

EFFECT OF FORMATIVE ASSESSMENT-BASED INSTRUCTION ON HIGH SCHOOL STUDENTS' CONCEPTUAL UNDERSTANDING OF BALANCE AND TORQUE

Nermin Bulunuz*, Mızrap Bulunuz**

ABSTRACT

The intent of this research is to evaluate the use of a formative assessment probe about balance and torque. The lesson was conducted with 52, 11th grade students studying in two physics classes at a state high school. A formative assessment probe was used at both the beginning and end of the study. After the students' prior knowledge about equilibrium and torque was determined, the demonstration experiment on this topic was applied to include the processes of Predict-Explain-Observe-Explain. At the beginning of the instruction most students believed that the weights of the objects on both sides were equal, though they in fact cannot be equal in the physical situation shown. After instruction, students showed significant increase on their conceptual understanding of the topic. Applications of this research include using formative assessment probes followed by experimentation in high school science classes as well as using such methods in teacher preparation programs.

Keywords: formative assesment, torque, balance, mass, weight.

BİÇİMLENDİRİCİ DEĞERLENDİRME UYGULAMALARININ LİSE ÖĞRENCİLERİNİN DENGE VE TORK KAVRAMLARINI ANLAMALARINA ETKİSİNİN DEĞERLENDİRİLMESİ

ÖZ

Bu çalışmanın amacı denge ve tork ile ilgili gündelik yaşamdan bir biçimlendirici değerlendirme sorusu kullanarak yapılan öğretim uygulamasını tanıtmak ve değerlendirmektir. Uygulama bir devlet lisesinde fizik dersinde iki şubede öğrenim gören toplam 52 tane, 11. sınıf öğrencileriyle gerçekleştirilmiştir. Veri toplama aracı olarak denge ve tork ile ilgili biçimlendirici yoklama sorusu çalışma başında ve sonunda kullanılmıştır. Öğrencilerin denge ve tork ile ilgili sahip oldukları bilgiler ortaya çıkarıldıktan sonra, bu konuda hazırlanan gösteri deneyi Tahmin-Açıklama-Gözlem-Açıklama süreçlerini içerecek şekilde uygulanmıştır. Öğrencilerin yapmış oldukları tahminlerin frekansı ve açıklamaların örnekleri sunularak değerlendirme yapılmıştır. Uygulama öncesinde öğrencilerin çoğunluğunun özdeş olmayan nesnelerin ağırlık merkezinde her iki taraftaki ağırlığın eşit olduğu düşüncesine sahip oldukları anlaşılmıştır, ancak bunun fiziksel olarak mümkün olmadığı çalışmada gösterilmiştir. Yapılan uygulama sonrasında, öğrencilerin denge ve tork konusundaki kavramsal anlama düzeylerinin karşılaştırılması sonucunda anlamlı bir fark bulunmuştur. Biçimlendirici değerlendirmeye dayalı öğretim uygulamalarının lise fen bilimleri dersleri ve öğretmen eğitimi programlarında yaygınlaştırılmasına yönelik çalışmaların yapılması önerilmektedir.

Anahtar kelimeler: biçimlendirici değerlendirme, tork, denge, ağırlık, kütle.

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* Assoc. Prof., Uludağ University, Faculty of Education, Department of Mathematics and Science Education, nermin.bulunuz@gmail.com

** Assoc. Prof., Uludağ University, Faculty of Education, Department of Elementary Education, mizrap@gmail.com

INTRODUCTION

Science Education Teaching Program (Standards) has adopted a measurement-evaluation approach aimed at monitoring and directing students in the teaching process, identifying and eliminating learning difficulties, and providing continuous feedback for meaningful and permanent learning (Ministry of National Education, 2013). According to the renewed Bloom taxonomy, assessment refers to quantitative and qualitative judgment based on evaluation criteria and standards (Anderson et al., 2001). However, in Turkey when it comes to assessment in educational practices, first, written or oral examinations and scores from these examinations come to mind. This shows that the quantitative dimension of assessment and ordering practices are dominant, whereas the qualitative dimension is ignored. Three types of assessment are defined in the literature: diagnostic, formative, and summative (Keeley, 2008; Tan, 2010). While the diagnostic assessments are used to determine students' prejudices, learning difficulties, and logic errors, the summative assessments are the academic achievement tests used to determine if the teaching has reached its goals and, if so, at what level (Keeley, 2008). Formative assessment is beyond grading, it is an assessment type that is interwoven with teaching and involves the process of finding out students' existing knowledge and shaping the teaching in this direction (Bulunuz & Bulunuz, 2013; Keeley, 2008).

