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Sectoral Needs Analysis to Develop Training Programs for Hybrid and Electric Vehicles

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Abstract
Car manufacturers worldwide are switching to hybrid and electric vehicle production models, which are cleaner and more sustainable alternatives. This rapid change situation has also significantly increased the need to maintain and repair these vehicles. Professionals in the motor vehicle maintenance and service industry must be up-to-date on the technological developments that occur with these increases and the critical safety measures on these vehicles. Within the scope of this study, a comprehensive training needs analysis was conducted to determine the vocational education and training needs of those working in the field of hybrid and electric vehicle technologies, and the findings were evaluated. In the study, 30 questions on a 5-point Likert scale were applied to the participants, which was structured under the headings of perception, knowledge, skills, and expectations about hybrid and electric vehicle education. 54 sector representatives, 650 students, and 652 vocational high school teachers and administrators participated in the surveys. Interestingly, in the needs analysis results, all three groups provided a similar response in all questions; that is, they stated the exact needs. Therefore, the training programs to be developed based on these results will meet all three priority stakeholder groups' hybrid and electric vehicle training needs.

Keywords
electric vehicles, hybrid vehicles, vocational training, needs analysis

1. Introduction

Car manufacturers worldwide are moving to a cleaner and more sustainable alternative to the hybrid and electric (H/E) vehicle production model. Turkey's Automobile in Turkey Initiative Group Industry and Trade Inc. (TOGG) makes a rapid entry into the electric car industry. This situation has significantly increased the need to maintain and repair these vehicles. Professionals in the motor vehicle and repair industry must be up-to-date on the technological developments that occur with these increases and the critical safety measures implemented in these vehicles. Again, the design of electric vehicles is quite different from conventional vehicles and involves more risks than other vehicles. These risks may be related to the employee's knowledge, experience, and psychosocial situation. In order to minimize employee-related problems, schools and businesses need to develop serious training programs to eliminate this three-way problem [1]. In their study, Pandjatian et al. [2] investigated the effect of teachers' approach to students on the adoption of electric vehicles and technological innovations in Vocational High School Education. One of the most exciting results of the study is the type and quantity of modern learning approaches (student-centered approaches) implemented by teachers, which significantly impact the adoption of electric vehicle technology innovation among public vocational high school students. In this research results, student-centered education is 37.7%, classical education method is 30.6%, and both teaching methods in the form of individual teaching approach and group work were determined as 31.5%. According to Adam R. et al. [3], it is necessary to simplify and

strengthen the training of vocational high school teachers to improve their competencies by providing them with knowledge and skills on electric vehicle maintenance and repair using a multi-training approach. For this purpose, the multiple approaches they use in their studies are persuasive, collaborative, and participatory. The method includes discussion, lecture, question-answer, demonstration, and applications on electric vehicles and their components. In the evaluation, the pre-test and post-test performance tests and the success level of the teachers based on knowledge and skills showed an 80% increase in competence with this method. Fechtner H. et al. [4] in their study investigating new methods in electric vehicle education, it is emphasized that the increasing diffusion of electric vehicles causes a new challenge and program development needs for the education sector. For example, applying a high-voltage system to automobiles creates a new potential for danger to working people, necessitating a new and specialized training program. To meet this need, this study presents a student-centered model with a modular approach in which different technologies and occupational safety concepts are integrated. In another study, Fechtner H. et al. [5] investigated the training needs of employees in areas such as technicians and firefighters on electric vehicles, including occupational safety risks. An approach to the development of a unique training program for working on electric vehicles is also presented in this paper. This training program focuses on improving the learning process with a learning concept blended with a modular approach. In a study related to determining the training needs of the sector employees and developing a program, the contribution of the group training program developed between the Bosch Diesel Systems factory operating in Bursa and the Technical Sciences Vocational School of Uludag University to the competencies of the employees was investigated. 360-degree feedback was used in evaluating this 240-hour training program, in which 325 people participated between 2001 and 2008. A 4% increase in competence was observed in the group head personnel who received training compared to those who did not [6]. In a similar study conducted by Arslan and Kuş [7], the modular certificate training they received at Uludag University contributed to the performances of the Bosch Car Service employees operating in Turkey, which was developed by determining their training needs, was made by peer assessment method. A study conducted on 220 Bosch employees determined that those who participated in modular certificate training had a 5.58% increase in their technical and behavioural performance compared to others. Again, this increase represents a significant value in terms of performance evaluation. Again, Kuş A. et al. [8] conducted an international training needs analysis on Technical Drawing and standards in their study and published the results according to their needs priorities. 320 people from Turkey, England, and Bulgaria participated in the study, which was conducted as an online survey and included education perception, knowledge, skills, and expectations. One of the most important results of the study is that since the results from each country and stakeholders overlap, the training program modules to be developed and the priorities in their contents will make a serious contribution to vocational education.

