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Examining the Integral Problem Solving Processes of Engineering Students in Terms of Conceptual and Operational Knowledge Using Bloom's Taxonomy[1]

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ABSTRACT : In this study, the performances of engineering students according to their engineering departments were examined in terms of remembering, understanding, applying, analyzing, evaluating, and creating steps following the revised Bloom's taxonomy on integrals. In addition, their performance in solving the problems within the scope of conceptual, applicational, conceptual–applicational, algebraic quality, visual quality, and real-life problems was evaluated. An integral test consisting of eighteen questions was developed based on the knowledge and cognitive process domain of Bloom's taxonomy to measure knowledge and skills related to the topic of integrals. It was applied to 55 engineering students from different universities selected according to the convenience sampling method from different engineering departments in the 2019-2020 academic year. The data were obtained in written form. The performance of the students was set forth according to the steps of the revised Bloom’s taxonomy. The highest performance was at the application stage, while the lowest performance was at the creation and evaluation stages. The findings showed that their conceptual knowledge about integral is stronger. They make more mistakes in applicational knowledge questions and perform poorly, and their conceptual–applicational knowledge is insufficient to solve non-routine real-life problems.

KEYWORDS: Revised Bloom's Taxonomy, Conceptual Knowledge, Operational Knowledge

I. INTRODUCTION

“What is the use of mathematics for us?” This is a question frequently asked by students. First of all, it is a branch of science that develops the analytical thinking ability of the individual, facilitates analysis, and is a tool for solving the problems s/he encounters in daily life. Mathematics, which is a part of life, forms the basis for constructing and studying many materials that make life easier. One of the application areas of mathematics is engineering. Engineering can be defined as the application process to create new products for the use of the individual by using the knowledge of mathematics and natural, technical, and social sciences. In other words, it is a profession based on technology, science, and mathematics that combines all these fields to solve real-life problems and make life easier [1]. Engineering can also be defined as the combination of mathematics, science, and technology to create new products and solve real-life problems [2]. Engineers can be defined as people who know mathematics, technology, and science and use this knowledge to produce solutions to real-life problems [3]. Mathematics, which is defined as the language of engineering, is encountered in courses such as calculus, differential equations, linear algebra, and discrete mathematics in the first years of engineering degrees at universities. While accepting the importance of mathematics in engineering education, discussions continue about how and how much it should be taught. Some state that students' mathematics knowledge in the engineering faculty is insufficient [3]. Mathematics provides key foundations for many of the technological innovations that support engineering applications. Excellence in many of these technological innovations relies on good mathematical knowledge and skill in many aspects of engineering. The link between mathematics and engineering is so well established that any new development in engineering means that new mathematical theories must be explored [4].

It is necessary to determine the objectives of teaching the students' mathematics knowledge and to measure the achievement of the objectives with appropriate measurement and evaluation tools. The goals of teaching

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behaviors are classified in three domains: cognitive, affective, and psychomotor [5]. This classification is referred to as Bloom's taxonomy. The cognitive domain consists of six steps. These steps from bottom to top are knowledge, comprehension, application, analysis, synthesis, and evaluation. The first three steps are considered the lower cognitive level and the last three are considered the upper cognitive level. These categories are ordered from simple to complex and from concrete to abstract, and mastering each simple category is a prerequisite for mastering the next more complex category [5]. The knowledge domain of this taxonomy consists of four steps by adding a new step with the developing cognitive psychology. These are factual knowledge, conceptual knowledge, applicational knowledge, and metacognitive knowledge. The cognitive process domain steps were rearranged, and the steps of knowledge, comprehension, analysis, and synthesis were transformed from noun form to action form as recall, comprehension, analyzing, and creating. In addition, the creation and evaluation steps were replaced. The cognitive domain steps were reordered as knowledge, comprehension, application, analysis, evaluation, and creation, and the sub-dimensions of these steps increased. This generated taxonomy is referred to as the revised Bloom's taxonomy (REBT) [6]. This taxonomy, which is used to develop problems that will benefit teachers in measuring students' thinking skills, also contributes to the development of cognitive and procedural skills [7]. Students build their level of thinking based on the types of questions from teachers. Therefore, the more cognitive level questions students encounter during the assessment and evaluation phase, the more they will display mental activity and tend to be more inquisitive and creative [8]. It shows that the mathematics curriculum of engineering faculties is insufficient in terms of content, and they generally do not know where and how the skills they need are taught. Moreover, it indicates that mathematics instructors have a limited understanding of how mathematical concepts are applied in engineering courses [9]. It was determined that engineering students learned problem-solving strategies and developed positive feelings and beliefs about mathematics and engineering. Further, it was recommended to consult engineers to make engineering students' mathematics education suitable for engineering [10].

