Industry 4.0 Briefcase: An Innovative Engineering Outreach Project for Professions of the Future

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Abstract. This paper presents an engineering outreach project titled "Industry 4.0 Briefcase" that has been developed to introduce the concept of Industry 4.0 to undergraduate students. The project aims to support participants to become aware of Industry 4.0 related topics such as machine learning, data mining, industrial automation, human-machine interface, and product life cycle, and to stimulate the curiosity of them towards these topics. The scope of the project consists of presentations, experimental applications, observations, individual and collaborative studies, assessment and evaluation practices, e-learning applications, and a social program. The project was conducted as a one- week program at a public university in Turkey with the participation of 18 undergraduate 3rd-year students. Participants consist of students from computer engineering and software engineering departments of the engineering faculties and the business department of the faculty of economics and administrative sciences. Thus, participants of the project had the opportunity to exchange information with students and faculty members from different academic backgrounds. The study utilized the mixed methods approach by performing both quantitative and qualitative measurements. To collect data, mini projects and project evaluation forms were used for quantitative measurements and daily virtual classroom sessions and a general evaluation session (focus group interview) were used for qualitative measurements. The success rates of the participants based on the evaluation of the reports they presented were obtained as 91% in data mining, 95% in industrial automation and human-machine interface, and 89% in machine learning course, respectively. It was observed that the overall satisfaction level of the participants from the project activities was over 95%. These findings were also supported by the qualitative findings as the students indicated their overall satisfaction from the organization of the project and stated that working in teams and attending the social program contributed to developing positive relationships with each other and increasing their success.

Keywords: Engineering education · Engineering outreach · Industry 4.0 concepts · Industrial automation

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1 Introduction

Nowadays, Industry 4.0 is one of the most studied concepts in all engineering fields. This concept has its roots in the industrial revolution. According to the Cambridge dictionary, the industrial revolution is defined as "the period of time during which work began to be done more by machines in factories than by hand at home" [1]. The topic of Industry 4.0 was first defined by the German Government and adds a new layer of automation to the foundation provided by the industrial revolution. Industry 4.0 includes nine main topics: autonomous robots, simulation, system integration, internet of things, cybersecurity, cloud computing, additive manufacturing, augmented reality, and big data [2]. In recent years, the interest of academia, industry, governments, and non-governmental organizations on the topic of Industry 4.0 has been increasing. According to [3], the number of academic conferences and academic articles on Industry 4.0 has doubled in 2015 compared to 2013.

In [4], the focus was on facilitating mobile learning processes in vocational, technical, and engineering education, and also integrating business scenarios of Industry 4.0 into learning environments. The learning environments include distribution of classical learning materials such as pictures, videos, or simulations, where workplace-related learning environments are considered particularly important.

By utilizing web-based technologies, [5] discusses how a remote and distributed control system can be used to create an efficient laboratory learning model and enable remote access to physical processes. Besides, how to diagnose faults by using online, remote technologies and SCADA is also demonstrated.

On the other hand, there are also studies approaching robotics and other technologies covered by Industry 4.0 from educational perspectives. These studies are commonly organized around the world as educational robot camps. Carnegie-Mellon University [6] and the University of Minnesota [7] robot camps can be given as examples of these activities. In [8], it is emphasized that the main objectives of these camps are to direct secondary and high school students to a career in technology, computer, and engineering. In [9], it was pointed out that in educational robot camps, students were given the opportunity to apply the information they learned in their schools with appropriate group sizes. Similar studies can also be organized as engineering outreach projects [10]. When these types of studies are examined, it can be observed that robot camps are mostly organized with the participants consisting of middle and high school students and their objectives are limited.

In addition to these resources, widely used massive open online learning environments such as Coursera [11], and EdX [12] include the topics covered by Industry 4.0 as separate courses.

Advancements in computer technologies and the Internet do not only effect industrial areas, but also change higher education processes. Recently, in higher education, solving real-world problems, interdisciplinary work, and teamwork skills have attracted more attention [13]. Therefore, especially engineering students are required to experience these skills during their undergraduate studies [14, 15]. For this purpose, an engineering outreach project titled "Industry 4.0 Briefcase" was planned and carried out to both increase the motivation of undergraduate students of engineering and

business school for topics covered by Industry 4.0 and to reinforce their individual and teamwork skills.

The project was titled "Industry 4.0 Briefcase" because it combines different components of Industry 4.0 as a briefcase. The main aim of the project is to stimulate the curiosity of the participants towards Industry 4.0 related topics such as machine learning, data mining, industrial automation, human-machine interface, and product life cycle to increase their awareness. In addition to the academic content of the project, learning experiences such as learning by doing/living, and individual and teamwork activities were included in the project. As these experiences are among the essential learning experiences of the Industry 4.0 era [16], the project was specifically designed to have these experiences as much as possible throughout the project.

