THE ASSESSMENT OF UNIVERSITY STUDENTS' CONCEPTUAL UNDERSTANDING AND INTERPRETATION ABILITIES ON ELECTROMAGNETIC INDUCTION

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ABSTRACT

This study is about the conceptual understanding of first and last year Turkish University students' on electromagnetic induction. The questions used in this study have been selected and designed from Electromagnetic Induction unit in Physics to probe conceptual understanding and interpretation abilities of students. This will also be an attempt to obtain and interpret valuable information about the knowledge and understanding of the teacher's teaching, students learning and curriculum used. Prepared questions were administered at Balıkesir University Necatibey Education Faculty. The results obtained from this study revealed that a low proportion of students involved in this study were able to give acceptable explanation about the Electromagnetic Induction concepts.

Key Words: Conceptual Understanding, University students, Physics Education, Electromagnetic Induction

ÖZET

Bu çalışmada birinci ve son sınıf üniversite öğrencilerinin elektromanyetik indüksiyon ünitesine ait kavramsal anlama düzeyleri irdelenmiştir. Çalışmada kullanılan sorular fizikteki '*Elektromanyetik İndüksiyon*' ünitesinden seçilerek öğrencilerin kavramsal anlama ve yorumlama yeteneklerini incelemek amacıyla hazırlanmıştır. Bu inceleme, konuyu öğretmenlerin öğretimi, öğrencilerin öğrenmesi ve kullanılan program konusunda yararlı bilgilerin elde edilip yorumlanması açısından da önemlidir. Çalışmada kullanılmak üzere hazırlanan sorular Balıkesir Üniversitesi Necatibey Eğitim Fakültesindeki öğrencilere uygulanmıştır. Elde edilen sonuçlar oldukça düşük bir öğrenci grubunun Elektromanyetik İndüksiyon kavramları üzerine bilimsel olarak kabul edilebilir açıklamalar verdiğini ortaya koymuştur.

Anahtar Kelimeler: Kavramsal Anlama, Üniversite Öğrencileri, Fizik Eğitimi, Elektromanyetik İndüksiyon

1. INTRODUCTION

There is no national curriculum for the university Physics courses offered to students in science education in Turkey. Most Physics courses are based on texts. By considering the criteria used to determine the pass-fail rates for the first year Physics courses, it is possible to estimate the performance of students who were selected through the University Entrance Examination (OYS), and thus, to a certain degree, the Physics attainments learnt in lycee. The assessment instruments used in the courses are written examinations with open questions, testing basic concepts and problem solving skills [1].

The low graduation rates can be attributed to low attainment in university Physics in Turkey. Reasons for this issue are the entrance examination system for being unable to weed out students [2], inadequacy of Physics courses offered at the university, abstract and mathematically oriented teaching language and teachers who are methodologically ill-prepared and do not adopt their teaching to the needs of the students.

As Gemici et al. [3] investigated, there were statistically significant background and attainment differences between university first and final year Physics students. Indeed, nobody in the final year group passed the test which was included 50 multiple-choice Physics questions from different units at the university entrance examination level. These questions were mainly testing students' scientific knowledge in terms of recalling related equations to show their problem solving abilities.

It is therefore necessary to increase the quality of undergraduate students many of who would be trained to become primary or secondary school teachers. After the graduation from education faculties many school administers entrust the unqualified teachers with the teaching of science. This process affects the student achievement and reduces the efficiency of education. Basaran [4] and Ayaz [5] attribute the poor record of secondary schools in the university entrance examinations to unqualified teachers and overcrowded classes.

Even at Universities overcrowded classes forces lecturers to adopt the same '*chalk and talk*' method of teaching as in secondary schools. It is obvious that individual student attention is limited by the size of the classes. There is very little interaction between the students and the teacher during lectures and this makes students passive recipients of the new knowledge and minimally actively involved in most of the activities. The common problem that lecturers complain about is over-loaded syllabuses and as a result limited time allocated for practical work. Additionally, shortage of apparatus makes it impossible to perform whole experiments. As a result, teaching of science becomes predominantly teacher-centred rather than student-centred, an obstacle to effective science teaching.