According to Bransford, Brown, and Cocking (1999), students do not begin to learn science as a blank board waiting to be filled. If the students' prior knowledge is not taken into consideration, it is very difficult to reach conceptual understanding. For this reason, there is a need to plan and carry out the instruction based on students' existing knowledge (Metin & Birişçi, 2009). Formative assessment requires that teaching is based on data. The data are not simply the sum of the scores of a test. Data comprises evaluations of the interactions among the students, observations of their actions, and analyses of the answers students give to the questions posed in class. The use of formative assessment data helps teachers to make their

own assumptions, to explore their own questions about the teaching process, to discover the strengths of their students that have not been noticed before, to ask questions about their practice, to develop the education, and to improve new perspectives (Love, 2002). According to Sato (2003), defining, collecting, and using information during a lesson is a complex task.

There are two types of formative assessment: planned and interactive (Hall & Burke, 2003). Planned formative assessment is a form of formal or semi-formal assessment planned prior to the teaching to gather information about student thinking. The information required for assessment is gathered and interpreted by means of formative questions and strategies and techniques such as predict-explain-observe-explain. Interactive formative assessment usually has the potential to occur during student-student or student-teacher interactions in a coincidental or unexpected situation during an instructional activity. While interactive formative assessment is more difficult to plan, there may be opportunities to some degree during classroom observations, discussions, and sharing of ideas. Formative assessment is only one means of achieving a teaching or learning goal. According to Carlson et al. (2003), just like students analyze and use data collected while learning science, teachers should analyze classroom data that will support student learning and their own professional development and use findings that emerge.

Formative assessment allows students to question their own thoughts and compare them with their peers' thoughts. Previous knowledge and experiences that students have are used to give feedback to students in the teaching process. Formative assessment, according to Keeley (2008), helps providing feedback to students and shaping teaching, as well as contributing to the development of cognitive and profound thinking skills of students. In addition, with formative assessment, teachers have the opportunity to monitor teaching speed, identify possible conceptual misconceptions, take preventive measures against the problems that may occur in the learning process, and find more time to change and develop student ideas (Keeley, 2008).

There are many studies in the world that investigate the influence of formative assessment on the education and learning of students from primary school to university. For example, in their research with primary school teachers, Keeley and Harrington (2010) found that the use of formative inquiry questions contributed to issues such as teachers designing instruction, choosing activities, identifying students' ideas, and choosing the right methods for teaching content standards. In support of this finding, in their work with elementary school students, Trauth-Nare and Buck (2011) found that formative assessment reveals ways to support the academic needs of students.

The number of studies on formative assessment in Turkey is rather limited. The research studies have focused more on topics such as participating in the lesson, motivation, test anxiety, and academic achievement (Aydeniz & Pabuçcu, 2011; Büyükkarcı & Kağan, 2010; Ökten, 2009; Solgun, 2014). However, the number of studies evaluating formative assessment practices in science teaching is rather limited (Bulunuz, Bulunuz, Karagöz, & Tavşanlı, 2016; Bulunuz, Bulunuz, & Peker, 2014). In two studies (Bulunuz & Bulunuz, 2013, 2014) introducing formative assessment practices, it was observed that the prospective teachers participated enthusiastically with great interest in the applied formative inquiry questions. Bulunuz, Bulunuz, Karagöz, and Tavşanlı (2016) compared the achievements in standardized tests with the scores determined by using formative inquiry questions posed to identify the level of conceptual comprehension of middle school students in sinking and swimming topics. The results of the study showed that the scores from the standardized science test were higher than those from the formative inquiry questions. This result shows that students are successful in answering multiple-choice questions but have poor performance in formative inquiry questions measuring conceptual understanding, explanation, and interpretation skills. In another study, in their work with middle school students, Bulunuz, Bulunuz, and Peker (2014) showed that formative assessment practices, used in addition to the curriculum, provided a significant increase in students' understanding of basic physics concepts. It is underlined that

it is necessary to evaluate the existing knowledge of the students and to make connections between the concepts taught and real life.