In this study, the findings of comprehensive training need analysis made to determine the Vocational Education and Training needs of the employees in the field of hybrid and electric Vehicle Technologies were evaluated, and it was aimed to provide the infrastructure for teacher training and training programs to be developed in line with these needs, thus strengthening the existing education infrastructure.

2. Needs Analysis

2.1. Stakeholder analysis

In this study, which was mainly carried out to determine the training needs for teachers giving vocational training, stakeholder analysis was carried out in order to take into account the opinions of all parties interacting with the subjects of "new generation vehicle technologies" in order to determine the expectations correctly and to ensure participation, which is one of the essential elements of planning. Three different methods were followed during the identification of stakeholders, and the groups forming the common denominator were determined as stakeholders. The first method is a national and international literature review, the second method is interviews with sector and NGO representatives, and the third phase is a mini workshop consisting of lecturers, teachers, educators in the sector, and sector representatives. As a result of these studies, ten stakeholder groups were identified, especially

teachers, students, and sector representatives who worked together in this study.

2.2. Needs analysis methodology

In 2020-2021, the "Electric Vehicles Branch" was opened as a pilot in Bursa Automotive Industry Exporters' Association Vocational and Technical Anatolian High School. The programs opened are rapidly spreading in other vocational high schools and Vocational Schools. Therefore, teachers who give or will teach in this field have in-service training needs, equipment needs, and course materials. In order to determine these needs, three different questionnaire scales were prepared for students/teachers and the sector within the scope of the study in order to determine the in-service training needs, qualifications, equipment infrastructure of the vocational education institution, and the level of deficiency of the training materials of the teachers who provide training on New Generation Vehicle technologies. Questionnaires for vocational education needs analysis were applied to MEB Vocational and Technical Education institutions' school principals, assistant principals, relevant field chiefs, and teachers. The Differences Approaches used in data analysis. This approach reveals the difference between observed and expected success levels. According to this approach, the need is arises from the difference between the expected skill level and the real/existing skills. This difference shows the features that the program should bring to individuals.

3. Findings and Evaluation

3.1. Statistical analysis

In this study, a difference analysis was made by comparing the current situation with what should be. The questionnaire, prepared on a 5-point Likert scale and did not contain any sentence or judgment sentence, was directed to all parties determined by stakeholder analysis through the Google survey application. With these question groups, which will allow making very different evaluations during the analysis, first of all, the relationship between education levels and knowledge skills, qualifications of education levels, differentiation between institutions and demographic characteristics, etc. it was possible to examine the findings. The evaluation method used in the differences approach was made by converting the 5-point Likert results into percentages and evaluating these percentages. While the questions for the teacher/administrator and students are being prepared, since the scale is designed with the expectation of a "5" answer, that is "I totally agree", the ratios obtained in the analysis determine the current situation in that question title. The difference that emerges by subtracting the obtained results from 100, the equivalent of "5", shows us the need, that is, the gap that needs to be closed. On the other hand, in the sectoral needs analysis, the questions were structured according to the needs, that is, the respondents' expectations. Therefore, the results obtained out of 100 in these two surveys directly show the current need. The obtained results were evaluated with a statistical method used to reveal whether the mean of the measurement results of the single-sample group was different from each other by using the Excel statistics program (95% confidence interval).

3.2. H/E tools training needs analysis (teacher/trainer/administrators)

In the needs analysis for vocational high school teachers and administrators, there are 30 with 5-point Likert-scale survey questions. The first 5 questions were formed as question groups to measure the education perception of the participants, the continuing 20 questions about their knowledge and skill levels, and the last 5 questions to measure the expectations of the participants' education.

As can be seen from the results in Table 1, the statistical reliability value is much lower than 0.05, indicating that the data distribution is significant. In other words, the reliability rate is high.

Table 1. Statistical results of the evaluated data

N	Mean ($\bar{x}$)	Std. Deviation	Reliability
19560	2.86	1.221	0.0171

Within the scope of the study, 652 people in teacher and management positions were surveyed nationwide. 94.6% of the participants are male, 5.4% are female, and the average age is 48.6. The occupational distribution of the respondents are given in Figure 1.

