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Seventh Grade Students' Mathematical Difficulties in Force and Motion Unit

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ABSTRACT Integration of science and mathematics as well as with other disciplines is overarching goal of science education. In spite of its importance, teachers have concerns about mathematical difficulties that their students encounter during their teaching. One of the most common subjects that students have mathematical difficulties was reported as physics. With this regard, the present study is aimed to investigate seventh grade students' mathematical errors in a physics related subject, specifically force and motion unit. We collected data from 129 seventh grade middle school students which were chosen conveniently throughout an open-ended questionnaire. The findings revealed that the students encountered difficulties in ratio and proportion and conversion of units, topics as well as ordering numbers while answering the questions in this unit. Implication for science courses was discussed.

Keywords *Force and motion, mathematical difficulties, integration, science, mathematics*

Yedinci Sınıf Öğrencilerinin Kuvvet ve Hareket Ünitesi'nde Yaşadıkları Matematiksel Zorluklar

ÖZ Fen-matematik disiplinlerinin entegrasyonu, fen eğitiminin önemli amaçlarından biridir. Fen-matematik entegrasyonun önemi vurgulanmasına rağmen, fen bilimleri öğretmenleri derslerinde sıklıkla matematiksel zorluklarla karşılaştıklarını belirtmektedir. Öğrencilerin matematik temelli zorluklar yaşadığı konulardan biri de fizik konularıdır. Buradan yola çıkılarak bu araştırmada, yedinci sınıf öğrencilerinin bir fizik konusu olan Kuvvet ve Hareket Ünitesinde yaşadıkları matematik temelli sorunların belirlenmesi amaçlanmıştır. Veriler, uygun örneklem yöntemi ile seçilmiş yedinci sınıf öğrencilerinden (*N*=129) açık uçlu sorular yardımıyla toplanmıştır. Bulgular, bu ünitede öğrencilerin oran-orantı ve birim çevirme gibi matematiksel zorluklar yaşadığını ortaya koymuştur. Bulgulara dayanılarak fen dersleri için çeşitli öneriler getirilmiştir.

Anahtar Kelimeler *Kuvvet ve hareket, matematiksel zorluklar, entegrasyon, fen, matematik*

GENİŞLETİLMİŞ ÖZET

Fen ve matematik alanlarının diğer alanlarla ilişkilendirilmesinin gerekliliği, bu tür ilişkilendirmelerin öğrencilerin kavram öğrenmelerini geliştirdiği yönünde araştırma sonuçları ile desteklenmiştir (Czerniak, 2007; Roehrig, Moore, Wang & Park, 2012; Wang, 2005). Çalışmaların ortak bulgusu olarak, fen ve matematik entegrasyonunun öğrencilerin başarısını (Hurley, 2001; Kıray ve Kaptan, 2012), motivasyon ve problem çözme yeteneklerini etkilediği (Offer ve Vasquez-Mireless, 1999; Venville ve diğerleri, 2004) rapor edilmiştir. Çetin ve arkadaşları (2015) öğrencilerin fen ve matematik başarıları arasında güçlü bir ilişki olduğu sonucuna varmışlardır. Farklı alanların entegrasyonunun öneminin artması, bu alanda yapılan çalışmaların sayısını etkilemiştir (Berlin ve White, 2005). Bu önem, ayrıca öğretmenler tarafından da sıklıkla dile getirilmiştir (Akinci, Uzun, & Kisoglu, 2015; Baskan, Alev, Karal, 2010; Frykholm & Glasson, 2005; Karaer, 2006; Kiray, Gok, Caliskan, & Kaptan, 2008; Koirala & Bowman, 2003; Riordain, Johnston, & Walshe, 2015). Başkan ve arkadaşlarının (2010) yaptıkları çalışmada, öğretmenlerin fen ve matematik entegrasyonunun öneminin farkında oldukları ancak bu entegrasyonu nasıl gerçekleştireceklerinin yeterince farkında olmadıkları vurgulanmıştır. Yine öğretmenler, fen kavramlarını öğretirken matematiksel zorluklar yaşadıklarını dile getirmişlerdir (Akıncı ve ark. 2015, Karaer, 2006, Venville ve ark. 2004). Çalışmalar ayrıca, öğrencilerin de fen kavramlarını öğrenirken matematiksel zorluklar yaşadıklarını vurgulamaktadır (e.g., Akatugba & Wallece, 1999; Basson, 2002; Bütüner ve Uzun, 2011; Corlu & Corlu, 2012; Howe, Nunes, Bryant, 2010a; 2010b; Roth ve Bowen, 1999). İlgili alan yazında rapor edilen zorluklar; birim çevirme (Kocaoğlu ve Yenilmez, 2010), oran-orantı (Dole ve Shield,2008), grafik okuma ve anlama (Capraro ve ark. 2005; Demirci & Uyanik, 2009; Roth ve Bowen, 1999), doğru-ters orantı (Akatugba & Walelce, 1999; Howe ve ark. 2010a, 2010b; Lamon, 2007) ve kesirli sayılardır (Lamon, 2007).

