I” and “MECE 408 Undergraduate Research Projects II”. MECE 407-MECE 408 (referred to hereafter as UR I-II) courses were offered in the 2006-2007 academic year for the first time, when the very first group of mechatronics students were at their senior year. The above-named courses continued for about 10 years as designed. During the curriculum change in 2016-2017, the UR experience became embedded in the capstone design course due to administrative requirements.

This paper presents a research which aims at determining the effect of experiences gained upon the completion of the UR I-II course sequence on the career development of students, as well as on their professional life after graduation. The research is based on the alumni perspective in determining this effect and, for this purpose, a survey is conducted with 97 graduates (19 females and 78 male) who were enrolled in the UR I-II courses during their undergraduate education.

The results of the evaluation survey reveals that the UR experience in undergraduate education contributed positively to the career development of the graduates. More specifically, this contribution emerges in the process of the graduates' employment by companies, or in their applications for various institutional supports as entrepreneurs. In addition, the UR experience is shown to encourage the participants to opt for graduate education, and to be methodologically useful in this process, even if the participants work on different projects.

The remaining parts of this paper are organized as follows; Section 2 provides a literature review on undergraduate research in engineering education and its role in the professional career development of the alumni. Section 3 introduces the basic structure, methodology and achievements of the UR I-II course sequence at the Mechatronics Engineering Department in question. Section 4 explains the results of a survey-based investigation of the alumni's perception concerning these courses. Finally, Section 5 includes the discussion and conclusions regarding this work, and describes the future research directions in this context.

2. Literature Survey

Various studies present different approaches for incorporating undergraduate students into research, benefits of the undergraduate research experience, and the comparison of such approaches and benefits

with the expected outcomes of the UR experience (Sabatini, 1997). The establishment of formal research programs for undergraduate engineering students is one way to encourage critical thinking, life-long learning, and the pursuit of graduate education. Jemison et al. (2001) discuss the participation of undergraduates in engineering research, and present potential modifications and enhancements to meet the changing needs of students and graduate schools. The impact of UR on Engineering Technology education and future challenges are also discussed by Yeh et al. (2003). A Research Communications Studio (RCS) is described by Thompson et al. (2005) as a structured approach for teaching undergraduate researchers to do authentic written, oral, and graphical communications tasks while learning to do research. The frequency of undergraduate student research experiences at different types of colleges and universities from the early 1990s through 2004 is compared by Hu et al. (2007). The results indicate that the frequency of student research experiences had increased since 1998 at all types of institutions, and that the students at research universities were not more likely than their counterparts elsewhere to have such experiences. Nava-Medina et al. (2017) explored various formats of undergraduate research as high-impact learning experiences within engineering technology programs. In Bali and Giriyapur (2015), research activities are embedded into non research-oriented courses. According to them, rigorous research is needed to identify ways to design research experiences so that they promote integrated understanding. Linn et al. (2015) states that creating research experiences that meet the needs of interested students and make effective use of scarce resources requires systematic and iterative studies with multiple indicators of success. Garcia et al. (2014) investigated the process of social interaction; whereas, Pai et al. (2015) focused on students' awareness, experiences, and perceptions through involvement in research.

The UR experience is of great importance for the field of robotics and mechatronics, since the design and development of intelligent and adaptable robotic systems with embedded control software needs extensive research. For example, Singh et al. (2010) advocate a research-driven model for a Modern Robotics course design that, based on a principled approach, prepares students to consider and adopt the most recent advancements in mechatronics within their own specific project applications. The importance of undergraduate robotics research is emphasized in Berri et al. (2012) in terms of freshman students' involvement in team work, creativity, and extracurricular activities.

As stated earlier, several studies on the assessment of undergraduate experience have been published. Some of them evaluate the impact of a research experience for undergraduates course in enhancing the attainment of learning outcomes (Shettar & Mudenagudiemail, 2015; Carter et al., 2016; Powers et al., 2018). Others measure the impact of undergraduate research experience on the motivation of students to pursue higher studies and research careers, and the results prove to be positive (Zydney et al., 2002b; Bauer and Bennett, 2003; John and Creighton, 2011; Shettar & Mudenagudiemail, 2015; Popescu et al., 2019; Trott et al., 2020). Additionally, Lopatto (2004) examined the reliability of student evaluations of summer undergraduate research experiences using SURE (Survey of Undergraduate Research Experiences), and a follow-up survey was carried out later. Accordingly, students reported gains in independence, intrinsic motivation to learn, and active participation in courses taken after the summer UR experience (Lopatto, 2007). Zydney (2002a) presents the perceptions of the science and engineering faculty at a mid-size university with a very extensive UR program. The faculty who supervised the undergraduates for a longer period of time and who modified their research program to accommodate undergraduates perceived a greater enhancement of important cognitive and personal skills. Budiman and Zheng (2018) discuss the UR experience from the perspectives of both the mentor and the mentee. In this study, mentor's motivation to recruit UR students could include (i) high probability of finding talented students to work on project of relatively short duration (i.e., one year); and (ii) producing solutions to a variety of problems that could lead to research problems. These motivations are shown to align well with those of the UR mentees - i.e., experience in solving more realistic (open-ended) problems and strengthening their research portfolios. Myres et al. (2018) analyzes a research collaboration between faculty and undergraduates at a teaching-intensive university within a teacher education program to expand the opportunities for undergraduates to engage in meaningful research. Powers et al. (2018) establish a context for understanding the characteristics and attitudes of students who participate in internships and undergraduate research. In Youngblood et al. (2018), the role of social inquiry as a bridge between

education and practice for undergraduate student researchers in engineering is examined to investigate their ability to work in complex socio-technical systems - a critical competency for professional engineers.