Another study that examined students' conceptual understanding of inertia (Bulunuz & Bulunuz, 2016) found out that students actually know that objects that either stop or have constant velocity have inertia. But, these students have little understanding of the fact that objects that either accelerate or decelerate have inertia as well. As a result of formative assessment-based instruction, the students were able to understand that if a vehicle decelerator changes its direction have inertia. The results of the analysis of the research conducted in this area show that formative assessment would improve the ability of students to organize their own learning. These results support formative assessment-based program development efforts (Clark, 2012, 2015; Meusen-Beekman, Brinke, & Boshuizen, 2015).

In the related literature, it has been revealed that in relation to equilibrium and torque, learning difficulties are observed in obtaining balance in the horizontal and vertical directions, balancing in the non-symmetric situations, determining the vertical distance of the force, and displaying the force acting on the body (Akkaya, 2006; Rowlands, Graham, & Berry, 1998; Trumper & Gorsky, 1996). This research has two goals. The first goal is to reveal the prior knowledge that 11th grade high school students have about equilibrium and torque using planned formative inquiry questions; the second goal is to increase the students' level of conceptual understanding of equilibrium and torque by implementing planned formative assessment practices. According to the Ministry of National Education, the Board of Education, High School 11th Grade Physics Program (2013), students should structure the concept of torque by analyzing the rotation effect of the force. By utilizing the concept of torque, students are expected to be able to explain the equilibrium conditions of objects encountered in daily life. The content standards related to this subject at the 11th grade "Force and Movement" Unit are as follows:

11.1.8. Torque

11.1.8.1. Explains the torque (force momentum) from the effect of force and gives examples.

11.1.8.2. Analyzes the variables on which the torque is dependent and determines the direction of the torque vector.

a. The students are provided with opportunities to conduct experiments and use simulations to make conclusions about the variables on which the torque is dependent.

11.1.8.3. Presents daily life problem situations related to torque concept and produces solutions.

11.1.9. Equilibrium

11.1.9.1. Analyzes the equilibrium state of objects.

11.1.9.2. Presents daily life problem situations related to the equilibrium of forces and produces solutions.

11.1.9.3. Compare the location of mass and weight centers of objects.

a. Students are asked to make calculations to find the locations of mass and weight centers of everyday objects

b. Situations where the center of mass and gravity cannot be used in place of each other are emphasized.

The teaching of the concepts of force and motion in the 11th grade physics program is discussed in two dimensions. First, it is aimed for students to be able to demonstrate what variables torque and equilibrium depend on and secondly, students should be able to solve problems related to daily life applications.

ACTIVITY IMPLEMENTATION

In this study, case study method which is one of the qualitative research approaches is used. Case studies are the in-depth description and analysis of a situation or a limited system of real life, contemporary context or environment (Cresswell, 2013; Merriam, 2013; Stake, 2003). The focus of this study was to reveal the high school 11th grade students' knowledge about weight, center of gravity, and moment and to investigate the effect of teaching based on formative assessment method on their conceptual learning.

The participants of the study consists of 52 high school students who are studying in two different 11th grade classes during 2015-2016

academic year with 26 students in one class (17 girls, 9 boys) and 26 students in the other class (15 girls, 11 boys) at an Anatolian High School located in central Bursa, Turkey. Convenience sampling method was used in determining the participants of the study. The reason for selecting the convenient sample group is to prevent the loss of time and labor (Yıldırım & Şimşek, 2011). Both quantitative and qualitative data collection techniques were used in the study. In this way, it has been aimed to increase the validity and reliability of assessments by partially providing data diversification (McMillan & Schumacher, 2010). In the study, the quantitative data were students' scores that they received from their answers given in the two-step formative inquiry question and the qualitative data were the explanations that the students wrote in the open-ended part of the formative inquiry question. The formative inquiry question is adapted from the book "Uncovering student ideas in physical science" by Keeley and Harrington (2010). Below is a two-step formative inquiry question. The first step is aimed at revealing students' existing knowledge and prior experience about the concepts of equilibrium and torque by asking them to make predictions. In the second step, students are asked to make scientific explanations about their predictions. In this way, the forms of reasoning used by the students about the situation given in the question are determined. The answers of the students were analyzed using the rubric developed by Karataş (2003).