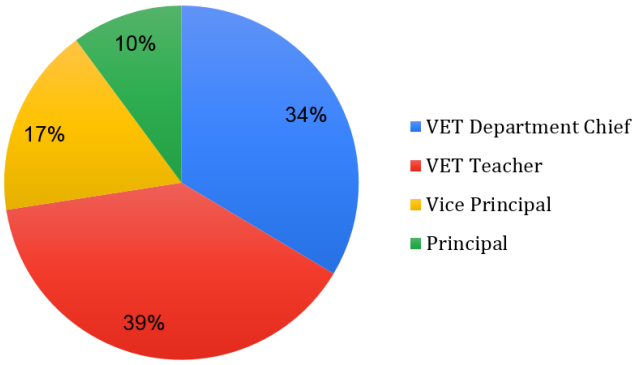

Fig. 1. Occupational distribution of training needs analysis participants

In the graph in Figure 2, the answers given to the 5 “perception of education” questions directed to teachers and administrators and the order of these answers according to the percentage of need/priorities are shown in Table 2.

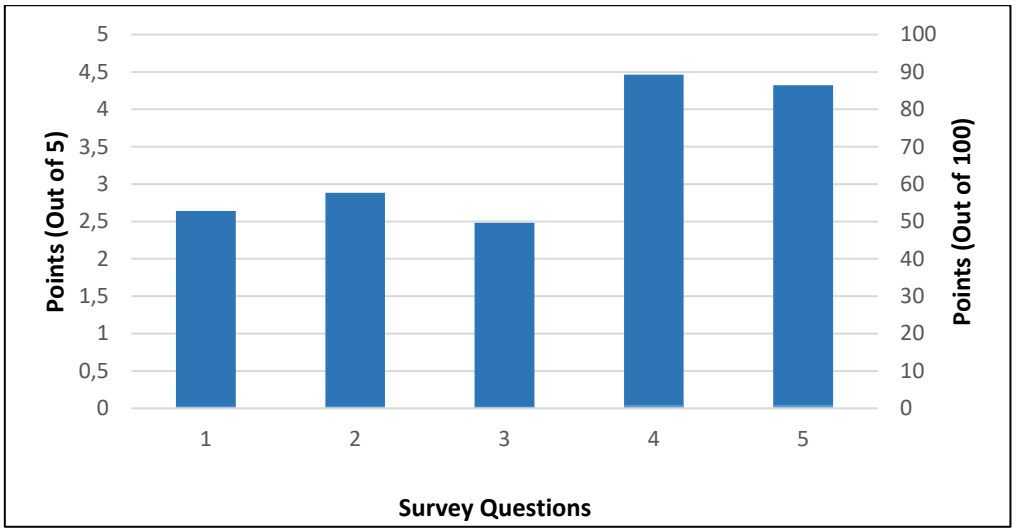

Fig. 2. Responses to the “perception of education” questions directed to teachers and administrators

Table 2. The answers given to the “perception of education” questions directed to teachers and administrators, sorted by need percentage-priorities

Question	***I think, as an H/E vehicles trainer, you…***	%
3	You have enough practical skills to support your theoretical knowledge of H/E vehicles	50
1	You have the technical knowledge and skills to provide H/E vehicles training	53
2	You use a common communication language with all relevant stakeholders and sector employees on H/E vehicles issues	58
5	You think that students' lack of knowledge and skills on H/E vehicles will create serious risks and deficiencies in service operations	86
4	You think it is vital for learners to properly teach current knowledge and skills about H/E vehicles	89

It is seen that the lowest average value in the table is in the questions "You have enough practical skills to support your theoretical knowledge of H/E vehicles" and "You have technical knowledge and skills to provide training on H/E vehicles," with 50% and 53%. It needs to be worked on.

Another important topic, "You use a common language of communication with all relevant stakeholders and sector employees on H/E vehicles," received a response of 58%. Here, too, it is seen that there is a 42% gap or need that requires to be closed. At the end of the ranking, 86-89% answered

the questions "You think that students' lack of knowledge and skills on H/E vehicles will create serious risks and deficiencies in service operations" and "You think it is vital for learners to teach their current knowledge and skills about H/E vehicles correctly." such returns. Therefore, this gap can be closed with little perception support work in these topics where high perception is formed.