Certainly, factors effecting success of students are not limited with the factors above. Many studies in Physics Education put forward that students already form ideas on a natural phenomena before they are trained on it [6, 7]. These ideas that may be called as *preconceptions* or *everyday concepts* include inadequate and usually wrong ideas [8]. On the other hand, even after related topic has been taught, it is also observed that students have misconceived or interpreted that topic wrongly [9]. Therefore, it is widely accepted that it is necessary to identify what kind of preconceptions and ideas students have had and to build up further ideas to provide students with effective learning atmosphere.

In order to investigate the effectiveness of Physics instruction and to pinpoint areas for improved teaching the concept area of electromagnetic induction unit was chosen on the basis of the researcher's interest. The purpose of this study is to report different kind of explanations to electromagnetic induction questions and to show to what extent students successfully use electromagnetic ideas in a meaningful way.

2. METHODOLOGY

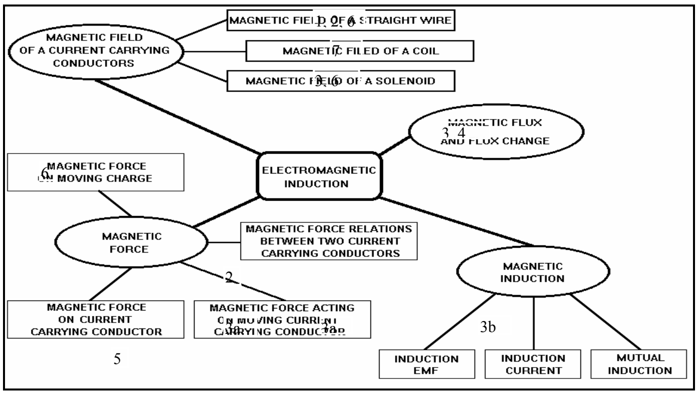
Formative assessment technique was used to monitor students' progress through their training. A package of 7 questions was developed. After the construction, piloting and administration of the questions, data analysis stage came to agenda. At the beginning, the complexity of coding responses and the time-consuming nature of the analysis forced the researcher to select 3 questions, namely questions 2, 4 and 5, from the concept area of electromagnetic induction to probe students' understanding. The selected 3 questions were typical of those which would be written to cover the whole electromagnetic induction unit.

The study is mainly based on written responses given by 18 and 21 year-old students to seven questions. Question 1 was taken from Joint Matriculation Board [10] and question 7 from Advanced Physics Project for Independent Learning [11] at A level respectively and rest of them were designed by the researcher.

It is hoped that the analysis of the responses will give insight into the ways in which students conceptualise different terminology, and that this can inform teaching. With this in mind, alternative types of responses used by students in their responses have been analysed.

2.1 Construction of the Questions

Topics involving ideas about magnetic field, force, induction flux and flux change are common throughout science lessons in upper secondary level and universities. Figure 1 shows a concept map of topics for all seven questions.



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* Each number next to the circle or rectangles shows the question number related to particular concept

Figure 1. A Concept map of questions.

Students in Physics Education department are usually encountered with these concepts in first and last years of university. In many courses, the idea of the effect of current carrying conductor and the formation of magnetic field around conductor is introduced in detail early in the first year and continued to be developed throughout the course.

To produce questions, the classifications based on Bloom [12] taxonomy have been used. This taxonomy was useful during question construction in moving the emphasis in questions away from Knowledge (recall). Attention was drawn to the Application, Analysis, Synthesis and Evaluation end of the taxonomy and questions were written to try to cover these abilities. Table 1 shows the distribution of objectives covered by the selected three questions.

Table 1. Distribution of the questions in the Bloom's taxonomy.