Apart from this, UR provides an opportunity for research advisors to guide students on their path to becoming engineers and help them to explore career opportunities that may not be available otherwise. Bass et al. (2018) showed that the students' UR experience has highly influenced their future career path in engineering. In McLening and Burgess (2018), a UR study is conducted in the form of comparing team projects to individual ones. The results indicate that team-based projects may offer improved employability for graduates. What is more, the experience of a team project increased the positive perceived impact above that of an individual project when applying and securing employment, and even as far as the early stages of her or his career in engineering and design roles. Gilmore et al. (2015) investigate the association between UR experiences and actual research performance in graduate schools. Adedokun et al. (2012) offer descriptions drawn from an analysis of students' reflective journals, mainly in the form of three processes through which UR experiences affected their educational and career aspirations. Based on the results of this study, it is concluded that through UR experiences, students learned more about their career options, clarified their career choices, and enhanced their professional credentials.

In the literature, there are many studies that measure the contribution of undergraduate UR courses and practices to students, alumni, faculty, and/or related programs. However, no study has been found that measures how the UR experience contributes to the career development of graduates working in the industry. Therefore, the present article seeks answers to the following research questions based on the UR course experience given at the Atilim University Mechatronics Engineering Department:

RQ1: What is the effect of the UR experience in the mechatronics engineering undergraduate education on the career development of graduates working in the industry?

RQ2: In line with this effect, what are the suggestions for undergraduate UR courses/practices in mechatronics engineering education?

In order to find answers to these research questions, the data were collected by conducting a survey on the graduates with UR experience during their undergraduate education and presently working in the industry. Before proceeding with the analysis of the survey results, the following section clarifies the structure and methodology of the UR courses under concern in this study.

3. The UR I-II Course Sequence in Mechatronics Engineering

A. History and Overview of the UR I-II Courses

The UR I-II courses were designed during the establishment of the Department of Mechatronics Engineering at Atilim University and they were embedded into the 7th and 8th semesters of the curriculum. Since the first year students of the department started their education in the 2003-2004 academic year, these courses were given for the first time in the 2006-2007 academic year. Within the scope of this course sequence, the students participate in research projects offered and supervised by various faculty members, one of whom is responsible for theoretical lecturing on research methodology as well as for the coordination and organization of the courses. The students are organized as project teams, and they are required to present the progress of their research studies via both written reports and oral presentations during and at the end of each semester.

The main purpose of the UR courses is to raise awareness of and implement research methodology to solve engineering problems. The course is designed so that student teams learn to work on a special research project offered by the instructor(s) of the course. They are free to select one of the research topics offered depending on the expertise domain that they would like to focus on in their future professional life. Teamwork is strongly encouraged and required. As for the research projects, they are selected in such a way that the planned work is completed within one academic year to satisfy the expected requirements. Extensive laboratory work, analytical modeling, and design experiences are also expected.

Based on the educational philosophy during the establishment of the department, it is very important for the students of mechatronics engineering to be educated as researcher engineers. For this reason, these courses are the ones to which the department attaches a lot of importance and preserves its structure

and philosophy. This philosophy is based on the completion of the undergraduate program by providing students with a strong design culture as well as a reliable research background; hence, the availability of the core courses "capstone design" and "capstone research" in the senior year. This philosophy and the underlying UR course structure have also been recognized and approved by "The Association for Evaluation and Accreditation of Engineering Programs" (MUDEK), and the Department has so far received two consecutive five-year certifications. The MUDEK (Association for Evaluation and Accreditation of Engineering Programs, 2022) is a non-governmental organization which aims to contribute to the enhancement of engineering education quality by the accreditation and evaluation of such programs in various disciplines. For this reason, the fulfilment of the MUDEK criteria is a significant step in order to improve engineering education in Turkey and obtain international notoriety.

B. UR I-II Course Methodology, Projects and Achievements

The UR I-II course sequence spreads over an academic year, and it is designed such that the project assignments are divided into two semesters. Each faculty member prepares a document including the project topic, objectives, and assignments before the Fall semester starts. The project topics and supervisors are announced to the students within the first week of the semester. After the formation of research teams, the projects are assigned to the teams mainly based on the students' preferences. After an extensive literature survey and determination of research question(s), each team uses a proper methodology depending on the characteristics of their project.