The graph in Figure 3 shows the answers given to the 20 “Knowledge and Skills” questions directed to teachers and administrators, and Table 2 shows these answers in order of need percentage-priorities.

While evaluating these questions, which were prepared to determine the current knowledge and skill situation and to see the need, instead of analysing one by one, sorting them according to the priority and percentage of needs as given in Table 3, and the priority method in writing the content was based on these results.

Table 3. The answers given to the “Knowledge and Skills” questions directed to teachers and administrators, sorted according to the percentage of need/priorities

Question	***I think, as an H/E vehicles trainer, you…***	%
11	You have sufficient technical knowledge and skills about electric vehicle conversion and modification technologies systems	47
18	You are familiar with embedded systems used in automotive electronics	49
20	You know and can apply diagnostic and troubleshooting procedures in electric vehicles	49
25	In H/E vehicles, you know and can apply the necessary rules for removing the vehicle battery from the vehicle, diagnosing and repairing it	49
17	You know the troubleshooting and troubleshooting processes in H/E vehicles, and you can use electrical measurement and control equipment by the instructions	50
19	You know and practice diagnostics and troubleshooting in hybrid vehicles	51
9	You have sufficient technical knowledge and skills about fuel cell battery and charging systems of H/E vehicles	52
12	You have sufficient technical knowledge and skills about autonomous and advanced driving support systems	52
24	In H/E vehicles, you can apply the rules to be followed in making the vehicle electrically safe before maintenance and removing the safety after maintenance	52
8	You know and can distinguish high voltage lines and battery systems of H/E vehicles in terms of their types and functions	54
16	You can read the block diagrams used in automotive electronics and interpret the algorithm through the diagram	55
23	H/E you know the risks of dangerous electrical high voltage in vehicles and the precautions to be taken	55
13	You have sufficient technical knowledge and skills about vehicle communication technologies systems	56
14	You have sufficient technical knowledge and skills about vehicle electronics and comfort systems of H/E vehicles	56
10	You have sufficient technical knowledge and skills about power transmission and motion control systems in hybrid vehicles	57
21	You know the concepts of sensor, ECU (brain), and actuator and open and closed circuit control systems in H/E vehicles	57
22	You can use diagnostic devices at full capacity with their advanced functions	57
7	H/E you know the electronic control systems of vehicles structurally and in terms of operation	59
6	You can recognize different H/E vehicles in terms of engine and vehicle mechanics and interpret the differences	61
15	Technological differences and basic distinguishing features of electric motor vehicles	62

The fact that the results remain in the 47%-62% band indicates that we are on average in all topics, which indicates an average of 50% need in all headings, that is, the need for improvement. For this purpose, the foresight study in Table 4 was carried out to enrich the content by adding these priorities

to the training titles envisaged for this purpose. This table constitutes important data on which topic and sub-title to be worked on during the content writing, with what weight and method.

Table 4. Matching of "Knowledge and Skills" answers to the predicted training titles

	Name of the training	**Sub-topics / priority orders asked in the analysis**	
1	Electric Motor Vehicles Technology	Electric Motor Vehicles Technology H/E Risks caused by dangerous electrical high voltage in vehicles and precautions to be taken	12
		Technological differences and main distinguishing features of electric motor vehicles	20
2	Fuel Cell Battery Charging Systems	Necessary rules for removing the H/E vehicle battery from the vehicle, diagnosing and repairing it	4
		H/E Sufficient technical knowledge and skills about fuel cell battery and charging systems of vehicles	7
3	Electric Vehicle Conversion and Modification Technologies	Adequate technical knowledge and skills about electric vehicle conversion and modification technologies systems	1
4	Hybrid Motor Vehicles Technology	H/E Types and functions of high voltage lines and battery systems of vehicles	10
5	Powertrain and Motion Control Systems in Hybrid Vehicles	Powertrain and Motion Control Systems in Hybrid Vehicles Adequate technical knowledge and skills about powertrain and motion control systems in hybrid vehicles	15
		Technological differences and main distinguishing features of electric motor vehicles	20
6	Autonomous and Advanced Driving Assistance Systems	Autonomous and Advanced Driving Assistance Systems Sufficient technical knowledge and skills about autonomous and advanced driving assistance systems	8
7	Vehicle Communication Technologies	Adequate technical knowledge and skills about vehicle communication technologies systems	13
8	Vehicle Electronics; Vehicle Comfort Systems	Adequate technical knowledge and skills about vehicle electronics and comfort systems of H/E vehicles	14
9	Automotive Electronics	Reading block diagrams used in automotive electronics and interpreting the algorithm over the diagram	11
		Concepts of open and closed circuit control systems with sensors, ECUs and actuators in H/E vehicles	16
		H/E Structure and operation of electronic control systems of vehicles	18
10	Maintenance Troubleshooting in Automotive Electronics	H/E Troubleshooting processes in vehicles and using electrical measurement and control equipment in accordance with the instructions	5
		Rules to be followed for making the vehicle electrically safe before maintenance and removing the safety after maintenance in H/E vehicles	9
11	Embedded Systems in Automotive Electronics	Sufficient knowledge of embedded systems used in automotive electronics	2
12	Vehicle Diagnostics and Troubleshooting	Knowing and practicing the diagnostic and troubleshooting processes in electric vehicles	3
		Knowing and applying the diagnostic and troubleshooting procedures in hybrid vehicles	6
		To be able to use diagnostic devices at full capacity with advanced functions	17