It was reported that a collaborative learning environment in the mathematics course in the engineering faculty encourages students to communicate with each other [4]. Other authors stated that they positively evaluated the role of mathematics in the development of students' cognitive skills and they willingly used the presented interactive study materials, but not everyone was ready to make serious efforts to develop this ability [11]. The conclusion was that in mathematics and science education the concepts of the area under a curve and anti-derivative are insufficient in applications to which a certain integral depends. In contrast, the concept of 'sum of parts' of definite integrals based on a Riemann sum is more useful and helpful [12]. It is reported that the conceptual mathematical approach is more important than the operational approach regarding the engineering subjects and engineering designs of second- and fourth-year engineering students [13]. It is stated that an engineer needs to have conceptual knowledge and it should be taught more than applicational knowledge [14]. Expressing everything in life using a function is complex but possible. To understand these functions better and make them useful, their properties should be determined. We can determine the properties of these functions by plotting their graphs. If there is a need for an instantaneous change or slope, it will be sufficient to simply derive at that point instead of solving the problem at length. In the case of finding the numerical value of an area that cannot be calculated with geometric formulas, the integral of the function that creates the area in a certain range gives the result. Although limit, derivative, and integral, which are the basic concepts of analysis, are regarded as concepts consisting of formulas and rules, they are among the indispensable elements of mathematical thought development and daily life applications due to their conceptual structures [15, 16, 17]. The subject of integrals has an important place in solving problems related to both real life and engineering. Both conceptual and applicational knowledge must be well organized together to be understood [18]. It was aimed to determine how the integral, one of the subjects of the mathematics course, which has an important place in the engineering departments, is perceived by the engineering students, what this subject means to them, what kind of knowledge they have in terms of applicational and conceptual knowledge, and what their level of knowledge is. In line with this, answers to the following questions were sought:

1) What is the performance of engineering students in solving integral problems?

a) What is the integral problem performance of engineering students according to Bloom's taxonomy?

b) What is the performance of engineering students in solving integral problems according to conceptual and applicational knowledge?

c) What is the performance of the engineering students in solving integral problems according to the problem type?

d) What is the integral problem performance of engineering students according to engineering branches?

2) Examining the characteristics of solution processes used by engineering students for integral problems

a) What is the relationship between the integral problem-solving processes of engineering students and the problem types classified according to Bloom's taxonomy?

b) How should the integral problem-solving process of engineering students be evaluated in the context of conceptual and procedural knowledge?

II. METHOD

Considering the aims and research questions of the present study, it was a case study. The study sample was created using the convenience sampling model, which is a non-probabilistic sampling method. Fifty-five students from different engineering departments of universities (industry, computer, machinery, electrical and electronic, shipbuilding, and ship machinery, aerospace engineering, and other engineering departments) in the spring semester of the 2019-2020 academic year participated in the research. The data were collected using a test on integrals. This test was prepared based on the knowledge acquired on the subject of integrals in the curriculum of the mathematics courses in the 1st year curriculum of the engineering faculties of the universities. While preparing the test, first of all, basic concepts related to integrability conditions, basic theorem of analysis, Riemann sums, calculation of the area under a curve, integration methods, and volume calculation basic skills were focused on. In addition, some questions measured high-level thinking skills such as the concept of function, the relationship between derivative and integral, estimation of Riemann sums and areas, using Riemann sums in real-life problems, and using equal areas by combining parts. The questions prepared were classified according to the revised Bloom’s taxonomy. In this test, there are a total of eighteen questions: one in recall, two in comprehension, eight in application, five in analyzing, one in evaluating, and one in creating steps. The answers given by the students to this test were examined in three categories: Bloom's taxonomy, conceptual–procedural information types, and problem nature. The evaluation criteria for the answers given to the integral test according to the students' ability to arrive at the result are given in Table 1. The engineering students were analyzed in the context of performance according to Bloom's taxonomy, conceptual and applicational knowledge, and their engineering departments.

Table 1 Evaluation Criteria for Integral Test Questions

Categories	Description
Correct	The way of solution and solution result are correct
Incorrect	The result and the solution way are incorrect
Partial Answer	Although the solution is correct, the result is incorrect
No Answer	Typing the same question, leaving it blank, or typing answers like 'I don't remember'

III. RESULTS

The percentages of the answers given by the 55 engineering students to the questions in the integral test according to engineering departments are shown in Table 2.

Table 2 Distribution of Answers to the Questions Based on Departments

Department	Correct (%)	Incorrect (%)	Partial Answer (%)	No Answer (%)
Industrial Engineering	30	25	18.9	26.7

Computer Engineering	28.3	15.6	27.2	28.9
Mechanical Engineering	31.1	15.6	25	28.3
Electrical and Electronic Engineering	40	19.4	23.3	17.2
Naval Architecture and Marine Engineering	35	15	23.9	26.1
Aerospace Engineering	46.1	25	22.2	7.2
Other Engineering	18	26.3	26.3	29
General	30.0	22.2	24.4	23.9

The percentage of computer engineering students and other engineering groups who answered the questions correctly is below the general percentage. It is noteworthy that the students in the aerospace engineering group answered the questions correctly at a rate of 46.1%, and the percentage of wrong answers was above the average. Students in the aerospace engineering group did not answer 7.2% of the questions. While 40% of the questions were answered correctly, the electrical and electronic engineering students did not answer 17.2% of the questions. Engineering student groups outside these two fields are above average in terms of unanswered questions. It was determined that there were no students who answered the algebraic knowledge type of questions correctly, which measures the conceptual–operational knowledge of the real-life problems, and the creation step, which measures conceptual knowledge, and in the evaluation step of the cognitive process domain of the revised Bloom's taxonomy (Figure 1).