Let's Make Our Ideas Clear!

Below is a formative inquiry question consisting of two steps. In the first step, you will make a prediction and in the second step, you will explain your thoughts about the prediction that you made in the first step.

Log Cutting

Three woodsmen went to the forest to make wood from dried up trees. They found a long timber in the forest. They wanted to divide the timber into two equal pieces to carry them on their backs to the truck on the road. To equal the weight of the two parts, Hasan said: "Let's balance the log on a rock and cut it from the

balance point." There was a debate between them after balancing the log on a rock.

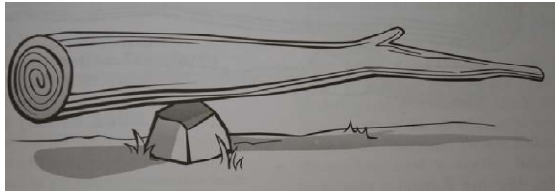


Figure 1. *The Log on a Rock*

Hasan: "The weight of both parts is equal."

Ahmet: "The part to the right of the equilibrium point weighs more."

Mustafa: "The part to the left of the equilibrium point weighs more."

Mark the right answer. Explain the rules or thoughts that you used to reach this judgment.

Let's Share Ideas!

Share your predictions and explanations with your classmate sitting next to you and other classmates in the class. If they have different judgments from your judgment, try to understand the reasons. Then, share and discuss your thoughts briefly in whole class or small groups. This will help you and your classmates to understand different points of views.

Exploration and Discovery Time

1. Which One is Heavier

As shown in the Figures 2 and 3 below, students could be engaged in an activity by bringing a branch and a scale into the classroom. This activity can be implemented in every socio-economic environment of the students since it contains simple and inexpensive materials that can be found almost everywhere. This ensures that the activity benefits students equally.

Materials: branch, dynamometer/scale.

Implementation: After the piece of the branch is balanced on an object, as in the Figure 2 below, the students are asked: "Which part of the branch intersected from the equilibrium point is heavier? Explain." Then the branch is cut from the equilibrium point and weighed on the scale. Students are asked to record their observations by writing and drawing. The same experiment can be done using a pencil with an eraser at one end, instead of a branch.

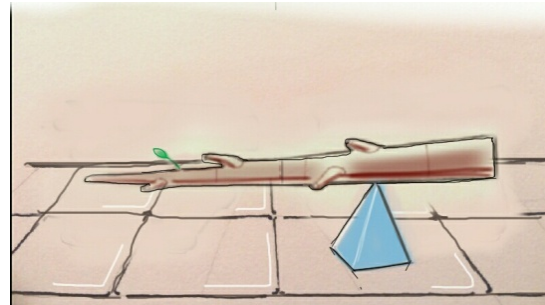


Figure 2. *Balanced Branch*

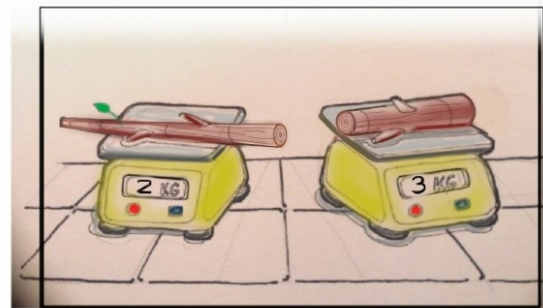


Figure 3. *Branches on the Scale*

Explanation:

Question 1: What is the reason that the shorter branch piece is heavier than the longer branch piece? Please explain.