In the graph in Figure 4, the answers given to the 5 "H/E education expectation" questions directed to teachers and administrators and the order of these answers according to the percentage of need-priorities are shown in Table 4.

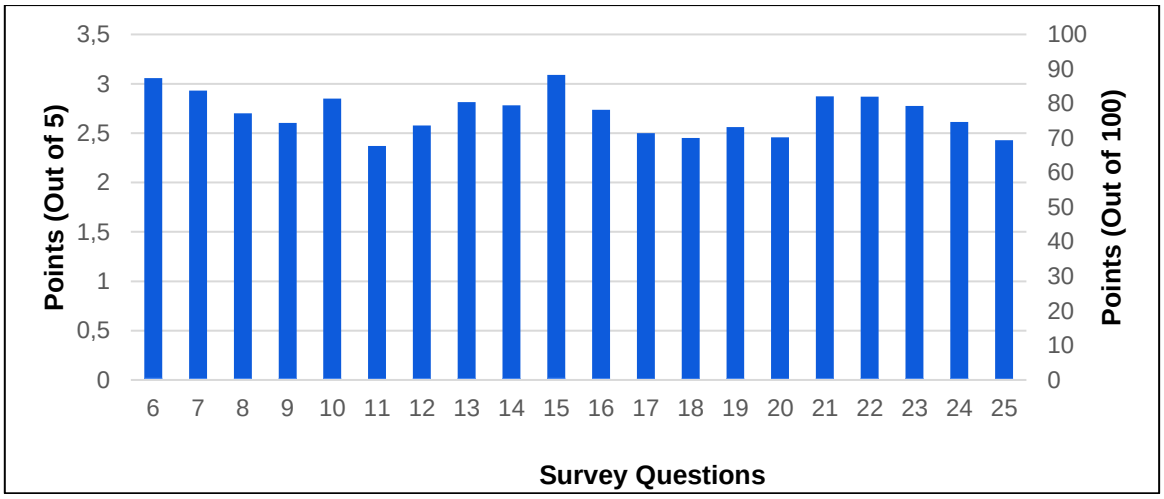

Fig. 3. Answers to the "Knowledge and Skill" questions directed to teachers and administrators

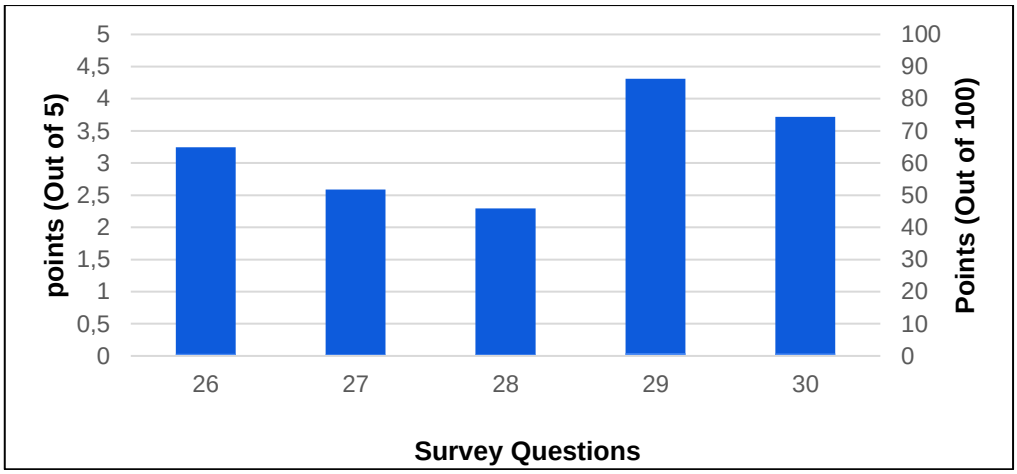

Fig. 4. Responses to the questions of "H/E education expectation" directed to teachers and administrators