		Q 2	Q 4	Q 5
Knowledge	Knowledge of Specifics			
	Knowledge of Terminology	✓	✓	✓
	Knowledge of Specific Facts			✓
	Knowledge of Ways and Means of Dealing with Specifics			
	Knowledge of Conventions	✓	✓	✓
	Knowledge of Trends and Sequences		✓	✓
	Knowledge Classifications and Categories		✓	
	Knowledge of Criteria		✓	✓
	Knowledge of Methodology	✓	✓	✓
Comprehension	Transition			
	Interpretation	✓	✓	✓
	Extrapolation	✓		✓
Application	Application	✓	✓	✓
Analysis	Analysis of Elements	✓		✓
	Analysis of Relationships	✓	✓	✓
	Analysis of Organised Principles		✓	✓
Synthesis	Production of a Unique Communication			
	Production of a Plan or Purposed Set of Operations		✓	
	Derivation of a Set of Abstract Relations	✓		✓
Evaluation	Judgements in Terms of Internal Evidence		✓	
	Judgements in Terms of External Criteria	✓		

An open-ended statement after the multiple-choice part in each question was added for diagnostic purposes in order to find out how well the teaching and learning have gone and the ideas students have. This was also useful to balance tension between reliability and validity. The multiple-choice part of questions can be marked reliably however, reliability alone was not enough. Hanna [13] states that "*one of the arts in examining is to increase validity without decreasing reliability*". Thus, to prepare valid questions the open-ended part was added.

Carey [14] emphasises that "*written instructions should also be clearly stated so that all students understand what is wanted*". Therefore, on the first page, the precise response instructions were politely given. In order to foster students' motivation and ensure anonymity a brief explanatory note and time allocated for answering were provided as well.

The questions were validated by being reviewed by experts in the area of assessment in science and in the area on which the study is focused. After careful inspection, questions were ready to pilot them in an education faculty.

2.2 Piloting

In practice, 61 Physics Education students who were attending evening sessions in the Balıkesir University were selected to complete the pilot version.

The pilot form of the questions provided spaces for students at the bottom of each page to make any additional comments about the question itself. After piloting was completed, responses were checked question by question and feedback used to improve questions.

2.3 Administering the Questions

After all improvements were made, the revised questions were administered to Physics Education students who were attending the morning sessions. Every student was informed about the aim of this research and asked to answer each question clearly. 80 Students (47 male and 33 female) responded to all the questions. 41 of the students were first year and 39 of them were final year students.

2.4 Analysis of Responses

In the analysis part of this study, a number of aspects of students' ideas about electromagnetic induction will be reported. All of the questions used in this study required explanatory written responses. A list of ideas used by students in response to each question has been generated and these ideas have been classified into mutually exclusive sets. Since each set refers to a particular aspect of the problem and each response can be constituted of different linked ideas this analysis technique has been chosen.

For this study, 80 responses for a representative sample of three questions have been analysed in detail to characterise students' understanding. This involved listing of the series of ideas, including low-level responses given. These ideas were then grouped together under a general category according to the kind of aspects contained. This was done for each of the three questions: Suspended Frame (Question 2), Dropping Coil (Question 4) and Conductive Rod (Question 5) analysed. It was attempted to make these general categories similar for ease of the comparison of the kinds of ideas used in answer to the different questions.

3. FINDINGS

3.1 Findings Obtained From Suspended Frame Question

This question aims to reveal whether or not students figure out the direction of magnetic field for a straight wire and they appreciate that the magnetic force is a consequence of magnetic field. Furthermore, they should be able to grasp the idea that magnetic force reduces with distance as it happens in the case of magnetic field. In responding to this question, students need to consider that magnetic field created by current on straight wire reduces with distance. Since magnetic force is proportional to B (F=B.i.l) force on lower section of frame, which is suspended above the straight wire and carries a current, is always bigger than upper section. By applying the right-hand rule it can be demonstrated that force on lower section is downwards whereas on upper section is upwards.

Table 3. Percentages of Students Giving Particular Kinds of Explanation in Response to Suspended Frame Question (n = 80).