The UR I-II courses are conducted by a team of project advisors and a coordinator faculty member, who is also responsible for giving theoretical lectures on research methods and tools, how to plan and execute the research project, and techniques for written and oral presentation. The coordination of advisors and project teams, planning and organizing the submission of written reports as well as oral and poster presentations, grading of common and general parts of the reports, and organization of "Mechatronics Engineering Student Conference" (short name MeMOK after the abbreviation of its Turkish name) are the other duties of the coordinator. The advisors are responsible for determining the research project, providing academic support and guidance to the students in the project team, and evaluating the research results and grading reports based on the contents. The students are expected to contribute to their projects both individually and as a team, to gain their first experience in scientific research, and also to improve their abilities in teamwork, project planning, and oral/written presentations. In addition to these achievements, each research project is expected to make some form of contribution to the related literature, and this is considered as the main success criterion.

The UR I-II course chain was a unique approach for engineering education in Turkey at the time it started due to its systematic nature to convey the culture of research as an initial experience to undergraduate students. Table 1 lists the selected projects carried out at the undergraduate level in these courses. Some of these projects were even developed further in the upcoming semesters, leading to graduate research studies/projects and to related publications.

The UR I-II courses have been successful not only

Table 1 :
Selected Project Topics in the UR I-II Courses

Academic Year	UR I-II Project Topics
2017-2018	• Haptic devices and interfaces as a means of physical interaction among humans, robots, and animals • Behavioral modules for social robots using a 3D design structure matrix • Target tracking and shape estimation
2016-2017	• Development of behavioral modules for mechatronic systems
2015-2016	• Real-time embedded control of a dynamic system • A microcontroller -based, two -axis solar tracking system • Development of a cognitive system for communication and beverage transportation among a waiter robot, a bartender robot, and a customer.
2014-2015	• Development of a rose -harvesting robot • Design methodology for platform -based modular mechatronic products • Imitation of human jaw movements by robots
2013-2014	• Design and performance development of swarm robots • Micro air vehicles with axial propellers • Conceptual design of a wearable artificial hand for the handicapped
2012-2013	• The bioinspired design of a platform for mimicking human gait on a tread mill. • Coaxial rotor miniature air vehicles • Air-ground hybrid flying robots • Bioinspired control architectures for robotic mirror therapy • Fuzzy logic speed control of a 4 -wheel vehicle
2011-2012	• A dragonfly -like robot • Swarm robotic systems with infrared technology • Flying robots

in terms of research, but also in philosophy and practice, and have led to other unique practices over time. The first impact is the institutionalization of undergraduate research throughout the University via an Undergraduate Research Program (called LAP as its equivalent Turkish) (Atilim University, 2022) upon fixed financial support. The LAP program started in 2010 as a result of the success of the projects in UR I-II course chain and the impact of the outputs of these projects (Akay and Erden, 2012). The program is mainly a faculty-mentor driven model based on team research. The LAP model has been instrumental in providing high-quality research experiences for undergraduate students in multiple disciplines. The institutional funding it receives contributes to its success, and so do the faculty support and student excitement.

Another impact of the UR courses is the Mechatronics Engineering Student Conference (MeMOK in short as its Turkish acronym). Between 2007-2010, the oral presentations made at the end of each academic year within the scope of this course chain were held as the end-of-year project presentations. Starting from 2010, the project presentations become more structured with the aim of providing a scientific conference environment for students to present their undergraduate research conducted within the scope of the UR I-II courses and to publish the results of their research in the form of a scientific paper in the MeMOK proceedings. The first three MeMOK conferences between 2010 and 2012 were organized as internal events of Atılım University with the participation of students mainly from the Mechatronics Engineering Department. The papers presented in the said period were also published as proceedings and handed out freely as CDs. Between 2013-2015, MeMOK was organized as a national event with the participation of students from other Turkish universities, thereby setting a novel example for engineering education in general and for mechatronics engineering education in particular across Turkey. Figure 1 illustrates a view from MeMOK 2014. The papers presented in the MeMOK as of 2013 were published as e-proceedings, thus making an important contribution to the respective resource database.

In addition to the oral presentations, physical demonstrations of the UR I-II projects are materialized at a university-wide project exhibition festival called the Mechatronics Engineering Day (MECE Day in short), which is organized traditionally

Fig. 1: A view from MeMOK 2014

at the end of each academic year. The MECE Day forms an enthusiastic atmosphere for all students of the department, since it offers a chance to present all projects from freshman to the senior year. Figure 2 depicts one such demonstration on an exhibition day. In addition to the students, the faculty and other staff of the university, the MECE Day is also open to families and friends of students as well as representatives from the industry. The participation of representatives from various companies and their interest in student projects resulted in the invitation of some senior students to job interviews even before they graduated, and eventually to their employment.

In addition to contributing to the research-oriented academic studies of graduates in the future, the UR I-II courses also pioneer the development of traditional and institutionalized organizations and programs throughout the university. Apart from all these effects, the main question of this paper is how UR I-II courses contribute to the careers of the graduates working in industry. In order to find answers to this question, a survey is conducted among the graduates of the department about the impact of the UR I-II courses on their career development, and the results obtained are explained in what follows.