In an interesting and expected way, it is seen that the lowest answer to the question "You think that the H/E Vehicles training still given are given using adequate infrastructure and meet the expectations of the sector," with 46%. The main reason is that H/E training and education infrastructure still need to be established and disseminated in Turkey and worldwide. In this case, it is natural that a need-expectation of 54% occurs when viewed from the opposite side.

Table 5. Listed according to the percentage of needs/priorities of the answers given to the questions of "expectation of H/E education" directed to teachers and administrators.

Question	***I think, as an H/E Vehicles trainer, you…***	%
28	You think that the current H/E Vehicles trainings are given by using adequate infrastructure and meet the expectations of the sector	46
27	You think that hybrid and electric vehicles basic education can be given by distance education method	52
26	You think H/E Vehicles training should be transferred to virtual reality (VR / AR) applications	65
30	You think that H/E Vehicles trainings do not eliminate the need for basic engine and vehicle technologies training	74
29	You think that their training should be given with real vehicles and in the form of on-board training	86

Remarkably, the rate of the answers given to the question “You think H/E vehicles basic training can also be given by distance education method” in question 27 is 52%. The following answer, "You think that H/E vehicles trainings should be transferred to virtual reality (VR/AR) applications" is 65%. It is understood that the expectations of the participants in this matter are not high, and there is serious hesitation; therefore, there is a need to increase the expectations-meet the needs in both distance education and virtual reality. This result again confirms that VR training predictions are significant.

The percentage of answers given to the last questions “You think that H/E Vehicles training does not eliminate the need for basic engine and vehicle technologies training” and “You think that training should be given with real vehicles and in the form of on-vehicle training” is 0.74 and 0.86, respectively. These high expectation rates are an important paradigm currently being discussed. Hybrid vehicles training can be given to classical automotive training programs with only one or two courses. There is an intertwined nature in the content of electric vehicle training, from vehicle mechanics to motion control systems, and the answers confirm this. There is a need to be sensitive to this issue in content writing. The on-board training expectation in the last question is naturally high; while almost a hundred results are expected, it can even be considered that 86% remains low. On board training is one of the most successful learning-teaching methods in practical training, so this should be taken into account when writing content.

3.3. Training needs analysis (sector representatives)

Face-to-face interviews were envisaged in the needs analysis to measure the expectations and needs of the sector regarding H/E Tools Training. However, due to the difficulty of reaching representatives outside the Bursa, a questionnaire study was conducted with the question scale adapted to the sector for Vocational High School teachers. In other words, there are 30 with 5-point Likert-scale survey questions, which are asked in a way that prioritizes the expectations and needs of the sector. The first five of these questions were formed as question groups to measure the participants' education perception, the continuing 20 questions about their knowledge and skill levels, and the last five questions to measure their expectations regarding their education.

In the study of sector representatives, a wide range of participants, especially production such as TOGG, TOFAŞ, BOSCH, and private or authorized service network managers spread throughout the country, such as BOSCH CAR SERVICE, were interviewed face-to-face or by telephone, their approvals were obtained, and the survey links were sent to them, and the study was completed. Within the scope of the survey, a survey was conducted with 54 sector representatives, whose average age is 39, and 94% of them are male. In Figure 5, the answers given to all 30 questions are shown to be evaluated in the next step.