Explanation	Percentage of Responses
Correct answer to multiple choice part	47.5
No explanation about the direction of force or field	43.8
Bigger current $\Rightarrow$ bigger force/effect	18.8
Increase in I $\Rightarrow$ increase in F (link F and I)	37.5
Right-hand rule to predict direction of magnetic field	3.8
Right-hand rule to predict direction of magnetic force	15.0
Magnetic field reduces with distance	7.50
Magnetic force reduces with distance	13.8
Force on upper side is less than force on lower side	6.3

* Note that the % column sums to more than 100% since students used more than one idea in their response. Shaded rows also show the incomplete or implicit explanations.

The multiple-choice section of the item was answered correctly by nearly half of the students. Their list of explanations and the percentages of responses in each category for suspended frame question are shown in the right column of Table 3.

Looking first at the scientifically unacceptable ideas, Table 3 shows that the largest proportion of students (43.8%) gave no explanation about the direction of force or magnetic field. They mainly said '*bigger current causes bigger effect*' (18.8%) or that '*increase in current i_2 causes increase in F*' by linking force and current (37.5%).

Turning now to other classes of response a small minority of students used the right-hand rule to predict the direction of magnetic field and only 15% predicted direction of force. This outcome suggests that most of the students did not know how or perhaps when to apply the right-hand rule. Only 7.5% of students mentioned the reduction of magnetic field with distance while about double that number mentioned reduction with distance for magnetic force. Five students predicted that '*force on upper side would be less than force on lower side*'.

3.2 Findings Obtained From Dropping Coil Question

This question is concerned with the phenomenon of flux change by dropping a circular coil between the poles of a magnet. It therefore aims to show how students conceptualise the induction of current through a magnetic field. Students need to appreciate that when the rate of change in velocity of frame is maximum, the induced voltage will be maximum. In that case maximum changes in flux lines and in time interval occur, the fact that induced voltage will be maximum should be realised.

The multiple-choice section of the item was answered incorrectly by 76.2% of the students. The list of some different types of explanations and the percentages of responses in each category for Dropping Coil question are given below.

Table 4. Percentages of Students Giving Particular Kinds of Explanation in Response to Dropping Coil Question (n = 80).

Explanation	Percentage of Responses
Correct answer to multiple choice part	23.8
No explanation about the flux change	56.3
Incorrect use of induction current	21.3
Induced voltage is proportional to B	46.3
Maximum number of field lines⇒maximum voltage	37.5
Increased induction current ⇒ increased voltage	7.5
Gravitational force⇒coil accelerated as time passes	3.8
Induced voltage linked to velocity of frame	18.8
Induced voltage is proportional to Δflux/Δt	8.8

* Note that the % column sums to more than 100% since students used more than one idea in their response. Shaded rows also show the incomplete or wrong explanations.

If we first glance at incomplete or scientifically unacceptable ideas in Table 4, it is interesting that more than half of the students (56.3%) were unable to give an explanation about the flux change by comparing four instants. About 21.3% of the sample used induction current incorrectly.

Turning now to other classes of response almost half of the responses (46.3%) predicted that induced voltage is proportional to B. The reason for this prediction was '*maximum number of field lines cause maximum induced voltage*' and stated by 37.5% of students. On the other hand, only 7.5% of the students attempted to write '*increased induction current causes increased voltage*'. Only three students considered the acceleration of coil due to gravitational force. The low proportion of students (18.8%) linked induced voltage to velocity of frame. Seven students proposed flux change per unit time interval in responsible for induced voltage.

3.3 Findings Obtained From Conductive Rod Question

This question involves the composition of ideas in former questions and relating the idea that a current carrying conductor in a magnetic field suffers from a magnetic force. By applying right-hand rule, students should be able to demonstrate that the force is rightwards. According to the Lenz's law, induced current opposite to the battery's should be created to increase flux lines passing through the area surrounded by the circuit.

The multiple-choice section of the item was answered correctly by nearly one in four students. The list of explanations, and the percentages of responses in each category for Conductive Rod question are provided in Table 5.