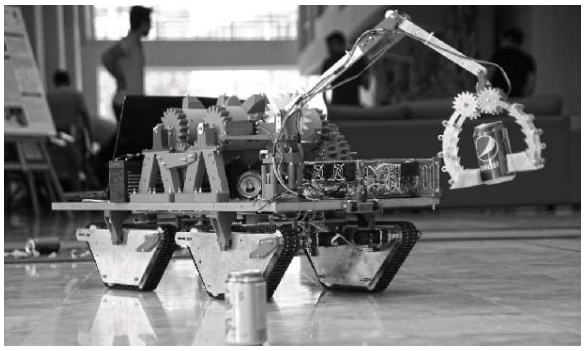

Fig. 2 : A student project in operation during a MECE Day.

4. Evaluatıon of the UR I-II Chaın Effect on Professıonal Career Development of Alumnı

The present study examines the impact of the UR I-II courses on the professional career development of mechatronics engineering graduates of Atılım University in the industry. For this purpose, a Google Survey was used to obtain alumni feedback for evaluating the UR course chain and its effects on their career development. The survey was approved by the Institutional Review Board of Atilim University prior to its administration, and all the alumni were asked to read and give informed consent to the anonymous use of the survey data for this research. The questionnaire was sent to 97 (19 females, 78 male) graduates who took the UR I-II course chain between 2006-2007 and 2017-2018 academic years. In all, 43 (44.3 %) completed the questionnaire. There are 20 questions, 19 of which are classified as shown in Table 2 based on the main aspects to be measured. Qualitative comments involving suggestions to improve the UR course were specifically requested in the given space for the last question.

Table 2 :
Taxonomy of Questions in the UR Questionnaire

Question No	*What is measured*
1-2	Professional experience (in years)
3-5	Professional area of specialization
6-9	Effect of UR courses on the decision to continue to graduate studies and the quality of such studies in time (if any)
10-12	Contribution of UR courses to establishing one's own enterpreneurship
13-14	Contribution of UR courses to enhancing one's employment opportunities
15-19	Impact of knowledge and skills gained in UR courses on professional career

A. Quantitative Evaluation of UR Course Chain Effect on the Alumni's Career Path

The survey results show that 60.5% of the respondents graduated between the years 2010 and 2015. Considering the total number of respondent graduates, 41.9% stated that they have been working in the current company/institution between 5 to 10 years, and 44.2% between 1 to 5 years. In total, 72.1% are working at private companies and 14% have established their own entrepreneurships. As a result, 86.1% is working in the private sector, where the competition is fierce.

Concerning questions 4 and 5 dealing with the area of expertise, the respondents could mark more than one option and add their own items. The distribution of the answers to these questions concerning the working area and the subject of study is given in Figure 3 and Figure 4, respectively. As it can be noticed from Figure 3, most of the graduates are working in Research and Development (51.2%), Product Development (44.2%) and Production/Manufacturing (39.5%). Considering the specific topics that graduates are working on in these fields, Figure 4 shows that approximately half of the graduates (48.8%) work on system modeling and design. The "robotics applications" was marked by 25.6%, and "sensors and actuators" and "control" marked equally with 23.3% each. The other important topics include "industrial automation" (18.6%), "signal/data/image processing" (18.6%), and "software design/artificial intelligence" (16.3%). As it can be understood from these results, the graduates who participated in the survey mostly work in areas/subjects that require extensive research.

Questions 6-9 are used to evaluate the effect of the UR courses on graduate studies. The results show that 44.2% of the graduates have either completed or are in postgraduate education. These graduates were asked the question "Did/does the project work in the UR course have an impact on your decision to pursue graduate education?" The answers to this question were "yes" or "partially yes" with 68.5%, and "no" with 31.5%. When we examine the relationship

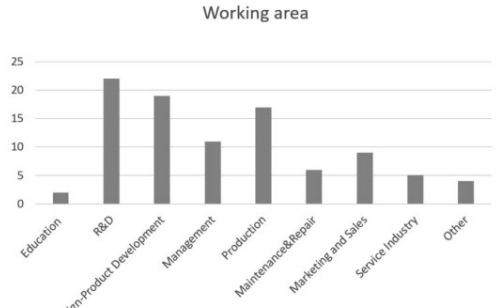

Fig. 3 : Percent Distribution of Alumni Answers for Working Area.

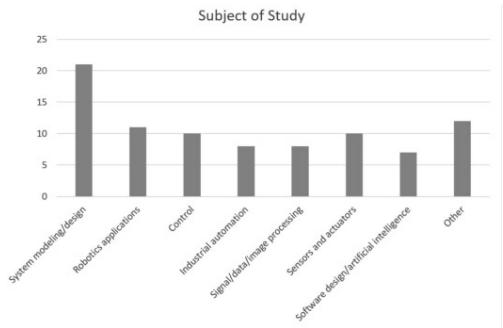

Fig. 4 : Percent Distribution of Alumni Answers for Subject of Study.

between the research topics in graduate education and the project topics in the UR course, it is seen that 31.6% of the thesis studies are either completely or partially related to the UR course projects. Additionally, 78.9% of the graduates with postgraduate education give positive answers (52.6% as "Yes" and 26.3% as "Partly Yes") to the question "Do you think that your project work in the UR course contributed to your graduate education?" Of these respondents, 68.4% answered "No" to the question "Is your graduate study topic related to the project topic you did in the UR I-II courses?". These results show that although the UR I-II course chain may not be directly relevant to research-intensive graduate studies in terms of the subject, it still contributes both to encouraging the pursuit of graduate studies, and to supporting graduate studies methodologically.