Question 2: Instead of using a branch, if you divide a pencil that is not sharpened and does not have an eraser, into two pieces at its equilibrium point in the same way, what would be the weight of each piece? Discuss.

2. Who is Heavier at the Seesaw?

As presented in the animation below, two children, one of whom is slim and the other one is heavy, were playing on a seesaw in the park, but they did not seem to be balanced.

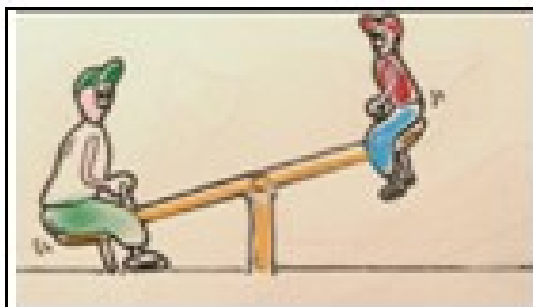


Figure 4. *Children on Seesaw*

Prediction and Explanation: Can these two children be balanced on seesaw? What do they need to do to play together? Please explain.

Observation: How did you get them to play together? Record your observations by typing and drawing.

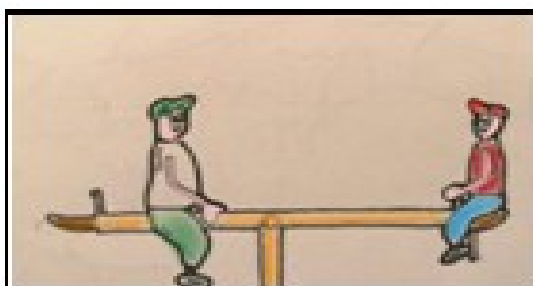


Figure 5. *Balanced Seesaw*

Explanation: As shown in Figure 5, the seesaw can be balanced. What is the reason for the heavy and slim child to be balanced on the seesaw?

Assessment: After these experiments and discoveries you have made, go back to the question of "Log Cutting" and look back at the answer you have given. Discuss with your classmates and make any necessary corrections to your predictions and explanations based on your discoveries and observations.

APPLICATION GUIDE FOR TEACHERS

Correct Answers and Scientific Explanations

Log Cutting. In this question, it is revealed that when a log, which is not symmetric, is in equilibrium on a support, the weight of the two sides will not be equal to each other. The correct answer is Mustafa's answer: "*The part to the left of the equilibrium point weighs*

more." Because more mass will be closer to the support point and the less mass should be away from the support point for equilibrium. Students may confuse the concepts of weight and equilibrium. Torque, force moment or rotation moment, is a tendency to turn around the support point under the influence of force. Whether the force is pushing or pulling, torque can be thought of as rotating an object around an axis. Mathematically, torque is equal to the cross product of the distance and the force vector. The weight of two parts can be equal when a symmetric ruler, an unsharpened pencil, a lath is cut from the equilibrium point. Since the amount of matter on both sides of the support point is the same, the weight of the two parts is equal. In the case of seesaw, the reason behind the balance of the fat and the weak child is not the equality of the masses. The equilibrium state is due to the fact that the products of the masses by the distances to the support point on both sides are equal to each other.

Things to Consider When Using Formative Inquiry Questions

- The correct answer to the formative inquiry question "Log Cutting" should not be immediately provided to the students. The process of accessing knowledge is as crucial as the knowledge itself for conceptual learning and mental development. Students should create knowledge in their own minds by doing, experiencing, discussing, and thinking like a scientist. For this reason, they should be able to express their ideas freely, justify their hypothesis, and develop evidence in order to refute their classmates' claims. Therefore, express to the students that "wrong" answers are important as well as "correct" answers in your lessons.
- In the question "Who is Heavier at the Seesaw," students are expected to make predictions based on their experience at playgrounds, to share their thoughts with classmates after explaining the reasons for their predictions. An in-class discussion environment should be created between students with the same opinion and those who disagree, then the phase of exploration and discovery should be introduced.