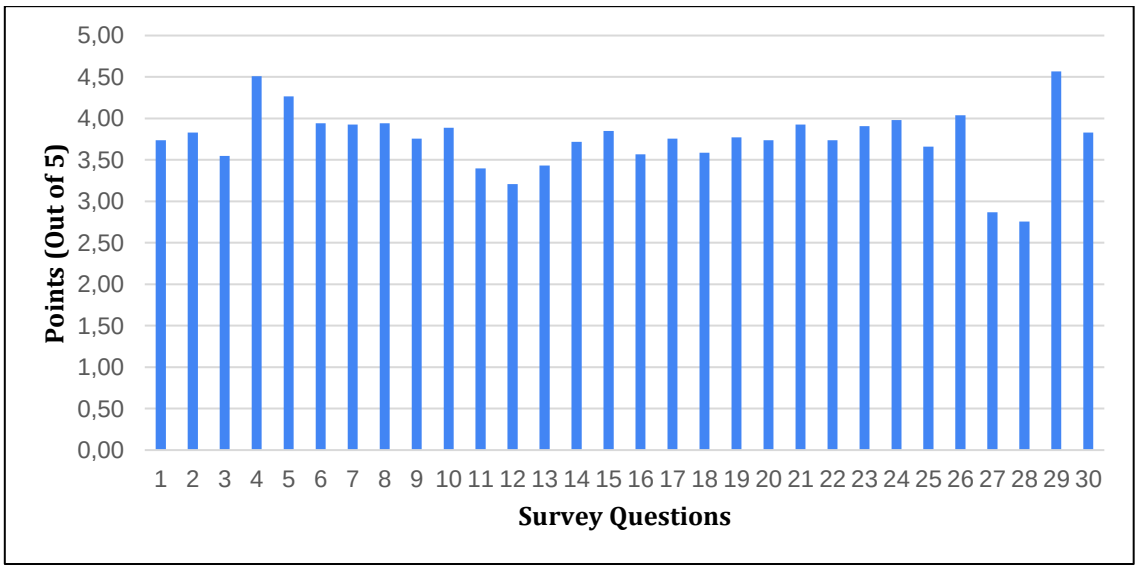

Fig. 5. Next generation vehicle technologies sector representatives needs analysis results

As seen in Figure 5, the average of the current situation of teachers was 57%, and the average of need was 43% in the weighted average of answers for all questions. However, the need-expectation average of sector representatives was found to be 75%. In other words, to meet the sector's needs, teachers and administrators first need to close the 32% gap and move it to the "0" difference point, which is the next step and is targeted as 100 in the survey scale. These results clearly show the need for teaching and in-service training of administrators.

3.4. Some critical sampling and evaluations in the analysis of sector representatives

Under the heading of perception, the question "You think it is vitally important for learners to teach their current knowledge and skills about H/E Vehicles correctly" revealed the highest expectation for the sector, which is very meaningful data about the quality of education to be given to students at every stage and process of vocational education. Again, the question "You think that students' lack of knowledge and skills on H/E Vehicles will create serious risks and deficiencies in service operations" came with a high rate, which both confirms the other and shows the expectation of a strong education infrastructure from graduates of the sector, especially in the service leg.

While the general averages under the heading of knowledge and skills are in the range of 70-80%, lower results were obtained in three questions. These are, respectively "You have sufficient technical knowledge and skills about autonomous and advanced driving support systems," "You have sufficient technical knowledge and skills about electric vehicle conversion and modification technology systems," and "You have sufficient technical knowledge and skills about vehicle communication technologies systems". At this point, it can be interpreted that this is due to the fact that autonomous driving systems still need to be widespread and that vehicle communication technologies are also part of the autonomous and smart vehicle/road system, which has been delayed a little further. Again, a low expectation arose in this question, as vehicle modification and conversion is a specific topic, and only the relevant sector group will have an expectation on this subject. On the other hand, there is a need to develop training programs for the relevant sector groups to raise these low results.

Finally, when we look at the remarkable results under the heading of the future expectations of the sector, the question "You think that training should be given with real vehicles and in the form of on-vehicle training" was received with a value of over 90%, which was a high expectation in all survey groups. Therefore, it is obvious that important infrastructure works need to be done in this regard.

With the lowest value in the expectation group, the question "You think that the H/E vehicles training still given are given using adequate infrastructure and meets the expectations of the sector" took place. Naturally, it is seen that the current education infrastructure in our country needs to meet the expectations of the sector and serious work is needed in this area. The last sample evaluation again creates a very low expectation: "You think that hybrid and electric vehicles basic training can also be given by distance education method". The question is that there is a serious reservation in the sector. Naturally, it can be said that being distant from distance education is normal and understandable in this survey, where the highest need result of the on-board application is given.

3.5. Training needs analysis (students)

In this context, 30 questions consisting of perception, knowledge, skill, and expectation groups were asked of the students via a Google survey to compare the data of teachers, industry members, and students and to make healthy comments. The results obtained were evaluated comparatively under the following heading.