In the alumni survey, the impact of the UR I-II courses on the graduates' entrepreneurial experiences is also examined. It has to be mentioned here that, in Turkey, entrepreneurships may be established by either submitting the respective authorities a project proposal in order to obtain a financial grant, or to establish one's own entrepreneurship using one's own resources. Accordingly, the percentage of graduates who set up their own entrepreneurships as independent of their family business based on a project proposal with or without government support, was determined as 37.2%. Although this rate is not very high, the data from these graduates reveal the impact of the UR I-II course chain on entrepreneurship. Additionally, 75% stated that their proposal was not related to their project in the UR I-II courses, yet, 68.8% of those who set up an entrepreneurship gave the answer "yes" or "partially yes" to the question "Do you think that your experience in the UR courses helped in preparing a project proposal?" This result shows that the UR I-II course chain also makes a positive contribution to the entrepreneurial experience.

Another issue examined in the research is the effect of the UR I-II courses on the graduates' employment. In all, 65.1% stated that they were asked questions about their UR projects in their job interviews. These graduates were asked the question "Do you think that the answers you gave in the job interview to the questions about the project you had undertaken in your UR courses had a positive impact on your employment?" The rate of those who answered "yes" to this question is 57.1%, and the rate of those who answered "partially yes" is 35.7%. Therefore, in total, 92.8% of the graduates working as employees think that the UR courses have contributed to their being employed.

Another dimension measured related to the UR I-II course chain in this study is the skills and abilities that this course sequence provides, and which have a positive impact on the graduates' career development. The answers to two questions on this dimension are presented in Figure 5 and Figure 6, respectively. It is understood from the results in Figure 5 that the UR courses mostly contribute to "performing literature survey" and "preparing written reports and presentations", with 86% for each item. Next come, "conducting research" and "team working", with %74 each. According to Figure 6, the graduates think that the UR courses mostly contribute to "project-based learning", "problem solving", and "collaborative learning".

The answers given to the question "In your opinion, which personal qualities/characteristics does the UR I-II course chain develop among the students?" are provided in Figure 7. The results show that 'proactive behavior' has the highest rate (89.5%), followed by 'leadership' (63.2%), 'adaptability' (57.9%) and 'risk taking' (52.6%). From the answers given to the remaining questions, it is understood in general that 88.4% of the graduates think that the UR

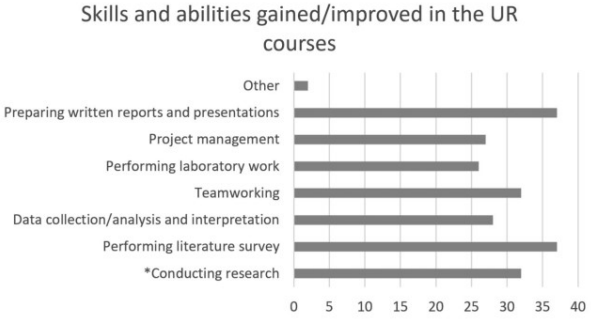

Fig. 5 : Survey Results for Abilities Gained / Improved in the UR Courses.
(*includes Modelling, Simulation, Prototyping, Testing).

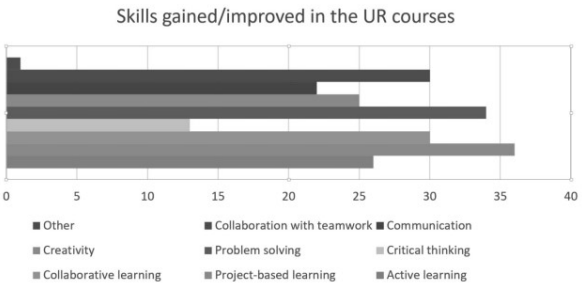

Fig. 6 : Results for skills gained/improved.

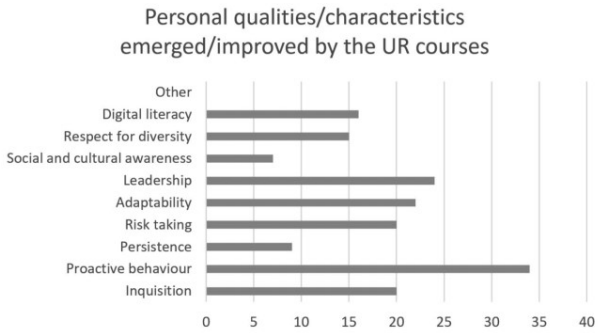

Fig. 7 : Answers Related to the Personal Qualities / Characteristics Developed Through the UR Courses.

courses contribute positively to the shaping of their careers. In detail, this contribution breaks down into technical (71.1%), personality-related (47.4%), administrative (44.7%), and social (36.8%) aspects, respectively.