Matematiğin fizik derslerindeki rolü pek çok çalışmada vurgulanmıştır (Fumer ve Kumar, 2007; Li ve ark. 2002; Orton ve Roper, 2000). Yer bilimleri, biyoloji ve kimya dersleri ile kıyaslandığında matematiksel ifadeler, fizik konularının anlaşılmasında önemli rol oynamaktadır (Li ve ark. 2002). Türkiye'de yapılan çalışmalarda, fizik kavramlarının anlaşılmasında matematiksel işlemlerin önemi (Aycan ve Yumuşak, 2003) vurgulanırken, Şahin ve Yağbasan (2012) öğrencilerin fizik konularındaki başarısızlığının nedeni olarak matematik konularındaki yetersizliği olduğunu ifade etmiştir. Öğrencilerin fizik konularında yaşadıkları matematiksel zorlukların belirlenmesi, bu zorlukların giderilmesi açısından önemlidir. Buradan yola çıkılarak bu araştırmada yedinci sınıf öğrencilerinin kuvvet ve hareket ünitesinde yaşadıkları matematiksel zorlukların belirlenmesi amaçlanmıştır.

Araştırma nitel araştırma yöntemlerinden olan doküman analizi yöntemi kullanılarak gerçekleştirilmiştir (Yıldırım ve Şimşek, 2008). Öğrencilerin yaşadıkları matematiksel zorlukların belirlenmesi amacıyla araştırmacılar tarafından hazırlanan sorular kullanılmıştır. Öğrencilerden elde edilen cevaplar kullanılarak sıklık tabloları oluşturulmuş ve her bir soru ayrıca yorumlanmıştır. Araştırmaya 2012-2013 yılında devlet okulunda öğrenim görmekte olan ve uygun örneklem yöntemiyle seçilmiş 129 yedinci sınıf öğrencisi katılmıştır.

Araştırmada kullanılan açık uçlu soruların oluşturulmasında var olan çalışmalardan (Bütüner & Uzun, 2011; Yazarlar, 2014) ve fen bilimleri müfredatındaki kuvvet ve hareket ünitesindeki kazanımlar yararlanılmıştır. Daha sonra fen ve matematik alanında doktora yapan uzmanlar ve fen bilimleri öğretmenleri tarafından incelenen sorulara son hali verilerek uygulanmıştır.

Araştırmanın geçerliliği; meslektaş teyidi, uzman incelemesi ve nitel sonuçların nicelleştirilmesi gibi (Maxwell, 1998) yöntemlerden yararlanılarak gerçekleştirilmiştir. Araştırmanın güvenilirliği ise araştırmacıların rolünün, katılımcı özelliklerinin, veri toplama yöntemlerinin ve veri analizlerinin nasıl yapıldığının açıklanması (LeCompte ve Goetz, 1982) ile gerçekleştirilmiştir.