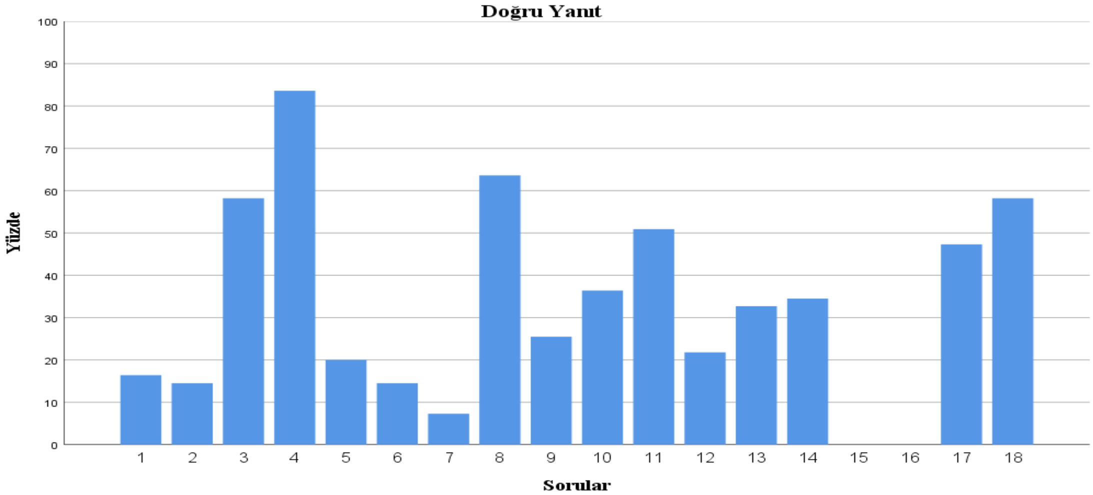


Figure 1. Percentage of correct answers of engineering students to the integral test

The revised Bloom's taxonomy refers to the comprehension step of the cognitive process domain and measures conceptual knowledge and algebraic knowledge; it belongs to the applicational step and is the least incorrectly answered questions in the conceptual–applicational information type (Figure 2).

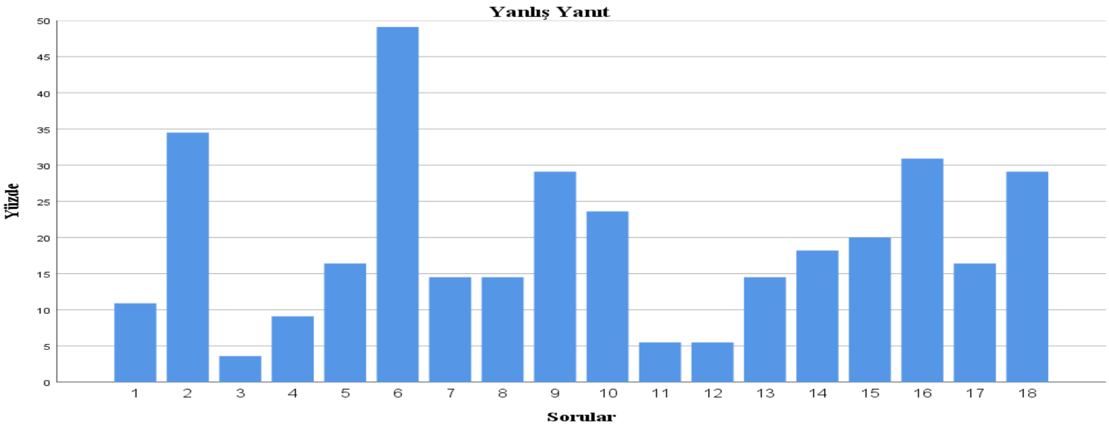
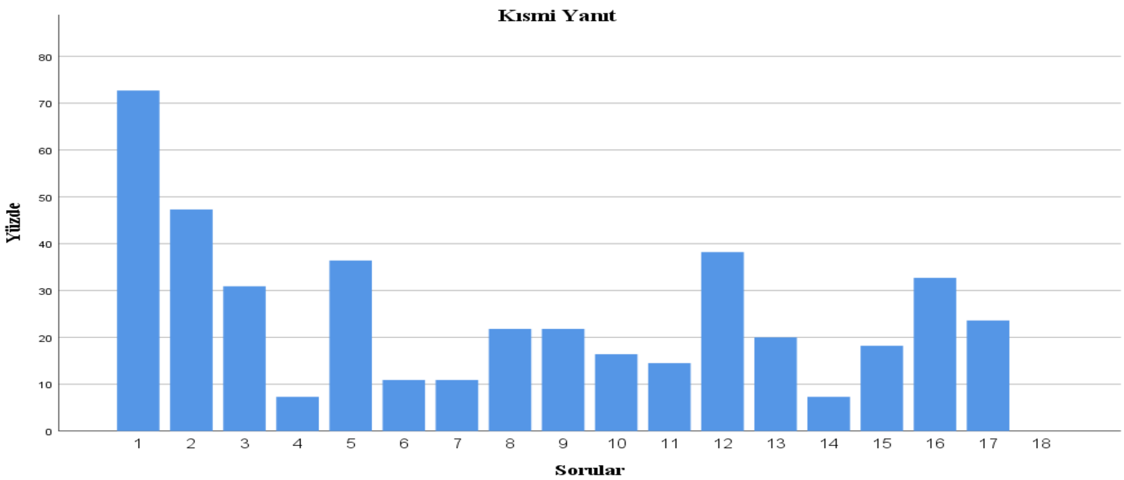