Things to Consider in the Exploration and Discovery Phase

Students use repetition and diversity in learning activities that attract them. Here, repetition is used to mean familiar, known, and similar; diversity is used to mean different and new. Repetition and diversity are indispensable for conceptual development, as they provide students with a constant connection between old and new, and known and unknown. It is very difficult for students to comprehend the concepts of weight, equilibrium, and torque, and the differences between these concepts without living various experiences about them. For this reason, the "Log Cutting" question has been prepared in the laboratory for students to learn through experimenting. In this activity, ask students to deduce and write about the masses of both parts when a branch and unsharpened pencil is cut through the center of gravity (see Figure 2). In addition, ask everyone to explain about the seesaw question in the park, which probably everyone experienced as a child (see Figure 4).

The animations used in the exploration and discovery phase were designed according to the Predict-Explain-Observe-Explain teaching technique. For this reason, students should be asked for their predictions and explanations when experiments are being carried out. This helps the teacher to identify the knowledge that the learner possesses while increasing the cognitive participation of the learner. The exploration and discovery phase is based on repetition and diversity. Accordingly, the basic principle adopted was providing as many diverse experiences as possible to the students about the topic or concept. The explanation phase includes reaching various inferences or making conclusions based on the students' observations and analysis of the data obtained during the discovery and exploration phase. After completing this phase, the students should be guided again to the formative assessment question "Cutting Log." Students should review their previous answer in the light of the new experiences. Encourage your students to discuss by sharing their mutual claims and evidence. For more experience with the center of gravity and an experiment that can be done at home, you may watch the video linked below:

<http://www.youtube.com/watch?v=G0NNRho b0PA> (Wayne, 2011).

Did You Know These?

- Archimedes, considered the first and the greatest scientist of the ancient world, was a mathematician, physicist, astronomer, philosopher, and engineer.
- At the same time, Archimedes was the first scientist to demonstrate equilibrium principles.
- "Give me a firm spot on which to stand, and I shall move the earth." Did you know that these words belong to Archimedes?

CONCLUSIONS and SUGGESTIONS

Students' answers to formative assessment probes on the concepts of equilibrium and torque were compared and scored. Pre-instructional and post-instructional scores obtained from students in the formative assessment probes were compared using the paired samples t-test. A significant difference was found between the mean of the pre-instructional scores ($M = 1.69$, $SD = 0.97$) and the post-instructional mean scores ($M = 2.69$, $SD = 0.73$) ($t(25) = 5$, $p < 0.05$). This result suggests that formative assessment with experimentation influences conceptual understanding of students.

The frequency analysis of the answers given by the students to the formative inquiry questions about equilibrium and torque was made. This analysis revealed that 70% of the students chose the "wrong" answer, Hasan: "The weight of both parts is equal." and 30% of the students chose the "right" answer, Mustafa: "The part to the left of the equilibrium point weighs more." Explanations that the students have made for this question can be grouped in three categories. Explanations of students who made incorrect choices and gave incorrect explanations can be grouped into two categories. Students who thought that the weight of both parts were equal, expressed that the weight was equal on both sides because the center of gravity of the log was at the equilibrium point. For example, a student named SB explained "I agree with Hasan because it is at the center of gravity. Therefore, the weight of two parts will be equal." Some of the students who responded incorrectly were trying to make an explanation

using whether the top of the supporting object (rock) was straight or not. For example, RE gave an explanation "If the surface of the rock is smooth, the weights are equal." (See Appendix 1 for the answer and explanation of this student). Similar results were found in a study aimed at introducing a formative assessment approach to prospective science teachers (Bulunuz & Bulunuz, 2013).

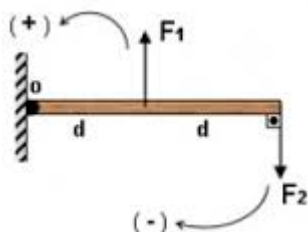


Figure 6. Force Momentum

In general, the torque or force momentum in physics textbooks is filled with problems based on the solution of an equation with one unknown ($F_1 \cdot d_1 = F_2 \cdot d_2$) as in Figure 6. Although the prospective teachers have solved such problems many times "correctly" in the physics courses they have taken in high school and college, they have difficulties in interpreting when they are asked about a problem chosen from real life (Bulunuz & Bulunuz, 2013). This indicates that they possibly memorized the rules. It shows they find the "right" results by sticking to formulas and this process indicates that they have ability in performing mathematical procedures but not a conceptual understanding of the concepts taught. Therefore, before solving problems involving mathematical manipulation skills and using algorithms, there should be more real life qualitative problems to improve students' ability to inquire, predict, observe, claim, discuss, and reason.