Araştırmanın bulguları incelendiğinde, öğrencilerin önemli bir kısmının (%74) sorulardan aldıkları toplam puanın 50'nin altında olduğu ve katılan öğrencilerin hiç birinin sorulan soruların tamamına doğru olarak yanıt veremediği görülmüştür. Bu sonuçlar, öğrencilerin sorulara cevap vermede zorluklar yaşadığını göstermiştir. Her bir sorunun daha detaylı olarak incelenmesi ile öğrencilerin yaşadıkları matematiksel zorluklar belirlenmeye çalışılmıştır. Öğrencilerin verdikleri cevaplar incelendiğinde, öğrencilerin önemli bir kısmının (%74) çizgi grafiğini yorumlayabildikleri**,** ancak çizgi grafiğini okuyup doğru orantı kullanarak cevap vermeleri gerekli olduğunda, bu oranın %27'ye düştüğü görülmüştür. Öğrencilerin neredeyse tamamına yakınının (%92) ise birim çevirmeyi yapamadıkları görülmüştür. İncelenen diğer sorularda ise öğrencilerin yarıya yakınının (%50) doğru şekilde iş formülünü uygulayamadıkları, %74'ünün ise potansiyel enerjilerine göre cisimleri sıralamada zorlandıkları görülmüştür. Ayrıca öğrencilerin dişli sorularına cevap verirken ters orantıyı kullanmada zorluklar yaşadıkları (%62 ve %84) görülmüştür.

Öğrencilerin kuvvet ve hareket ünitesinde yaşadıkları matematiksel zorluklar, ilgili alan yazında belirtilen matematiksel zorluklarla örtüşmektedir (Aycan ve Yumusak, 2003; Kararkuyu, 2008; Oon ve Subramaniam, 2011; Şahin ve Yağbasan, 201). Öğrencilerin çizgi grafiklerini yorumlamada yaşadıkları zorluklar (Capraro ve ark. 2005; Demirci ve Uyanik, 2009; Roth ve Bowen, 1999) tarafından da rapor edilmiştir. Ayrıca, Kocaoğlu ve Yenilmez (2010) kuvvet ve hareket ünitesinde yaşanan zorluklardan birinin birim çevirme olduğunu belirtmiştir. Bulgularımızdan biri olan öğrencilerin formülleri uygulaması ve doğru-ters orantı kavramlarında yaşanan zorluklar, yine ilgili alan yazında belirtilmiştir (Çorlu ve Çorlu, 2011; Karakuyu, 2008; Dole ve Shield, 2008; Howe ve ark. 2010a, 2010b; Lamon, 2007).

Sonuç olarak; formülleri uygulama, birim çevirme, grafik yorumlama, doğru-ters orantı gibi konularda öğrencilerin yaşadıkları matematiksel zorluklar, onların kuvvet ve hareket ünitesindeki düşük başarısının nedeni olabilir. Bu çalışma, neden-sonuç ilişkisine dayalı bir çalışma olmadığından, öğrencilerin kuvvet ve hareket ünitesinde gösterdikleri düşük başarının nedeninin matematiksel zorluklardan kaynaklandığını söyleyemeyiz. Fakat öğrencilerin matematiksel kavramları anlamadaki yetersizliklerinin onların fen kavramlarını anlamalarını etkilediğini söyleyebiliriz. Fen ve matematik konularını anlama ve başarı arasındaki ilişkilerin daha yakından incelenmesi için deneysel çalışmalara ve öğrencilerin fen ve matematik derslerindeki başarıları arasındaki ilişkinin daha derinlemesine incelenmesi için gözlem ve görüşmeler içeren nitel çalışmalara ihtiyaç vardır.

INTRODUCTION

The Principles and Standards for School Mathematics (National Council of Teachers of Mathematics [NCTM], 2000), the National Science Education Standards (National Research Council [NRC], 1996) and Next Generation Science Standards (NGSS Lead States, 2013) emphasized the connection between science and mathematics. This connection has also been highlighted in numerous studies (e.g. Basista & Mathews, 2002; Basson, 2002; Cetin, Corlu, Capraro, & Capraro, 2015; Frykholm & Glasson, 2005; Park-Rogers, Volkmann, Abell, 2007). Berlin and Lee (2005) reported that there had been an increase in the number of studies that focus on integration of science and mathematics in teaching and learning activities in their historical analysis during one hundred years (1901-2001). They, also, reported that there is an increasing emphasis on integrating science and mathematics education, particularly in teacher education programs.