Figure 2. Percentage of incorrect answers of engineering students to the integral test

The questions with the highest number of partial answers are in the recall and comprehension step of the revised Bloom's taxonomy's cognitive process domain. Both are types of algebraic questions that measure conceptual knowledge and the nature of the problem (Figure 3).

Figure 3. Percentage of partially correct answers of engineering students to the integral test



The questions most left unanswered by the students are in the analysis and evaluation stages of the cognitive process domain of the revised Bloom's taxonomy. These questions measure procedural knowledge and conceptual knowledge, respectively. The nature of the problem is again in the category of algebraic and real-life problems, respectively. The questions that the students did not leave unanswered were those of the recall and application step of the cognitive process domain of the revised Bloom's taxonomy. These questions appear to be algebraic questions measuring conceptual knowledge and visual questions measuring conceptual–applicational knowledge (Figure 4).

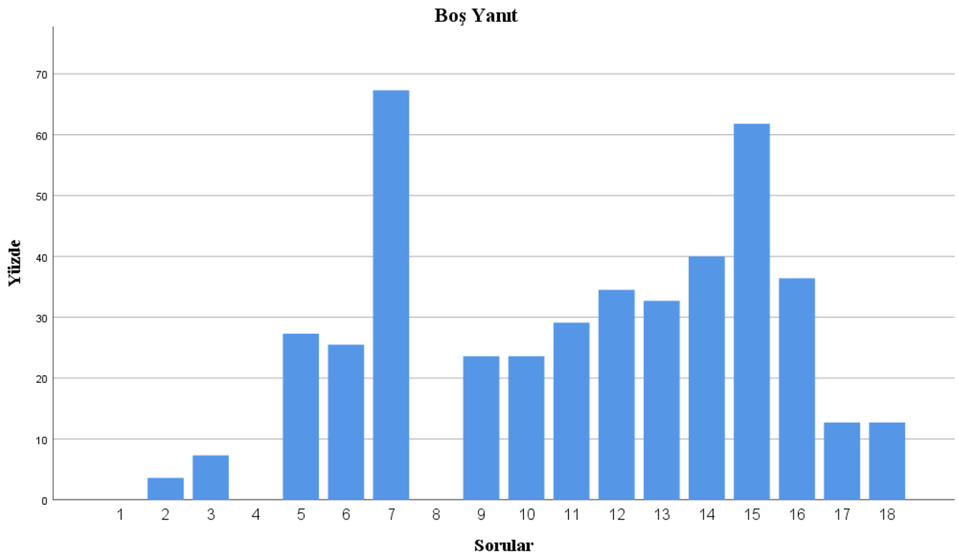


Figure 4. The percentage of blank answers in the integral test of engineering students

The results of the integral test according to the revised Bloom's taxonomy and the performance percentages of engineering students according to the recall, comprehension, application, and analyzing steps and their engineering departments are given in Table 3.

Table 3. Percentage table of answers according to Bloom's taxonomy

Bloom's Taxonomy Steps		Industrial Engineering	Computer Engineering	Mechanical Engineering	Electrical and Electronic Engineering	Naval Architecture and Marine Engineering	Aerospace Engineering	Other Engineering
Recall	C.	13	0	20	9	67	25	25
	IC	0	10	13	9	0	50	0
	PA	87	90	67	82	33	25	75
	NA	0	0	0	0	0	0	0
Comprehension	C.	44	15	35	45	35	75	25
	IC	6	20	25	20	15	0	38
	PA	38	55	40	35	35	25	25
	NA	12	10	0	0	15	0	12
Application	C.	41	40	41	55	42	60	25
	IC	20	16	15	13	16	18	34
	PA	13	19	23	18	17	22	22
	NA	26	25	21	14	25	0	19
Analysis	C.	22	32	30	34	34	35	10
	IC	38	10	18	28	6	30	20
	PA	8	24	10	10	26	20	25
	NA	32	34	42	28	34	15	45
Evaluation	C.	0	0	0	0	0	0	0
	IC	40	10	0	37	30	25	25
	PA	10	0	30	13	30	25	25
	NA	50	90	70	50	40	50	50
Creation	C.	0	0	0	0	0	0	0
	IC	46	40	10	34	30	75	0
	PA	24	20	40	46	40	25	25
	NA	30	40	50	20	30	0	75

C: Corretct, IC: Incorrect, PA: Partial Answer, NA: No Answer

There are no students that did not respond to the recall step of the revised Bloom's taxonomy. It is notable that the questions related to the creation and evaluation step could not be answered correctly by all engineering group students. It is observed that the students that gave the most incorrect answers to the questions in the recall step were those in the aerospace engineering group, with 50%. It is noteworthy that the students of industrial, naval architecture and marine engineering, and other engineering departments did not give an incorrect answer to this question. The highest correct answer average was 75%, by aerospace engineering students, and the highest average of partial answers was 55%, by computer engineering students, in the comprehension level questions of the revised Bloom's taxonomy. It is observed that the students of mechanical engineering, electrical and electronic engineering, and aerospace engineering answered all of the questions in this step.