Table 5 shows that significant proportion (77.5%) of students made no or improper explanation of flux change linked to current i. 18.8% of students reasoned that length of rod and magnetic field are constant. They basically concentrated on uniform field to predict that there will be no change to current i which was scientifically unacceptable idea. Slightly more than half (52.5%) students appeared to have no appreciation of the direction of force.

Table 5. Percentages of Students Giving Particular Kinds of Explanation in Response to Conductive Rod Question (n = 80).

Explanation	Percentage of Responses
Correct answer to multiple choice part	23.8
No or improper explanation of flux change linked to current i	77.5
Length of rod and B are constant ⇒ no change to current i	18.8
Uniform field ⇒ no change in number of flux lines	18.8
No explanation regarding the direction of force	52.5
Right-hand rule to predict direction of magnetic field	3.8
Right-hand rule to predict direction of magnetic force	5.0
Rod moves rightwards ⇒ area of circuit decreased	38.8
Proper use of Lenz's law	10.0

* Note that the % column sums to more than 100% since students used more than one idea in their response. Shaded rows also show the incomplete or wrong explanations.

As a result of being unable to use right-hand rule, 3.8% of them made reference to the right-hand rule to indicate direction of magnetic field while 5.0% of them specified the direction of force. Moreover, 38.8% of students explained that '*rod moves rightwards and area of circuit is decreased*'. The number of students who used Lenz's law properly accounts for approximately ten percent of them.

Finally, a few of students responded at a particulate level. The analysis also indicated that over 50% of students' arguments were unacceptable or wrong. They mainly based their responses on assumptions due to the lack of knowledge.

4. RESULTS

In the light of the findings obtained from this study, results are drawn firstly by emphasising specific points emerged from each question. Thereafter comparison of common aspects across three questions will be outlined.

Firstly, most of the students were suffering from the improper use of right hand rule as it was evident from the poor prediction level of direction of force. Secondly, the reduction of magnetic field and force with distance seem to be problematic for students in suspended frame question. This might be the results of less emphasis given on the inverse proportion between magnetic field and distance during teaching and the lack of concrete demonstrations to show the reduction in the intensity of magnetic field which is an abstract notion and difficult to grasp for most students.

The greatest difficulty encountered was predicting the rate of flux change with time in the dropping coil question. Indeed, no students explicitly discussed the reason of maximum induced voltage due to the lack of interpretation ability. They were struggling to explain their answer according to formula $\varepsilon=\Delta\Phi/\Delta t$ but few of them considered the time factor.

The results of conductive rod question are also supported by Galili's study. Galili [15], administered paper and pencil tests to high school students and prospective teachers aged between 16 and 30. He investigated whether students were able to apply mechanics principles to electromagnetism problems. A series of tasks was set in this study and one involved a current carrying wire in the vicinity of two magnetic poles. Students were asked to show all the forces exerted on each component of the system. A striking feature was that only 3% of all students showed correctly a force applied to the magnet. No other study has been found except for the study of Galili on students' conceptions about electromagnetic phenomena.

Table 6. Comparison of the Percentages of Common Aspects for Three Questions.

Common Aspects	Q 2	Q 4	Q 5
Correct answer to multiple choice part	47.5	23.8	23.8
Scientifically unacceptable or other inappropriate responses	57.5	50.0	52.5
Acceptable explanation about Force, Flux or Magnetic Field	56.3	43.8	22.5
Correct explanations including right-hand rule or Lenz's law	20.0	10.0	18.8

* Note that some % columns sum to more than 100% since students used more than one idea in their response. Shaded row also shows the implicit or wrong explanations.

Table 6 shows that almost half of the students, (47.5%) gave correct answer for question 2. However, they were not successful for question 4 and 5 (23.8%) as for question 2. What is interesting is that just more than half of the responses included scientifically unacceptable explanations or other limited basic ideas due to the lack of knowledge. Responses in this category were amazing. For example, for question 5, students noted that '*the movement direction of rod should be given*'. In the same question they interpreted circuit as it is in an electric field. Even worse they tried to apply right-hand rule to predict direction of electric field which was totally wrong. Having been unable to apply right-hand rule forced them to say '*rod does not suffer from a magnetic force*' or '*uniform field and constant length of rod make no change to current i*'. In question 4, students adopted the idea that only in between the poles of magnet induced current or voltage can be maximum due to intensive flux lines. Finally, in question 2, they used left-hand rule to predict direction of force whereas we normally use left-hand rule to predict direction of force acting on negative charges not for conductive wires. They also believed that current on the straight wire creates an electric field. All of these are the most prominent mistakes made by students and cannot be accepted scientifically.