Integration of disciplines such as science, mathematics and technology in teaching has long been aimed to deepen students' understanding by conceptualizing as well as broaden students' understanding (Czerniak, 2007; Roehrig, Moore, Wang & Park, 2012; Wang, 2005). As a common finding, studies indicated that integration of science and mathematics enhance students' achievement (e.g., Hurley, 2001; Kiray & Kaptan, 2012; Wang, 2005) as well as students' motivation and problem solving skills (Offer & Vasquez-Mireless, 1999) and helps students to make abstract concepts more concrete by using multiple representations (e.g. pictures, tables and graphs). Thus, they can develop deeper conceptual understanding in both disciplines (Park-Rogers et al., 2007). Integration of two disciplines **can also** enhance students' engagement in scientific tasks and problem solving skills (Venville, Rennie, & Wallace, 2004).

The importance of integration of science and mathematics has been also expressed by teachers as well as by pre-service teachers (Akinci, Uzun, & Kisoglu, 2015; Baskan, Alev, Karal, 2010; Frykholm & Glasson, 2005; Karaer, 2006; Kiray, Gok, Caliskan, & Kaptan, 2008; Koirala & Bowman, 2003; Riordain, Johnston, & Walshe, 2015). For instance, both science and mathematics teachers indicated that mathematics and science curricula have common principles and concepts. Furthermore, mathematics teachers stated that science should be related with mathematics for meaningful learning (Kiray et al. 2008). In another study, both physics and mathematics teachers appreciated the integration of science and mathematics but they were unable to explain how to connect these two disciplines (Baskan et al. 2010). On the other hand, they indicated the existence of problematic issues related to mathematics in their teaching (Akinci et al. 2015; Karaer, 2006; Venville et al., 2004).

Studies reported that students also struggle with mathematical difficulties (e.g., Basson, 2002; Bütüner & Uzun, 2011; Howe, Nunes, Bryant, 2010a; 2010b; Roth & Bowen, 1999). The reported difficulties were converting units (Kocaoglu & Yenilmez, 2010), ratio and proportion (Dole & Shield, 2008), understanding and interpreting the graphs (Capraro, Kulm, & Capraro, 2005; Demirci & Uyanik, 2009; Roth & Bowen, 1999), proportional concepts (Akatugba & Wallece, 1999; Howe et al. 2010a, 2010b; Lamon, 2007), computational fluency (Corlu, Capraro, & Corlu, 2011; Geary et al. 1999) and intensive quantities which combine direct and inverse proportion (Howe et al. 2010a, 2010b; Lamon, 2007) and fractions (Lamon, 2007).

The role of mathematics in science domains especially in physical science has been emphasized by Furner and Kumar (2007). The dependency of physics on mathematics was also referred in TIMMS data (Li, Shavelson, Kupermintz, & Ruiz-Primo, 2002). Algebra and data representation were reported as important predictors of physics domain when compared to other science domains including biology, earth science and chemistry (Li et al. 2002). Akatugba and Wallece (1999) indicated that physics concepts such as force, acceleration and pressure require a better understanding in mathematics including proportional reasoning.

On the other hand, students' mathematical difficulties in physics concepts have been well documented. For instance, Basson (2002) reported students' difficulties in mathematics were transferred to physics concepts such as force, velocity and acceleration. Some of the mathematical difficulties in physics unit (force and motion unit) were determined as drawing and interpreting graphs, ratio and proportion, and unit conversion problems (Bütüner & Uzun, 2011). Also intensive quantities such as density (directly proportional to mass, inversely proportional to volume) or speed (directly proportional to distance, inversely proportional to time) were reported as concepts that students had conceptual difficulties (Howe et al. 2010a, 2010b). In an earlier study, investigating students' difficulties in physics, Aycan and