The highest correct answer rate in the application step of the revised Bloom's taxonomy was by the aerospace engineering students group, with 60%. The highest average of those who did not answer the questions was of the students in the industrial engineering group, with 26%, followed by the naval architecture and marine engineering and computer engineering student groups, with 25%. Aerospace engineering students stood out by answering all the questions related to the application step. The highest correct answer rate in the analyzing step of the revised Bloom's taxonomy was by the aerospace engineering students, with 35%. This is followed by the electrical and electronic engineering and naval architecture and marine engineering students, with 34%. The highest number of incorrect answers was given by the industrial engineering students, with 38%. There are no student groups who answered the question correctly in the evaluation step of the revised Bloom's taxonomy. The student group that gave the highest number of incorrect answers to the question at this step was the industrial engineering students, with 40%. On the other hand, the computer engineering student group draws attention by 90% not answering the question. The question in the creation step of the revised Bloom's taxonomy was not answered correctly by any student group. While the partial answer rate for this question was higher than the incorrect answer rate, it was determined as 33%. In addition, this question was left unanswered by 41% of the engineering students. It is notable that 75% of the students in the aviation and aerospace engineering group gave the highest number of incorrect answers to the question. The student group that left this question unanswered, with 75%, was the other engineering department students. On the other hand, this question was answered by every student in the aerospace engineering group, and it was not left blank. The highest number of partial answers was given by the electrical and electronic engineering students, with 46%.

The performance percentages of the engineering students for the conceptual, application, conceptual–application, algebraic quality, visual quality, and evaluation steps of a real-life problem in line with the information required for the solution of the problem or to be used in solving the integral test questions are provided in Table 4.

Table 4. Percentages of answers according to Bloom's taxonomy

Question Level and Quality		Industrial Engineering	Computer Engineering	Mechanical Engineering	Electrical and Electronic Engineering	Naval Engineering and Marine Architecture Engineering	Aerospace Engineering	Other Engineering
At Conceptual Knowledge Level	C.	33	25	35	43	41	50	25
	IC	26	21	23	20	13	35	28
	PA	25	31	26	30	21	15	22
	NA	16	23	16	7	25	0	25
At Application Knowledge Level	C.	0	23	24	27	24	42	8
	IC	17	7	10	17	0	0	25
	PA	17	27	23	13	33	32	33
	NA	66	43	43	43	43	26	34
Conceptual–Procedural Knowledge Level	C.	40	34	30	43	33	43	14
	IC	27	13	10	20	24	25	25
	PA	13	23	24	20	23	25	29

	NA	20	30	36	17	19	7	32
Algebraic Quality	C.	29	26	30	41	34	49	16
	IC	22	16	17	18	16	20	29
	PA	22	34	27	25	26	26	30
	NA	27	24	26	16	24	5	25
Visual Quality	C.	40	37	37	49	39	48	20
	IC	32	18	17	20	18	34	27
	PA	10	19	18	19	18	18	21
	NA	18	26	28	12	25	0	32
Real-Life Problem	C.	0	0	0	0	0	0	0
	IC	40	10	0	30	30	25	25
	PA	10	0	30	20	30	25	25
	NA	50	90	70	50	40	50	50

In order to measure the relationship between the conceptual knowledge of engineering students and their performance, 5 questions were asked to the students in the integral test. The highest number of correct answers was from the aerospace engineering students, with 50%, and by the electrical and electronic engineering students, with 43%, to the questions aimed at measuring conceptual knowledge. The highest number of wrong answers was obtained from the students in the aerospace engineering group, with 35%. It is also significant that all students in the aerospace engineering student group answered all of the questions measuring conceptual knowledge.

In order to measure the relationship between the application knowledge of engineering students and their performance, 4 questions were asked to the students in the integral test. While 17% of the students answered the questions about measuring application knowledge correctly, 27% answered partially correctly, 13% answered incorrectly, and 43% did not answer at all. It is noteworthy that none of the students in the industrial engineering group answered the questions correctly. In addition, 66% of the students in this group did not answer the question. The students in the aerospace engineering group gave the most correct answers, with 42%. The naval architecture and marine engineering and aerospace engineering students gave correct answers or partial answers or did not answer these questions, but they did not give any incorrect answers, which is significant. In order to measure the relationship between the conceptual–application knowledge of the engineering students and their performance, 9 questions were asked to the students in the integral test. The highest correct answer average of 43% was given by the students in the aerospace engineering and electrical and electronic engineering groups to the questions aimed at measuring conceptual–application knowledge. The student group that left these questions unanswered the most was mechanical engineering, with 36%. The students of the aerospace engineering department gave the highest number of correct answers and it is notable that this group was among the student groups that gave the most wrong answers to the questions about this type of information. In order to measure the performance related to algebraic problems, 9 questions were directed to students in the integral test. The most correct answers to algebraic problems were given by students in the aerospace engineering group, with 49%, followed by electrical and electronic engineering students, with 41%. In order to measure the performance related to visual problems, 8 questions were directed to students in the integral test. While the students in the electrical and electronic engineering group gave the highest number of correct answers to the visual problems, with 49%, they were followed by the students in the aerospace engineering group, with 48%. This draws attention to the fact that all students in the aerospace engineering student group answered all of the visual questions and this was the group that gave the most wrong answers, with 34%.