In order to evaluate the effects of teaching practices based on formative assessment, the same question was asked to the same group of students again after about six months, and their prediction and explanation performance were evaluated. According to the findings obtained from the second analysis, 81.5% of the students selected the "Mustafa" option which is the "right" answer. When the explanations of the students who answered correctly were examined, it was seen that they could reason about the problem in terms of both weight and length. For example, a student named BD

explained "Mustafa is right. Since the length of the part to the right of the equilibrium point is longer, its weight will therefore be less." (See Appendix 2 for a section from the answer of this learner). Some of the students explained their ideas by drawing and using the formula that multiplies weight by length. Some of the students answered correctly by directly explaining the meaning of torque. For example, another student named MY explained "I think that Mustafa is right. Because when we get torque according to that point, it's got to be in equilibrium. According to the formula force \times length = load \times length, left side is heavier." Another group of students did not write any verbal explanations for the open-ended part of the question, although they selected the "Mustafa" option and wrote the formula alongside (See Appendix 3 for a section from the answer of a learner responded this way).

The proportion of students who marked the Hasan option, which is the common misconception of the first assessment, dropped to 18.5% in the second assessment. The reason for the increase in the success rate may be the fact that the students made a miniature example of the formative assessment question in the classroom. However, even six months after the implementation the students could still remember the correct answer can be regarded as a demonstration that the practice done in the classroom was effective. In addition, the activity related to the balanced children on the seesaw and the related videos about this topic probably contributed to the students' understanding. From these results, there is a need to work towards spreading the approach of teaching based on formative assessment to the whole science program. In this research, there is no way to separate what students learned through the probe and what they learned from the experimentation following the probe. Additional research using a control group to compare experimentation with and without the probe would help clarify the value of using probes.

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Citation Information

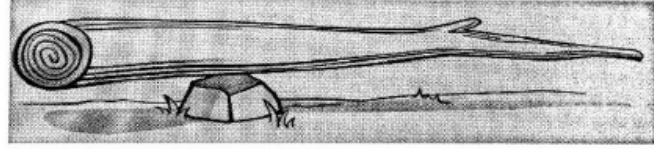
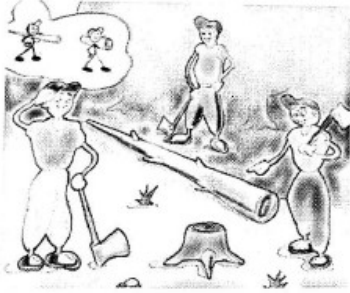
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Appendix 1

Incorrect Answer Sample of the "Hasan" Option from the Answer Sheet of a Student (RE)

TOMRUK KESME

Üç oduncu kurumuş ağaçlardan odun yapmak için ormana gitmişler. Ormanda uzun bir tomruk bulmuşlar. Yoldaki kamyonu kadar tomruğu sırtlarında taşımak için iki eşit parçaya bölmek istemişler. İki parçanın ağırlığının eşit olması için Hasan: "Tomruğu bir kaya üzerinde dengeleyip, denge noktasından keselim" demiş. Tomruğu bir kaya üzerinde dengeledikten sonra aralarında bir tartışma çıkmış.



Hasan: Her iki parçanın ağırlığı eşit olur. **X**

Ahmet: Denge noktasının sağındaki parçanın ağırlığı daha fazladır.

Mustafa: Denge noktasının solundaki parçanın ağırlığı daha fazladır.

En doğru cevabı işaretleyiniz. Bu yargıya ulaşmada kullandığınız kural ya da düşünceleri açıklayınız.

Eğer taşın üst yüzeyi düzgün ise ağırlıkları eşittir.