Yumusak (2003) reported that students' difficulties in physics were caused by the abstract nature of subject and the inclusion of mathematical computational skills. The role of mathematical formulas and computations in physics were also reported as a barrier in understanding physics by Karakuyu (2008). Exploring senior secondary school physics students' use of proportional reasoning while solving physics tasks, Akatugba and Wallece (1996) reported that students' lack of awareness about proportional reasoning and the inconsistency between the concept of proportional reasoning and their everyday life experiences hindered their use of proportional reasoning while solving physics tasks. In a similar manner, Corlu and Corlu (2012) reported that candidate physics teachers had difficulties in applying formulas into physics problems. Investigating college students' difficulties in understanding physics, Sahin and Yagbasan (2012) reported that students' lack of understanding in physics concepts were related with their incompetence in mathematics. The abstract nature of physics was also emphasized by Oon and Subramaniam (2011). The authors emphasized that the competency in mathematics was associated with better understanding in physics concepts. Oktay Ciminli-Sülün and Sanalan (2014) also highlighted the role of mathematics in force and motion unit in their study. Specifically, they investigated science teachers' mathematics teaching skills while teaching velocity concept in sixth grade. They reported that the teachers perceived their skills in using mathematics while teaching velocity as sufficient. While science teachers perceived themselves as sufficient in using mathematics while teaching physics contexts such as velocity, other studies in both national and international contexts (e.g., Oon & Subramaniam, 2011; Sahin & Yagbasan, 2012) reported that students' difficulties in physics concepts are related with their lack of competence in mathematics.

Students' reported difficulties can be handled by integrating science and mathematics as Westbrook (1998) reported. This integration will also enhance students' concept learning in physics. Czerniak, Weber, Sandman, and Ahern (1999) emphasized the importance of research in understanding the actual benefits of integration. On the other hand, students' inadequacy with respect to skills and knowledge in mathematics has a negative effect on their understanding of physic concepts as Basson (2002) indicated. Since physics is a mathematically based subject as Orton and Roper (2000) stated, it is important to determine students' specific mathematical difficulties in this subject. In this regard, this study can help to reveal students' mathematical errors in interpreting graphs, ratio and proportion, unit conversion, and applying formulas in force and motion unit. For this purpose, we aimed to investigate seventh grade students' mathematical difficulties while dealing with the questions in force and motion unit.

METHOD

This study was designed by using qualitative methods, namely document analysis. Document analysis is a useful method to investigate intended phenomena or research questions by analyzing any kind of written documents such as textbooks, public records, curriculum directives, diaries, letters, exam paper (Merriam, 2009; Yildirim & Simsek, 2008). Using documents in a study can be better source of data when compared to interviews or observations because of providing participant-generated data on a specific subject (Merriam, 2009). However, using documents in a study could have limitations as well as strengths (Merriam, 2009). For instance, the documents that are not generated for research purposes could not be useful or understandable to the investigator (p.154). Thus, we preferred to use a researcher-generated document. We generated a questionnaire in line with our research question and examined participants' answers in these specifically generated questions. The documents generated by researchers also can be as a potential source for the purpose of investigation (Merriam, 2009). The document used in this study is *researcher-generated documents* as Merriam (2009) identified. We adopted this approach in order to determine students' mathematical errors in force and motion unit. Thus, we generated a questionnaire and sought information about students' common mathematical errors in force and motion unit by analyzing students' written answers about given questions.

Data collection and analysis is a primary concern of a qualitative study as LeCompte and Goetz (1982) indicated. Replicability of a study is not possible without precise identification and a good description of the strategies to collect data (Le Compte & Goetz, 1982). Thus, we conducted a literature review including previous conducted studies and objectives of science curriculum regarding force and motion unit and examined teachers' questions in this unit in a previous study (Cebesoy & Yeniterzi, 2014). Therefore, we were aware of the teachers' possible types of questions in this unit. We used researcher-generated questions to gather much detailed and rich information from students' answers.

After data collection procedure, we quantized our findings. Quantizing of qualitative data is a common interpretation technique known as counting method for determining and comparing the frequencies of codes and categorizes (Miles & Huberman, 1994). In order to examine students' mathematical errors, we constructed frequency tables regarding students' answers and interpreted each question.

Participants

A total of 129 seventh grade students in a public middle school voluntarily participated in the study. Because of financial and time constraints, the school was chosen conveniently. Data was collected throughout 2012-2013 spring semester.