B. Qualitative Evaluation of Alumni's Feedback Concerning the UR Courses

The qualitative evaluation is based on the written comments and suggestions by the graduates gathered from the questionnaire. When filtered, it is seen that these comments and suggestions mainly fall into the following three categories:

i. Collaboration with the industry,

ii. Course methodology, and

iii. Selection of project topics.

In what follows, the following includes some of the comments and suggestions translated from Turkish. Among the suggestions from the graduates in the above-mentioned categories, 'collaboration with the industry' appears to be the most important one. The suggestions on this issue are expressed by the graduates from different perspectives; for example, some evaluated the relationships between the project topics in the UR courses and the industrial requirements, emphasizing the importance of choosing up-to-date research topics that are compatible with the actual market demands. These suggestions also fall into the "selection of project topics" category. Some of the comments from this perspective are as follows: "It is necessary to cooperate with the industry to carry out studies that fill in the product-technology gaps related to current issues", "Cooperating with companies and selecting project topics that best fit the market needs". In addition, 'collaboration with the industry' is discussed by some graduates from the systems approach and project management perspectives, rather than being project topic-based. They emphasize students' learning and obtaining actual business experiences during the project. This is given in a comment as follows: "Students' awareness concerning a real-life project can be increased if they are expected to create a system specifications document based on technical requirements. Report writing can also be organized in such a way that there are three reports on a quarterly basis as the Project Progress Reports, followed by an end-of-year Final Report. [Concerning real-life applications, it is more appropriate to stop the R&D process before the production phase and upon the assessment of the 2nd report]". Another comprehensive proposal from this perspective is stated as "Team-based system-level development projects can be conducted using a systems approach. For example, in a mobile platform development project, the mechanical design and the electronic design are made by different sub-teams, whereas another sub-team is responsible for software development. Then, these sub-teams work together for system integration and testing. Such a model is more suitable to the business life and the whole system can be matured within a-year-long project. Students can be encouraged based on their areas of interest". Another interesting and important perspective regarding 'collaboration with the industry' stands out as the adaptation to a professional culture, motivation and creativity. In one of the suggestions, one graduate says the following: "Developing projects in cooperation with industrial organizations will be useful for adaptation of students to business life more quickly in terms of technical, administrative, and professional culture". Another comment is "The R&D centers of large industrial enterprises can be visited periodically to introduce to students their current research activities with the aim of triggering motivation and creativity."

The comments on the teaching of the course regarding the 'course methodology' category state that the UR projects are very instructive in terms of research, teamwork, and project management. Still, some suggestions were made on important issues that could be improved; these stand out as: increasing the efficiency of teamwork in projects, carrying out more active laboratory studies, assessing each individual's contributions to the team more elaborately, providing training on effective presentation skills, and reviewing the criteria to pass the UR I-II course chain

such as publication in refereed conferences. Increasing financial support is also an important issue emphasized by the alumni; an interesting suggestion from a graduate even emphasizes better use of social platforms for disseminating the results of the UR projects as follows: "Announcing the projects in the field of mechatronic systems to more people and promoting the projects on social platforms will provide a great advantage both for our department and for the students who made the project. In this way, mechatronics engineering can make its name known to more people." Graduates, in general, appreciate the contribution of the UR courses to their professional career and support the continuation of the approach, as provided in the following comment: "I suggest that the approach be continued and preserved in such a way that individuals who can meet the course requirements are able to further anticipate the needs that may arise in the future [in their careers], and adapt themselves accordingly".

Most of the suggestions from the alumni on the 'selection of project topics' emphasize choosing topics by anticipating the future needs and requirements of the industry. One comment regarding this category states: "Innovative topics can be selected that can shape the industry and help establish new companies and jobs for students after graduation"; whereas, another one states: "It can be a course in which projects are made to make people's lives easier and where the techniques of various production processes are researched." In general, graduates emphasize the importance of software development, suggesting to increase the weight of software development in UR projects, as the following comments testify: "In projects, topics that will push students to learn about software a little more intensively can be selected", and "More focus on topic diversity and software direction".