Within the scope of this new study, a survey was conducted with 650 students with an average age of 21 and 97% male. The student survey was open to the participation of graduates or those who have received training from Vocational High School, Vocational High School engineering, or other institutions.

3.6. Teacher/student and sector representative's comparative evaluation results

Above, the training needs analysis for teachers and administrators and the study for sector representatives were evaluated separately. Again, to compare and evaluate the needs of "Teacher-student and sector representatives" of such a comprehensive study, a student-graduate analysis was

made, and the comparative results are presented in Figure 6. The main point to be emphasized here is that the same questions (the scale) were presented to three different groups, and revised according to the relevant groups. In other words, each group answered the same question titles with their own perspectives.

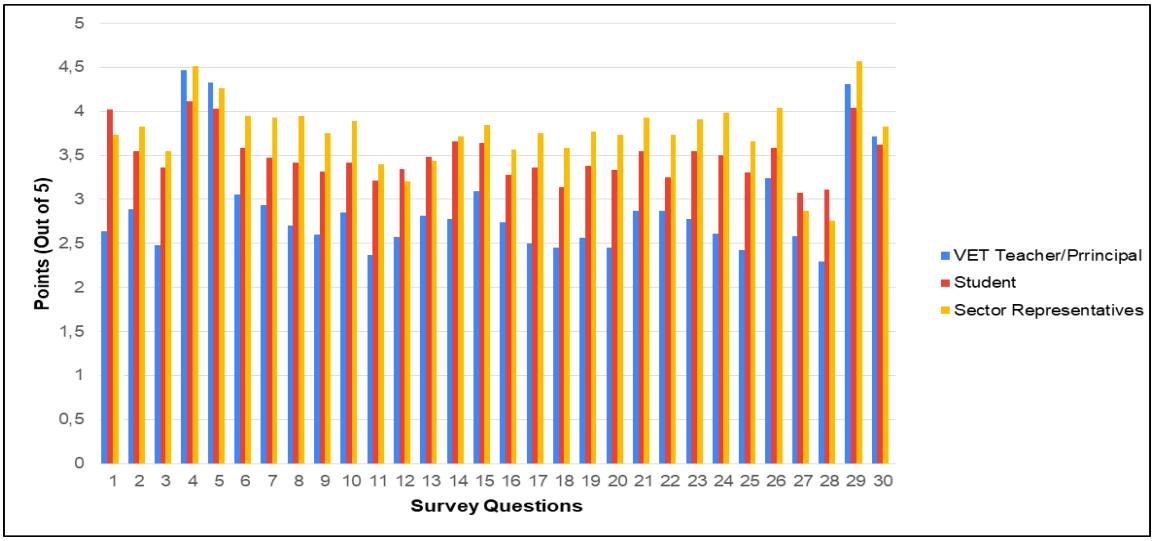

Fig. 6. Comparative results of needs analysis teacher/student and sector representatives

Again, the weighted average of answers for all questions was found to be 57% for teachers, 69% for students-graduates, and 76% for sector representatives. This situation shows that the highest average need percentage is in teachers, the lowest in sector representatives, and students are in the middle of these two groups. From this, it is possible to comment that the sector representatives put forward the expectations in all questions; the teachers presented their current situation realistically in these new fields and topics, where they did not even receive in-service training yet. The students and graduates made comments closer to the expectations of the sector. It is also interesting that all three groups responded similarly to all questions. That is, they stated the same needs. We see this similarity very clearly in the comparative results.

4. Conclusion

All these evaluations and comments are evaluations made on the general averages of the answers constructed under the headings of perception/knowledge-skill and expectation. As can be seen from the graphs, when a question-based analysis is made, the need percentages are very high in some question headings and lower in others. At this point, it may be more appropriate to make a question-based evaluation. Therefore, a detailed evaluation was made of this question and three titles in the teacher/administrator questionnaire. Again, whether there are topics in which teachers, students, and sector groups seriously diverge is important.

These three groups were compared, and it was seen that there was no such breakup or separation, and the results were overlapping. This ultimately confirms the accuracy of the scientific study.

This study, which constitutes an important database in terms of the number of participants, diversity of participants, and three different analyses in which many different analyses can be made, can also be carried out in many sub-analyses that are not given in the above findings. The clear truth that emerges is that there is an important gap that needs to be closed in all New Generation Vehicle Technologies education perception, expectations, knowledge, and skills areas.

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