Instruments

To examine the research question of the present study, an open-ended questionnaire which consisted of eight items regarding the objectives of force and motion unit was developed. These questions required mathematical knowledge to be solved. The questions were determined based on a) the science teachers' previous exam questions which were previously determined by Cebesoy & Yeniterzi (2014) and b) the reported mathematical difficulties in previous studies (e.g., Butuner & Uzun, 2011). In addition, the objectives of science curricula was taken into consideration during this process. After taking expert opinions from science and mathematics specialists and science teacher, the revised questionnaire was administrated to all students. The number of questions and the mathematical difficulties was presented in Table 1.

Table 1. Number of Questions with Respect to the Mathematical Difficulties

Related mathematical difficulty	Question numbers
Reading graph	1, 3
Direct proportion	2
Inverse proportion	7, 8
Ratio	2, 3
Unit conversion	3, 4
Using formulas	4, 5, 6
Ordering	5, 6

Validity

Validity in **a** qualitative research can be defined as "the correctness or credibility of a description, conclusion, explanation, interpretation or other sort of account" (Maxwell, 1996, p. 87). Some procedures such as searching for discrepant events, triangulation, feedback, member-check, rich data, quasi-statistics and comparisons were suggested to increase the credibility of a qualitative research by Maxwell (1998). As it was not possible to ensure all the suggested procedures, in this study, we tried to ensure the validity of study by adopting member-check, feedback and quasi-statistics procedures.

Member-check: Member check is a systematical way to get feedback about your conclusions from participants with, which is an important way to prevent misinterpretation of the meanings (Maxwell, 1998). To ensure this, the data gathered was coded by each researcher independently and then the coded data was compared to the other researcher's' coding in order to avoid misinterpretations between coders.

Feedback: Seeking feedbacks from a variety of people who are familiar to the setting or context that you are studying with could be a useful strategy to prevent researcher biases. Thus, we got feedback from a science and a mathematics experts who were PhD candidates and were specialized about both science and mathematics curricula and a science teacher about the content of the questionnaire.

Quasi-statistics: The results of qualitative studies could be presented with quantitative components which help researchers to "asses the amount of evidence in your data that bears on a particular conclusion" (Maxwell, 1998; p.95). For instance, tables and graphs and distribution of the observational and interview data could be used to support the conclusions (Maxwell, 1998). Based on this, we also used tables while interpreting the questions in the questionnaire.

Reliability

LeCompte and Goetz (1982) defined reliability as "the extent which studies can be replicated" (p.35). Establishing reliability for a qualitative study could create a problem because of nature of data and research process (LeCompte & Goetz, 1982). The external and internal reliability of the study were ensured as explained below:

The external reliability in qualitative studies can be ensured by handling researcher status position, informant choices, social situations and conditions, analytic constructs and premises and methods of data collection and analysis (LeCompte & Goetz, 1982). We tried to ensure some of the premises to increase the external reliability of our study as explained below:

Researcher status position: It is important to explain the researchers' role and positions in a qualitative study to ensure external reliability (LeCompte & Goetz, 1982). We informed the teachers who voluntarily wanted to take part in the study about the aim of the study. We preferred to be not at the class in order to prevent students' possible reactions to new people. The teachers applied the questionnaire to their students during their course.

Informant choices: Another important point in qualitative studies is to identify the informant who provides data (LeCompte & Goetz, 1982). We chose a school among a group of schools which had similar socioeconomic status (SES) based on our time and access constraints as well as voluntary participation of teachers for the study. We chose a school which had middle to low SES students.

FINDINGS

In the first part of this section, the findings regarding students' total test scores were presented. In the second part, students' correct, incorrect, and partial answers in each question were presented with frequency tables. The common mathematical errors found in force and motion unit were discussed.

Investigation of seventh grade students' total test scores in force and motion unit; In this part, students' total test scores in force and motion unit were presented. Students' correct answers were scored as 10 points, while students' incorrect answers were scored as 0 points. When students' total scores were computed, a student who correctly answered all eight questions could be given a maximum of 80 points (10 points for each). To make clear interpretations, scores were converted from out of 80 points to out of 100 points. Then the test scores were grouped and the total number of students in each test score group was determined. The students' total scores in each group were presented in Table 2.