5. Dıscussıon, Conclusıon and Future Work

The present research was an attempt to evaluate the effect of undergraduate research projects and the corresponding courses on graduates in the field of mechatronics engineering and their careers. The feedback from the alumni has revealed that this experience contributes significantly to the development of their research abilities. In addition, many graduates emphasized that the UR I-II experience is beneficial for employment as well as for their academic and professional development. The results of the alumni survey conducted in the present study point to the following key issues:

First of all, a project-based, one-year long systematic research experience for senior-level undergraduate education in mechatronics engineering is very important for professional life. It is strongly suggested that the UR experience framework be designed in collaboration with the industry. The details of this framework can be studied, and the models for the UR experience can be developed based on the needs and demands of countries, universities, industry and students. The model in which the UR experience is geared towards university-industry collaboration is, first, implemented by the determination of project topics and, later, conducting the projects in practice. In such a model, project supervisors are professionals picked up from both university and industry. As for the projects themselves, they can be designed so as to include the systems approach as well as alternative system integration perspectives. To illustrate, each student team can be assigned part of a holistic research project and, then, these parts can be integrated. While conducting the UR projects, students can work partly at the university laboratories, and partly at the selected industrial enterprise so that early adaptation to professional life is initiated. In addition, this methodology is useful in evaluating the students' contribution from both the teamwork and individual work point of views. To this end, both the university and the industry should participate in the evaluation and grading of students.

The results of this study provide a roadmap for educators and industrial partners who are interested in research-based product and system design. While the focus is limited to mechatronics engineering education, the discussion is also valid for other engineering disciplines. The undergraduate research to be integrated into engineering education in cooperation with industrial organizations provides an opportunity for active learning through real-life cases and scenarios and, thus, ensures adopting research culture and methodology. This study is limited to the perspectives of graduates concerning the effects of an undergraduate research experience on their professional life. As future work, a systematic collaborative UR model can be further developed by collecting data on the employers' view and combining the results of both perspectives, thereby complementing the present study and setting the grounds for future attempts in other disciplines and with alternative factors to be assessed.

References :

[1] Adedokun, O. A., Zhang, D., Parker, L. C., Bessenbacher, A., Childress, A., & Burgess, W. D. (2012). Understanding how undergraduate research experiences influence student aspirations for research careers and graduate education. Journal of College Science Teaching, 42(1), 82-90.

[2] Akay, H. & Erden, A. (2012). A Team-based Undergraduate Research Projects Program, 2nd International Engineering Education Conference (IEEC2012) "New Trends and Expectations", Antalya, Turkey.

[3] Akpinar, B. (2006). Mechatronics education in Turkey. Mechatronics, 16(3-4), 185-192. https://doi.org/10.1016/j.mechatronics.2005.11.001

[4] Association for Evaluation and Accreditation of Engineering Programs. (2022, December). Main Page. https://www.mudek.org.tr

[5] Atilim University. (2022, December). Internal Support Programs. https:// www.atilim.edu.tr/tr/argeda/page/945/lap---lisans-arastirma-programi

[6] Bali, J., & Giriyapur, A. (2015). Integrating Research Experience in Project Based Learning. Journal of Engineering Education Transformations, Special Issue (January 2015), 318-321. doi: 10.16920/jeet/2015/v0i0/59763

[7] Bass, P., Washuta, N., Howison, J., Gonzalez, R., & Maier, C. (2018). Benefits and Challenges of Undergraduate Research. ASEE Southeastern Section Conference, Daytona Beach, FL, USA. https://commons.erau.edu/asee-se/2018/technical-session/79/

[8] Bauer, K. W., & Bennett, J. S. (2003). Alumni perceptions used to assess undergraduate research experience. The Journal of Higher Education, 74(2), 210-230. https://doi.org/10.1080/00221546.2003.11777197

[9] Berri, S., Zhang, A., & Gailiani, G. (2012). Importance of undergraduate research in engineering technology programs. In ASEE Anual Conference. San Antonio, Texas. https://peer.asee.org/21497

[10] Budiman, R. A., & Zheng, Z. R. (2018). Making Undergraduate Research Experience More Productive. 2018 Canadian Engineering Education Association (CEEA-ACEG18) Conference, University of British Columbia, Canada.

[11] Carter, D. F., Ro, H. K., Alcott, B., & Lattuca, L. R. (2016). Co-curricular connections: The role of undergraduate research experiences in promoting engineering students' communication, teamwork, and leadership skills. Research in Higher Education, 57(3), 363-393. https://doi.org/10.1007/s11162-015-9386-7

[12] García, M. J. G., Téllez, E. A., González-García, C., & Ortíz, M. D. L. Á. G. (2014). Integration of teaching activities for training in research skills in Technical University of Madrid. The International Journal of Engineering Education, 30(6), 1613-1620.

[13] Gilmore, J., Vieyra, M., Timmerman, B., Feldon, D., & Maher, M. (2015). The relationship between undergraduate research participation and subsequent research performance of early career STEM graduate students. The Journal of Higher Education, 86(6), 834-863. https://doi.org/10.1080/00221546.2015.11777386

[14] González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st century skills frameworks: systematic review. Sustainability, 14(3), 1493. https://doi.org/10.3390/su14031493

[15] Hu, S., Kuh, G. D., & Gayles, J. G. (2007). Engaging undergraduate students in research activities: Are research universities doing a better job? Innovative Higher Education, 32(3), 167-177. https://doi.org/10.1007/s10755-007-9043-y

[16] Jemison, W. D., Hornfeck, W. A., & Schaffer, J. P. (2001). The role of undergraduate research in

engineering education. 2001 American Society for Engineering Education Annual Conference & Exposition, Albuquerque, New Mexico. https://peer.asee.org/9758