The rest of the paper is organized as follows; Sect. 2 introduces the method followed in the study. Section 3 presents the application process, Sect. 4 provides the findings, and finally, Sect. 5 concludes the paper.

2 Method

In this section, the research model, study group, data collection tools, and the application process will be examined.

Research Model
In this project, a mixed-methods approach which is based on qualitative and quantitative measurements was used. During the study, as the data collection tools, mini projects, and project evaluation form were used for quantitative measurements and daily virtual classroom sessions and a general evaluation session (focus group interview) were used for qualitative measurements. The triangulation method was used for evaluation purposes. In the triangulation method, quantitative and qualitative data are collected and analyzed together at the same time. The priority is equal for both data types. Data analysis is usually done separately, and integration takes place during the interpretation of the findings [17].

Study Group
The study group of the project consists of 18 engineering and business school undergraduate students. Application requirements for the project were to be at least a third grade (junior) student and to have a grade point average of at least 2 out of 4. The participants were selected from the applicants after the announcements were made to the computer engineering, software engineering, and management information system (MIS) departments. The distribution of the participants according to their departments is presented in Table 1. In addition, four project staff were assigned as guides to quickly solve the problems that participants may encounter during the course of the project.

Data Collection Tools
In this study, two separate groups of data collection tools were used to collect quantitative and qualitative data. Mini project evaluation form and general project evaluation form were used as data collection tools for quantitative measurements.

Table 1. Distribution of the participants (according to their departments)

Name of dept.	*Num. of participants*	*Percentage*
Computer eng.	12	66.7%
Software eng.	1	5.6%
Man. Inf. systems	5	27.7%
Total	18	100.0%

Video recordings of the daily virtual classroom sessions and the general evaluation session (focus group interview) were used for qualitative measurements.

3 Application Process

The project was conducted in five days between July 01-05, 2019. Academic activities were organized on various topics throughout the project and carried out with the order of introduction to Industry 4.0, product life cycle, data mining, industrial automation, human-machine interface, techno-park introduction, entrepreneurship presentation, and machine learning. In addition to the academic activities, an opening ceremony session, a technical trip, coffee & meal breaks, and a closing ceremony session were held respectively. All of the theoretical and practical activities (except the social activities) carried out during the project and types of these activities are summarized in Table 2, which presents the daily program of the project. The numbers in parentheses of the type of activities indicate the number of lessons the activity took in the program.

As listed in Table 2, a total of 27 h of academic activities were organized during the Industry4.0 Briefcase project. 33.3% of these activities were organized as presentations, 37.0% were practical activities involving applied laboratory work, 14.8% were distance learning activities as virtual classroom sessions, and 14.8% took place as the technical trip.

The first day of the program (July 1, 2019) started with the opening ceremony, an ice-breaking event, and the introduction of the project staff and the participants. Then, a presentation on the main concepts of Industry 4.0 was made and the content of the project was explained. As the main activity of the first day, the session on "Product Lifecycle Management" was held for 3 h in total. The first two hours of this session were theoretical and the last hour was laboratory work where the participants were divided into groups and the product life cycles of different products were discussed.

The Data Mining course, which was conducted on the second day of the project (July 2, 2019), started with 2-h of theoretical narration and continued with 3-h of laboratory work. Basic concepts of data mining and a basket analysis application software were introduced at the theoretical lectures. Then, at the practical hours, the participants were provided with a database containing sample products and sales records of an imaginary company and were asked to examine this database, prepare the inputs for data analysis, and analyze the sales data with the basket analysis software presented in the theoretical lectures. Finally, the findings obtained with the analysis were reported and presented by the participants.

Table 2. Daily activity program of the project

Date	*Activity*	*Type of Activity*
1.7.2019	Opening ceremony	
	Introduction to industry 4.0	Theoretical (1)
	Product lifecycle management presentation	Theoretical (2) Laboratory work (1)
	Evaluation	Virtual class (1)
2.7.2019	Data mining	Theoretical (2) Laboratory work (3)
	Evaluation	Virtual class (1)
3.7.2019	Industrial automation and human-machine interface	Theoretical (1) Laboratory work (4)
	Evaluation	Virtual class (1)
4.7.2019	Techno-park presentation	Theoretical (1)
	Entrepreneurship company presentation	Theoretical (1)
	Machine learning	Theoretical (1) Laboratory work (2)
	Evaluation	Virtual class (1)
5.7.2019	Technical tour	Technical tour (4)
	Focus group interview meeting closing ceremony	

On the third day, the project continued with 3 h of Industrial Automation and 2 h of Human Machine Interface courses, all of which were practical studies. For evaluation purposes, students formed groups of two members, and each group was asked to carry out two projects for each topic. The first project involved counting the number of products on a conveyor carrying the products, and the second project was to write a program to control a lamp with SCADA [18]. At the end of the day, the groups presented their project reports for each project.