Table 2. Students' Total Scores in Force and Motion Unit

Scores (Grouped)	Total number of Participants	Percentage (%)	Cumulative percentage (%)
91-100	0	0	100
81-90	1	0.78	100
71-80	8	6.20	99.22
61-70	10	7.75	93.02
51-60	14	10.85	85.27
41-50	13	10.08	74.42
31-40	9	6.98	64.34
21-30	11	8.53	57.36
11-20	43	33.33	48.83
0-10	20	15.50	15.50

As indicated in Table 1, majority of students' total scores were found to be 50 and under 50 (74.4%). In other words, only a quarter of the students scored over 50 points. That means majority of students did not answer half of the questions correctly. More interestingly, none of the students could correctly answer all the questions in the test. Only one student was able to obtain a score between 81 and 90 points. Besides, 15.5% of the students answered only one question or none of the questions correctly. Furthermore, more than a quarter of the students received a score of 20 or less points. Overall, these findings yielded that students had difficulties in answering the questions in force and motion unit. As these questions required some mathematical knowledge in their solution, we concluded that students encountered mathematical difficulties during solution of questions in the questionnaire. Thus, we further analyzed students' answers with respect to mathematical errors.

To categorize students' mathematical difficulties in force and motion unit, each question was further examined in detail and difficulty categories were revealed according to the structure of the questions.
Students' mathematical difficulties in force and motion unit; In this part, students' mathematical difficulties with respect to each question were examined and findings were represented by using frequencies and tables.
Students' mathematical difficulties in Question 1: The relationship between length and mass of a spring was asked for the purpose of investigating students basic graph reading skills specifically reading line graphs in the first question (see Appendix for this question given as a sample). The number of students who incorrectly answered the question and the percentage of incorrect responses was presented in Table 3.

Table 3. The Number of Students' Incorrect Answers in Question 1

	Related mathematical difficulty
	Reading graph
Number of students with incorrect answer	34
Percentage (%)	26

As seen from Table 3, more than a quarter (26%) had difficulty in reading and interpreting the given line graph. That means 74% of the students were able to interpret the line graph in given question and correctly answered the question.
Students' mathematical difficulties in Question 2: The second question investigated whether students could correctly use ratio and proportion (specifically direct proportion) after reading line graph of a spring as a follow up for the first question. The number of students who incorrectly answered the question and the percentage of incorrect response were presented in Table 4.

Table 4. The Number of Students' Incorrect Answers in Question 2

	Related mathematical difficulty	
	Reading graph	Direct proportion
Number of students with incorrect answer	94	94
Percentage (%)	73	73

As seen from the table 4, when the question got complicated and consisted of several parts (reading line graph and using direct proportion in this case) unlike the first question (just required reading and interpreting line graph), majority of students had more difficulties in the question (73%). As the question got complicated, the number of students' incorrect answers was increased. The students, who could not correctly read line graph, were not able to solve second question and its parts.
Students' mathematical difficulties in Question 3: Third question included three parts as a combination of rate-ratio, unit conversion and reading line graphs as a follow up for first and second question. As the question got complicated, the number of students who incorrectly answered the question was increased. Close examination revealed that 95 students could not answer any part of the question (regarding reading line graphs, rate-ratio and unit conversion). Additionally, while 23 students answered this question regarding rate-ratio step and reading line graph steps, they could not considered the unit conversion part (centimeter to meter conversion). Only nine students out of 129 students correctly handled all the parts of questions and reached the correct answer. It can be concluded that the most difficult part of question that students encountered was the unit conversion part. 118 out of 129 students (91.5%) could not convert the units. Even unit conversion was learned as an objective of fourth grade mathematics curriculum, great majority of seventh grade students had difficulty in converting units. This may be caused because of the students' being unaware of the unit that was asked in the question or not correctly doing first steps of the question.
Overall, when the first three questions interpreted together, we concluded that as the question got complicated and included more than one step in its solution, the number of students that were able to correctly answer the question slightly decreased.
Students' mathematical difficulties in Question 4: Fourth question consisted of two parts as applying the work formula and converting unit from km to meters. The number of students who incorrectly answered the question and the percentage of incorrect response were presented in Table 5.