In order to measure the performance related to a real-life problem, a question was directed to students in the integral test. Looking at the answers given to the real-life problem question, it is observed that none of the students answered the question correctly. While 50% of the engineering students did not answer the question, only 24% partially answered it. In addition, none of the students in the mechanical engineering student group gave wrong answers to such questions. It is significant that the students of the computer engineering department did not give correct answers, only partial answers to this question. Again, students in the computer engineering group left the most questions unanswered, with an average of 90%.

Below are the findings of the student groups regarding the revised Bloom's taxonomy, conceptual–application information types and the nature of the problem according to engineering departments. While examining the answers as conceptual knowledge, not only knowing the definition of the concept but also the situations of establishing relations between the concepts were considered. Mathematical literacy and knowledge of symbols, formulas and visual representations were taken into consideration in the evaluation as procedural knowledge. While examining questions and problems in terms of conceptual–application knowledge, students' behaviors such as knowing the meaning of a concept, establishing a logical relationship between the required and the given, drawing auxiliary figures, matching the problem with the given auxiliary figure, using the offered definition and propositional knowledge, etc. were deemed as proof of conceptual information and for the existence of conceptual information. In addition, it was evaluated that the students were able to master mathematical symbols and mathematical language in the problem-solving process, to use the necessary relations or formulas for the solution of the problem, and to arrive at the result by performing the necessary operations in a logical order.

It was observed that engineering students are successful in terms of implementing and using different methods when faced with a situation, event, or any problem, but have difficulty in producing correct result-oriented answers because they do not show the same success in arithmetic operations. Since the questions of the recall step in the integral test were close-ended, there were differences in the correct answer rates among the students. The only question with no blank answer and the one with the lowest rate of incorrect answers among the engineering groups belonged to this step. While these results show that students have some information about the recall step, they also support the idea that incomplete and incorrect information should be completed and corrected. The comprehension level performances of engineering students are higher than their recall level performances. In this step, while the students in the aerospace engineering group showed the best performance, the lowest performance was demonstrated by the students of the computer engineering department.

The performance levels of engineering students at the application level were determined to be higher than at the recalling and understanding steps. In fact, the highest performance in general was exhibited at this step. Therefore, it can be asserted that students are successful in using their existing knowledge. The lowest performance among the engineering groups was demonstrated by the other engineering student group. The performances of other groups were similar, especially students of aerospace engineering and electrical and electronic engineering. When the answers provided by the engineering students to the questions in the analysis step in the integral test were examined in general, it was determined that they could use the variable substitution method to solve the definite integral, could master the relationship between the derivative and the tangent line, and express the area of a given region in a different way. This shows that students have skills such as revealing the relationships between the parts, making associations, and organizing. However, at the same time, it is observed that students have problems in using a given rule, find it difficult to find the desired value in the function by using the graph of a function whose derivative is provided, and they are not very competent in analyzing the areas of different regions divided into parts under and above the curve. This shows that the students are not sufficient in skills such as analyzing, analyzing by distinguishing the parts from each other, and separating them into their own parts. When the answers provided by the engineering students to the question in the evaluation step in the integral test are examined in general, it is observed that the students gave inaccurate but partially correct answers, and they tried to make decisions based on the data they obtained with these methods they developed. Here, it was determined that the students could not adapt the Riemann sum to the real-life problem. They were requested to evaluate the answer to the problem by using the areas of similar shapes. However, due to their inability to choose the right method or strategy while approaching the solution, they stated that they could not adequately demonstrate skills such as valuation, assessment, and decision-making.

In the question at the creation step in the integral test, the students were asked to measure the idea that for the region between a line and the axes with the help of the Riemann sum of the whole area to be formed by the combination of the infinite number of rectangles under the curve. It was determined that the majority of the students did not know the Riemann sum. However, it is significant that the students who knew the rule of Riemann sum were unable to use this knowledge. This reveals that the formula required for the area calculation with the Riemann sum was memorized by the engineering students but could not be conceptualized. Therefore, it is observed that they are not sufficient in skills such as forming a whole by using parts, creating models, and formulating. The performance rate for the questions measuring the conceptual and application knowledge simultaneously was determined to be very close to that for the questions measuring the conceptual knowledge. While it is observed that the questions left unanswered the most are those that examine application knowledge, it is worth emphasizing that the most incorrect answers were given to questions measuring conceptual knowledge. Partially, the questions that received the most answers were those that required application knowledge. It can be asserted that students generally know which formula to use for what in questions that require application knowledge. It is noteworthy that the partial answers to the questions in the application knowledge type are more and the correct answers are less. This can be explained by the fact that students make calculation errors or logical errors or are extremely distracted.