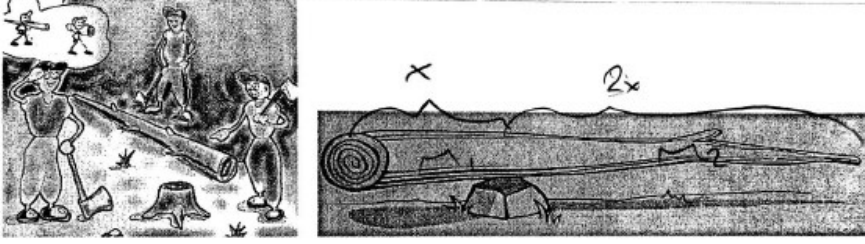
Translation of the student's handwriting: *If the surface of the rock is smooth, the weights are equal.*

Appendix 2

Correct Answer Sample of the "Mustafa" Option from the Answer Sheet of a Student (BD)

TOMRUK KESME

Üç oduncu kurumuş ağaçlardan odun yapmak için ormana gitmişler. Ormanda uzun bir tomruk bulmuşlar. Yoldaki kamyonu kadar tomruğu sırtlarında taşımak için iki eşit parçaya bölmek istemişler. İki parçanın ağırlığının eşit olması için Hasan: "Tomruğu bir kaya üzerinde dengeleyip, denge noktasından keselim" demiş. Tomruğu bir kaya üzerinde dengeledikten sonra aralarında bir tartışma çıkmış.



Hasan: Her iki parçanın ağırlığı eşit olur.

Ahmet: Denge noktasının sağındaki parçanın ağırlığı daha fazladır.

Mustafa: Denge noktasının solundaki parçanın ağırlığı daha fazladır.

En doğru cevabı işaretleyiniz. Bu yargıya ulaşmada kullandığınız kural ya da düşünceleri açıklayınız.

Mustafa haklıdır. Denge noktasının sağında kalan parçanın uzunluğu fazla olduğu için ağırlığı da bundan dolayı daha az olacaktır.

$$m_1 \cdot x = m_2 \cdot 2x$$

$$m_1 > m_2$$

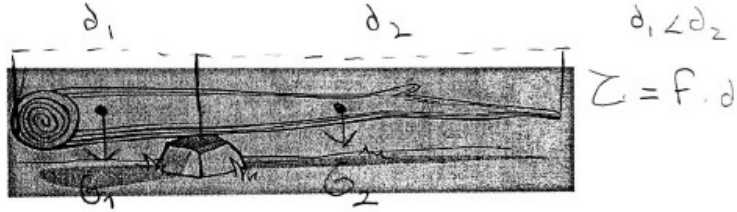
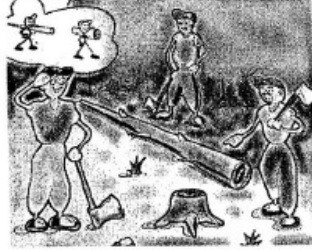
Translation of the student's handwriting: *Mustafa is right. Since the length of the part to the right of the equilibrium point is longer, its weight will therefore be less.*

Appendix 3

Correct Answer Sample of the "Mustafa" Option from the Answer Sheet of a Student Who Wrote the Formula but did not Make an Explanation

TOMRUK KESME

Üç oduncu kurumuş ağaçlardan odun yapmak için ormana gitmişler. Ormanda uzun bir tomruk bulmuşlar. Yoldaki kamyonu kadar tomruğu sırtlarında taşımak için iki eşit parçaya bölmek istemişler. İki parçanın ağırlığının eşit olması için Hasan: "Tomruğu bir kaya üzerinde dengeleyip, denge noktasından keselim" demiş. Tomruğu bir kaya üzerinde dengeledikten sonra aralarında bir tartışma çıkmış.



Hasan: Her iki parçanın ağırlığı eşit olur.

Ahmet: Denge noktasının sağındaki parçanın ağırlığı daha fazladır. X

Mustafa: Denge noktasının solundaki parçanın ağırlığı daha fazladır.

En doğru cevabı işaretleyiniz. Bu yargıya ulaşmada kullandığınız kural ya da düşünceleri açıklayınız. X