The fourth day of the project started with the description of topics such as technopark, intellectual property rights, and patents. Then, the technopark established at the university campus was introduced and the representative of a technopark entrepreneurship company working on Industry 4.0 presented their work. In the afternoon session, the machine learning course was held in the form of 1 h of theoretical presentation and 2 h of practice. As part of the practical study, the participants were divided into groups, and the groups were provided supplier selection records of an imaginary company and were asked to prepare the inputs for data analysis and find out the regression model. The results of the study were reported by the groups and the reports were presented at the end of the day.

On the last day of the project, the factory of a German textile company was visited and the real-world applications of the topics covered within the first four days of the project were examined in a factory environment. The German textile company is selected for the technical trip because it is one of the few companies that successfully apply Industry 4.0 processes. During the technical trip, the participants had the opportunity to observe the applications of big data, industrial automation systems, and

machine learning. Finally, at the end of the day, as the final activity of the project, a focus group interview was conducted with all of the participants. During the focus group interview, the previously prepared questions of a semi-structured interview form were answered by the participants. This interview was recorded on video and then, transcribed and analyzed.

Among the academic activities, theoretical courses such as introduction to Industry 4.0, product life cycle, technopark introduction, and entrepreneurship presentation were organized as presentations and included question-answer sessions by applying narrative/lecture and question-answer teaching methods. The other academic activities were carried out in two parts in a laboratory environment. In the first part, the topics were explained by using narrative/lecture and demonstration methods. In the second half of the courses, the participants were divided into groups and each group was assigned a mini project on the related topic and was asked to carry out the group project collaboratively. When the group projects were completed, the group members prepared and submitted reports both individually and as a group. After completion of each course, these reports were evaluated and the participants were given scores. Mini group projects were used three times during the project, on the second, third, and fourth days of the project. Mini projects are very useful to evaluate students' level of knowledge and to determine misconceptions and the concepts that are not fully learned after theoretical lessons [19].

At the end of each day, except for the last day, a virtual classroom session was also held to gather feedback from the participants about their experiences and impressions during that day. Adobe Connect Pro [20] virtual classroom interface was used for virtual classroom sessions between 8:00 pm and 8:30 pm. During this evaluation activity, the participants were asked to evaluate the activities performed that day verbally. In the virtual classroom sessions, the content of the activities and the approaches of the instructors who carried out these activities were also discussed. Besides, the participants were asked if they were satisfied with the social activities of that day. All virtual classroom sessions were recorded for evaluation purposes.

4 Results and Discussion

The quantitative and qualitative results of the project are presented below.

Quantitative Results

After the data mining, industrial automation & human-machine interface, and machine learning activities carried out during the project, the participants were divided into groups of two and carried out mini projects. The results of these mini projects are presented as both individual and group reports. The evaluation results of these mini project reports presented at the end of each activity are presented in Table 3.

At the end of the project, a general evaluation form was applied to the participants. In this form, the participants were asked to evaluate all activities carried out during the project on a 3-point Likert scale (Dissatisfied, Undecided/Neither Satisfied nor Dissatisfied, Satisfied). The evaluation results of the general evaluation form regarding the activities of the project are presented in Table 4.

Table 3. Average scores of mini-projects

Activity name	*Num. of participants*	*Average scores of mini-projects*
Data Mining	18	91%
Industrial automation and human-machine interface	18	95%
Machine learning	17	89%

Table 4. Average scores of the general evaluation form

Activity Name	*Not Satisfied*	*Undecided*	*Satisfied*
Industry 4.0 presentation	0.00%	11.10%	88.90%
Product lifecycle management presentation	0.00%	5.60%	94.40%
Data mining	0.00%	5.60%	94.40%
Industrial automation and human-machine interface	0.00%	0.00%	100.00%
Technopark presentation	0.00%	5.60%	94.40%
Machine learning	5.60%	5.60%	88.90%
Technical tour	0.00%	0.00%	100.00%
Social events (meal, coffee break)	0.00%	0.00%	100.00%
Average	**0.70%**	**4.19%**	**95.11%**

As can be seen from Table 4, the average satisfaction level of the participants is over 95%. The highest satisfaction levels are obtained in the activities where the participants are actively involved in the education process. It was observed that the participants were more passive in activities that they evaluated with lower satisfaction levels.