IV. CONCLUSION

This study determined that the engineering students showed the lowest performance in the creation and evaluation steps. No student could answer the questions in this step correctly. This revealed the need to determine whether the students have encountered the question of an adequate level of evaluation and creation of integrals in their undergraduate mathematics education. It was observed that while the levels of the mental process increased from the recalling level to the application level in the lower-level cognitive stages, their performance also increased. It was observed that the performance of the students decreased as the higher level cognitive steps increased. The fact that they also expressed that their performance decreases as the cognitive process steps increase supports this finding [19,20]. In the analysis step, the first level of the high-level cognitive learning group of Bloom's taxonomy, it was determined that the engineering students performed lower than in the previous steps. The students did not provide any correct answers and showed the lowest performance in the evaluation and creation step. This supports the conclusion that mathematics education programs in previous learning processes concentrate on lower cognitive steps and are insufficient in higher cognitive steps [21].

It was determined that the engineering students showed the highest performance in questions about conceptual knowledge and the lowest performance in questions about application knowledge. The fact that the students of the mathematics department stated that their performance was the highest in questions regarding conceptual knowledge and the lowest in questions regarding application knowledge supports these findings [22]. While this contradicts the finding that middle school students' performance of application knowledge of rational numbers outweighs their performance of conceptual knowledge, it is consistent with the result that they do not have sufficient levels of either type of knowledge [23]. The performance in answering the questions in which conceptual and application knowledge was tested at the same time was determined to be very close to that in the questions measuring the conceptual knowledge. In addition, it was determined that engineering students prefer not to answer questions that require application knowledge. This seems to support the conclusion that the conceptual mathematical approach is more important than the application approach in the context of engineering issues and engineering designs [13]. When the solution processes of engineering students in answering questions that require conceptual–application knowledge were examined, the highest performance was observed in answering questions measuring conceptual knowledge, while the lowest performance was observed in answering questions measuring application knowledge. This [24] indicates that teachers mostly ask questions at the application stage. It was determined that the correct answers given by the engineering students to the questions measuring application knowledge were lower than the correct answers given to the questions asked to measure both conceptual and application knowledge simultaneously. This finding seems to support the view that the acquisition of conceptual knowledge affects application knowledge and the acquisition of application knowledge has no effect on conceptual knowledge [25]. It is assessed that students leave questions that require application knowledge unanswered, that they do not have the skills to learn formulas and rules and apply them when and if necessary, and that they abstain when numerical expressions are involved. In the integral test, it was observed that the engineering students showed the best performance in answering the questions measuring conceptual knowledge according to their conceptual–application knowledge. The students could not create algebraically correct equations with the information provided in the problems and they could not arrive at the correct result by applying appropriate algebraic operations to the equations that formed it.

REFERENCES

[1] Morgan, J. R., Moon, A. M., & Barroso, L. R. (2008). Designing engineering project-based learning. In R. M. Capraro & S. W. Slough (Eds.). Project-based learning: An integrated Science, Technology, Engineering, and Mathematics (STEM) approach. Rotterdam, the Netherlands: Sense Publishers. (pp. 39-54). Rotterdam, The Netherlands: Sense Publishers.

[2] Zainuri, N., Nopiah, Z., Asshaari, I., & Yaacob, N. (2009). The level of mathematical knowledge of first year engineering students at the faculty of engineering and build environment. European Journal of Scientific Research, 32(2), 201-207.

[3] Güner, N., & Çomak, E. (2011). Mühendislik öğrencilerinin matematik I derslerindeki başarısının destek vektör makineleri kullanılarak tahmin edilmesi. Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi, 17(2), 87-96.

[4] Radzi, N. M., Abu, M. S., & Mohamad, S. (2009). Math-oriented critical thinking skills in engineering. International Conference on Engineering Education, 7(8), 212-2018.

[5] Bloom, B. S. (1956). Taxonomy of educational objectives, the classification of educational goals, handbook I: Cognitive Domain. New York: David McKay Company.

[6] Krathwohl, R. D. (2002). A Revision of Bloom's Taxonomy: An Overview. Theory Into Practice, 41(4), 212-218.

[7] Turgut, M. F. (1992). Eğitimde ölçme ve değerlendirme metotları. Ankara: Saydam Matbaacılık.

[8] Çepni, S., Ayvacı, H., & Keleş, E. (2001). Okullarda ve lise giriş sınavlarında sorulan fen bilgisi sorularının Bloom Taksonomisine göre karşılaştırılması, Fen Bilimleri Eğitimi Sempozyumu Bildiriler Kitabı. Maltepe Üniversitesi Eğitim Fakültesi, İstanbul.

[9] Willcox, K., & Bounova, G. (2004). Mathematics in engineering: identifying, enhancing and linking the implicit mathematics curriculum. American Society for Engineering Education.

[10] Cardella, M. (2007). What your engineering students might be learning from their mathematics pre-reqs (Beyond Integrals and Derivatives). 37th Annual Frontiers In Education Conference-Global Engineering: Knowledge Without Borders, Opportunities Without Passports, S4F-1-S4F-6. doi: 10.1109/FIE.2007.4418130.