The total percentages of responses including acceptable explanation about the force, flux or magnetic field, decreases across the three questions, which suggest that aspects of the question context influence the extent to which students draw on some ideas. The '*simplest*' context appears to be the one which requires the identification of force whereas the converse case requires the identification of reaction force as oppose to magnetic force appears considerably more difficult to understand.

There was no question having more than 20% correct usage of right-hand rule or Lenz's law. The percentage of students giving correct usage in their responses ranges from 10% to 20%. In summary, the curriculum background of the students appears to have little effect on the proportion giving accepted answers to all three questions.

5. DISCUSSION AND CONCLUSION

It has been the researcher's assertion that educators should always bear in mind the question '*What is assessment for?*'. Today at any rate within the world of education itself there is a shift from summative functions of assessment towards formative functions [16].

During the construction, piloting, administration and data analysis stages of the questions it was appreciated that it is harder to design a good question, which is probing understanding effectively, than might be imagined. Question of '*What will I assess regarding the outcomes of this question?*' should be asked regularly to define purpose of assessment. Moreover, the collection of data with open questions should not be regarded as a '*simple*' method if used properly [17, 18]. It has been my experience that the more questions you prepare the more time and labour you need to code and analyse.

In this study, formative assessment is used for diagnostic purpose to judge current teaching and learning. One of the aims of this study was to investigate students' ideas about electromagnetic induction since a very limited research has been done in this area. The results of this study suggest that despite the attention is given to accepted ideas about electromagnetic induction only a small percentage of students are able to learn and give with confidence, these ideas. For example, some students adopted the idea that current creates an electric field. If the ideas retained by the students are to be taken into account, teaching cannot be considered as the '*telling*' or '*giving*' knowledge to students. It is obvious that the accepted ideas are the subject of teaching which helps students to reconstruct these ideas. The starting point of a teaching sequence in universities should then be accommodated ideas students bring with them.

Having revealed the ideas accommodated by students the role of the lecturer should be to diagnose and define the appropriate learning activities. Assessment of students should aid to this purpose and give constructive criticisms [19]. More opportunities should be given to encourage students to talk about their own idea and share them with their peers [20]. This will initiate teaching practice, made them aware about their own, other students or scientists' ideas. Thus by adding and modifying ideas rather than substituting, learning process will be the discrimination of their own ideas and accepted science ideas. Alternatively, relating abstract phenomena to a model used to understand idealisations can be an appropriate method for learning [21].

The implications of this study for the preparation of a new curriculum as a whole suggest reinforcement of relating concepts to daily life. For example, working process of relays or doorbells can be introduced to support theory. Then the more abstract concepts of electromagnetism and implicit understanding of them can be developed. If they are set in meaningful contexts, creative thinking and a deeper understanding can be obtained by the time students graduate. In addition, more lectures for student investigation, practical work and scientific debates including first discussion of students' own ideas, and later acceptable scientific ideas should be allocated [22]. Furthermore, every opportunity should be given to encourage and strengthen these ideas whenever topics involving magnetic field, force, flux, induction and so on are confronted in universities.

There should also be harmony between what is taught and what is assessed. This is necessary to reveal whether or not the required objectives are reached. Therefore, it would also be helpful to provide formative assessment instruments for diagnosis and formative feedback.

In this study, context of question 5 was covering question 2 and 4 and results were fairly satisfactory for response diagnosis of 80 students. The outcomes of these questions and acquired experience will be used for further studies. In further comprehensive studies any differences in boys versus girls and differences between first and final years will be investigated thoroughly for all questions.

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