Qualitative Results

Daily virtual classroom sessions were organized with the participation of the students for the evaluation of the activities carried out during each day except for the last day. The data obtained from the virtual classroom sessions were evaluated and categorized as negative and positive. The findings are reported together with the data obtained from the focus group interview.

The focus group interview was held as a 60-min session on the last day of the project. In the focus group interview, the participants were asked to evaluate the project in all aspects. The negative aspects students declared are presented in Table 5, and the positive feedback gathered from the participants are presented in Table 6, together with the findings of the daily virtual classroom sessions, with their frequencies, respectively.

As stated in Table 5, the main negative aspects expressed by the participants are mostly related to the project duration being too short and some activities being only in the form of presentations.

Table 5. Negative qualitative feedback on the project

Category	*Frequency*
It would be nice if the project was conducted longer than a week	6
It was boring that some of the activities were instructed only through presentations	4
Some of the activities continued until late hours, as a result, we were very tired	2
It would be more fun if the project had more participants	2
The early start of the activities in the morning caused me to feel sleepless	2

Table 6. Positive qualitative feedback on the project

Category	*Frequency*
The technical trip was useful to reinforce the topics covered in the activities	15
The fact that many activities were practical increased my motivation	14
Social events were very well organized and sufficient	11
The lecturers teaching the courses were competent in their fields	11
The teamwork at some activities helped us to reinforce the topics	11
Having a mini project at the end of some activities helped us better understand the topics	7
Topics discussed at the activities were important for our career development	4

As given in Table 6, most of the participants stated that it was useful to reinforce the topics covered in the activities with a technical trip, their motivation levels increased due to many activities being practical, the social activities were well designed and applied, the lecturers teaching the courses are competent in their fields, and performing teamwork oriented activities contributed positively to their understanding of the topics.

The negative and the positive feedback of the participants regarding the project were categorized into four and seven main groups in Table 5 and Table 6, respectively. Therefore, the number of positive aspects reported by the students was higher than the number of negative aspects. Also, the number of students expressing positive feedback (frequency values at the tables) was much higher than the number of students mentioning negative feedback.

When the quantitative and qualitative findings were analyzed together, it can be observed that the quantitative and qualitative findings of the study complement each other. Overall, the participants were successful at the mini projects and stated higher satisfaction levels at the survey and the focus group interview for the activities they were more actively involved in the education process. Thus, it can be interpreted that practical activities such as applied laboratory works and mini projects contributed to the success of the project.

5 Conclusion

This paper presents an innovative engineering outreach project titled "Industry 4.0 Briefcase" that introduces Industry 4.0 related topics such as machine learning, data mining, industrial automation, human-machine interface, and product life cycle to undergraduate students. Thus, the main aim of the project is to increase awareness of the participants about these topics by organizing activities that stimulate their curiosity. After getting theoretical knowledge and performing practical laboratory work during the first four days of the outreach program, at the last day of the project, the participants had the opportunity to observe the topics they learned during the project in a real-world setting by attending the technical trip to a factory employing Industry 4.0 technologies.

It was observed that the students participated in the activities with a high level of motivation throughout the project. Thus, the overall participation rate during the project was over 90%. It is noteworthy that the participation of students in both individual and group activities is very high. As a result of the evaluation of the reports submitted by the participants after conducting mini projects, the success rates were obtained as 91% in data mining, 95% in industrial automation and human-machine interface, and 89% in machine learning courses, respectively. The results of the general evaluation form applied at the end of the project revealed that the participants were over 95% satisfied with the theoretical and practical activities, social program, and technical trip. The findings of the general evaluation form were also supported by the qualitative findings of the daily virtual classroom sessions and the focus group interview. The factors that may have been effective on obtaining positive findings can be interpreted as the subject of the project being a novel and interesting topic as Industry 4.0 is gathering more and more attention recently, and students developing positive relationships with their teammates as a result of working as teams and attending the social program.

The main contribution of this study is its novelty as one of the first outreach projects on Industry 4.0 concepts since this type of outreach studies are not very common in the literature. On the other hand, the duration and the size of the study group are the main limitations of this study, as the project was carried out in a limited time with a relatively low number of participants due to budget constraints and other restrictions. Thus, the generalization of the findings of this study are limited; however, the study is a good step for further research studies. For future work, organizing an outreach project with more participants that will be spread over a longer period will increase the contribution to the field.

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