[11] Zeidmane, A., & Sergejeva N. (2013). Indirect impact of mathematics in engineering educatıon. Engineering For Rural Development, 611-615.

[12] Jones, S.R. (2015). Areas, anti-derivatives, and adding up pieces: Definiteintegrals in pure mathematics and applied science contexts. Journal of Mathematical Behavior, 38, 9-28.

[13] Bergsten, C., Engelbrecht, J., & Kagesten, O. (2017). Conceptual and Procedural Approaches to Mathematics in the Engineering Curriculum – Comparing Views of Junior and Senior Engineering Students in Two Countries. EURASIA Journal of Mathematics Science and Technology Education, 13(3), 533-553. DOI 10.12973/eurasia.2017.00631a

[14] Engelbrecht, J., Bergsten, C., & Kagesten, O. (2017). Conceptual and procedural approaches to mathematics in the engineering curriculum: views of qualified engineers. European Journal of Engineering Education, 42(5), 570-586. https://doi.org/10.1080/03043797.2017.1343278

[15] Tall, D. O., & Vinner, S. (1981). Concept image and concept definition with particular reference to limits and continuity. Educational Studies in Mathematics, 151–169.

[16] Orton, A. (1983). Student's understanding of integration. Educational Studies in Mathematics, 14(1), 1-18.

[17] Rasslan, S., & Tall, D. (2002). Definitions and ımages for the definite ıntegral concept. In A. Cockburn & E. Nardi (Eds.) Proceedings of the 26th Conference of the International Group for the Psychology of Mathematics Education (Vol.4, pp. 89-96). Norwich: England.

[18] Baki, A., & Kartal, T. (2004). Kavramsal ve işlemsel bilgi bağlamında lise öğrencilerinin cebir bilgilerinin karakterizasyonu. Türk Eğitim Bilimleri Dergisi, 2(1), 27-50

[19] Dursun, A., & Aydin-Parim, G. (2014). YGS 2013 matematik soruları ile ortaöğretim 9. sınıf matematik sınav sorularının Bloom taksonomisine ve öğretim programına göre karşılaştırılması. [Özel Sayı]. Eğitim Bilimleri Araştırmaları Dergisi, 4(1), 17-37. DOI: 10.12973/jesr.2014.4os2a

[20] Toğrul, A. (2014). Lise öğrencilerinin Ebob-Ekok problemlerinin çözüm süreçlerinin kavramsal ve işlemsel bilgi açısından incelenmesi. (Yüksek Lisans Tezi). https://tez.yok.gov.tr sayfasından erişilmiştir.
[21] Aktan, O. (2019). İlkokul matematik öğretim programı dersi kazanımlarının yenilenen Bloom Taksonomisine göre incelenmesi. Pamukkale Üniversitesi Eğitim Fakültesi Dergisi, doi: 10.9779/pauefd.523545
[22] Mahir, N. (2009). Conceptual and procedural performance of undergraduate students in integration, International Journal of Mathematical Education in Science and Technology,40(2), 201-211. https://doi.org/10.1080/00207390802213591
[23] Birgin, C., & Gürbüz, R. (2009). İlköğretim II. kademe öğrencilerinin rasyonel sayılar konusundaki işlemsel ve kavramsal bilgi düzeylerinin incelenmesi. Eğitim Fakültesi Dergisi, 22(2), 529-550
[24] Bekdemir, M., & Baş, F. (2017). Matematik öğretmenlerinin sınavlarda kullandıkları soruların kavramsal ve işlemsel bilgi boyutunda analizi. Ondokuz Mayıs Üniversitesi Eğitim Fakültesi Dergisi, 36(1), 95-113. Doi: 10.7822/Omuefd.327392
[25] Aydın, L. (2015). Fen eğitiminte kavramsal ve işlemsel öğrenme üzerine akademisyen görüşleri. (Yüksek Lisans Tezi). https://tez.yok.gov.tr .
[26] H. N. Ho and E. Lee, "Model-Based Reinforcement Learning Approach for Planning in Self-Adaptive Software System," in Proceedings of the 9th International Conference on Ubiquitous Information Management and Communication, 2015.
[27] Elkhodary, N. Esfahani and S. Malek, "FUSION: A Framework for Engineering Self-Tuning Self-Adaptive Software Systems," in Proceedings of the eighteenth ACM SIGSOFT international symposium on Foundations of software engineering, 2010.
[28] N. Esfahani, A. Elkhodary and S. Malek, "A Learning-Based Framework for Engineering Feature-Oriented Self-Adaptive Software Systems," Software Engineering, IEEE Transactions on, vol. 39, pp. 1467-1493, 2013.
[29] S.-W. Cheng, Rainbow: Cost-Effective Software Architecture-Based Self-Adaptation, ProQuest, 2008.
[30] L. C. Briand, J. W. Daly and J. K. Wust, "A Unified Framework for Coupling Measurement in Object-Oriented Systems," IEEE Transactions on software Engineering, vol. 25, pp. 91-121, 1999.

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