[17] John, J., & Creighton, J. (2011). Researcher development: the impact of undergraduate research opportunity programs on students in the UK. Studies in Higher Education, 36(7), 781-797. https://doi.org/10.1080/03075071003777708

[18] Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate research experiences: Impacts and opportunities. Science, 347(6222). doi: 10.1126/science.1261757

[19] Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. Cell Biology Education, 3(4), 270-277. https://doi.org/10.1187/cbe.04-07-0045

[20] Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. CBE—Life Sciences Education, 6(4), 297-306. https://doi.org/10.1187/cbe.07-06-0039

[21] McLening, C., & Burgess, J. (2018). Engineering and design student projects-The impact of team based final major projects on graduate employability. The 20th International Conference on Engineering and Product Design Education (E&PDE 2018), Dyson School of Design Engineering, Imperial College, London. pp. 706-713.

[22] Myers, J., Sawyer, A. G., Dredger, K., Barnes, S. K., & Wilson, R. (2018). Examining perspectives of faculty and students engaging in undergraduate research. Journal of the Scholarship of Teaching and Learning, 18(1), 136-149. doi: 10.14434/josotl.v18i1.22348

[23] Nava-Medina, I., Price, A. H., & Kuttolamadom, M. (2017). Undergraduate Research in Engineering Technology as a High-Impact Learning Experience. 2017 ASEE Gulf-Southwest Section Annual Conference, Richardson, TX, USA. https://peer.asee.org/33833.

[24] Pai, P. S., Rao, B. S., Chiplunkar, N. N., & Bhat, K. S. (2015). Undergraduate Students' Research: A Case Study of their Experiences and Perceptions in an Autonomous Institution. Journal of Engineering Education Transformations, Special Issue (January 2015), 34-39.

[25] Popescu, D., Roibu, H., Abagiu, M. M., Popescu, R., Popescu, L. C., & Petrisor, A. (2019). Research as a Part of Education-A Case Study of Engaging Students in Research Activities. 29th Annual Conference of the European Association for Education in Electrical and Information Engineering (EAEEIE), Ruse, Bulgaria. doi: 10.1109/EAEEIE46886.2019.9000437

[26] Powers, K., Chen, H., Prasad, K., Gilmartin, S., & Sheppard, S. (2018). Exploring How Engineering Internships and Undergraduate Research Experiences Inform and Influence College Students' Career Decisions and Future Plans. American Society for Engineering Education Annual Conference, Salt Lake City, Utah. https://par.nsf.gov/biblio/10076373

[27] Sabatini, D. A. (1997). Teaching and research synergism: The undergraduate research experience. Journal of Professional Issues in Engineering Education and Practice, 123(3), 98-102. https://doi.org/10.1061/(ASCE)1052-3928(1997)123:3(98)

[28] Shettar, A., & Mudenagudiemail, U. (2015). An Experience of Introducing a Research Experience for Undergraduates (REU) Course. Journal of Engineering Education Transformations, 28(2 & 3), 153-160.

[29] Singh, S. P., Fitch, R., & Williams, S. (2010). A research-driven approach to undergraduate robotics education. Computers in Education Journal, 1(4), 21-27.

[30] Thompson, N. S., Alford, E. M., Liao, C., Johnson, R., & Matthews, M. A. (2005). Integrating undergraduate research into engineering: A communications approach to holistic education. Journal of Engineering Education, 94(3), 297-307. https://doi.org/10.1002/j.2168-9830.2005.tb00854.x

[31] Trott, C. D., Sample McMeeking, L. B., Bowker, C. L., & Boyd, K. J. (2020). Exploring the long-term academic and career impacts of undergraduate research in geoscience: A case study. Journal of Geoscience Education, 68(1), 65-79. https://doi.org/10.1080/10899995.2019.1591146

[32] Yeh, C. P., Drew, J., Rockwell, C., & Chien, H. C. (2003). Undergraduate Research Projects for Engineering Technology Students. ASEE Annual Conference, Nashville, Tennessee, USA. https://peer.asee.org/11746

[33] Youngblood, K. M., Roseberry, J. R., Van Winkle, A. L., Sochacka, N. W., Vanusupa, L., Thurman, C. J., & Prusko, P. A. T. (2018). A case for the student researcher: Expanding the role of undergraduate research in the professional formation of engineers. IEEE Frontiers in Education Conference (FIE), San Jose, CA, USA. doi: 10.1109/FIE.2018.8658757

[34] Zydney, A. L., Bennett, J. S., Shahid, A., & Bauer, K. (2002a). Faculty perspectives regarding the undergraduate research experience in science and engineering. Journal of Engineering Education, 91(3), 291-297. https://doi.org/10.1002/j.2168-9830.2002.tb00706.x

[35] Zydney, A. L., Bennett, J. S., Shahid, A., & Bauer, K. W. (2002b). Impact of undergraduate research experience in engineering. Journal of Engineering Education, 91(2), 151-157. https://doi.org/10.1002/j.2168-9830.2002.tb00687.x