Table 5. The Number of Students' Incorrect Answers in Question 5

	Related mathematical difficulty	
	Unit conversion	Using formula
Number of students with incorrect answer	129	65
Percentage (%)	100	50

In this question, nearly half the students could not apply work formula. In addition, all the students could not convert units. This finding is consistent with the findings of third question indicating students' difficulties in converting units were common regardless of question type. Even unit conversion was learned and as an objective of fourth grade mathematic curriculum, great majority of seventh grade students had great difficulty in unit conversion in related questions. Only small number of students could correctly convert units (for instance, from km to meters).

Students' mathematical difficulties in Question 5: In fifth question, students were asked to order three different objects which have different masses and different heights after computing their potential energies. The number of students who incorrectly answered the question and the percentage of incorrect response were presented in Table 6.

Table 6. The Number of Students' Incorrect Answers in Question 5

	Related mathematical difficulty	
	Using Formula	Ordering
Number of students with incorrect answer	98	96
Percentage (%)	76	74

Majority of students were unable to apply formula to compute the potential energies of objects (76%) (See Table 6). A similar percentage (74%) was also unable to correctly order the given objects. Less than a quarter (16%) could correctly apply potential energy formula and order.

Students' mathematical difficulties in Question 6: In sixth question, students were asked to order three different vehicles which have different masses and different velocities after computing their kinetic energies. A great majority of students were unable to apply formula to compute the kinetic energies of objects (94%) (See Table 7). Relatively fewer students were (78%) also unable to correctly order the kinetic energies of given vehicles. 6 students out of 129 total participants correctly answered both part of question (using formula and ordering).

Table 7. The Number of Students' Incorrect Answers in Question 6

	Related mathematical difficulty	
	Using Formula	Ordering
Number of students with incorrect answer	121	100
Percentage (%)	94	78

When the questions that required ordering after application of formulas in related questions (Question 5 and 6) were interpreted together, it was evident that even most students knew the formulas, whereas they had difficulties in applying them and then in ordering based on their findings. This difficulty in ordering and applying formulas in force and motion unit were not seen in previous studies (e.g., Butuner and Uzun, 2011).

Students' mathematical difficulties in Question 7 and Question 8: In seventh question, three gears which are connected were presented. Students were asked to use inverse proportion to calculate the number of turn of a gear by using another gear's number of turns and teeth. More than half of the participants (62%) could not correctly answer the questions (see Table 8). On the other hand, 49 students could correctly use inverse proportion.

Table 8. The Number of Students' Incorrect Answers in Question 7

	Related mathematical difficulty
	Inverse proportion
Number of students with incorrect answer	80

Percentage (%)	62

As a follow up for the seventh question, the last question investigated whether students could correctly use inverse proportion when calculating the first gears' number of turns by using third gears' number of turns. The number of students who incorrectly answered the question and the percentage of incorrect response were presented in Table 9.

Table 9. The Number of Students' Incorrect Answers in Question 8

	Related mathematical difficulty Inverse proportion
Number of students with incorrect answer	108
Percentage (%)	84

Findings indicated that a great majority of students (84%) could not correctly answer the question. In contrast, only a small number of students correctly used inverse proportion. Based on the findings of these questions (Question 7 and 8), we came up a conclusion that students had difficulties in regarding ratio and proportion concept (direct and inverse proportion). Although students learned ratio and proportion in previous years (ratio and proportion concept is an objective in 6th grade mathematics curricula) and use ratio and proportion concept in other science subjects, there were unable to use direct and inverse proportion.

DISCUSSION

We found that seventh grade students had difficulties in force and motion unit. The studies in the literature that examined students' difficulties in physics concepts (e.g., Akatugba & Wallece, 1999; Aycan & Yumusak, 2003; Corlu & Corlu, 2012; Kararkuyu, 2008; Oon & Subramaniam, 2011; Sahin & Yagbasan, 2012) concluded that student' lack of understanding in mathematics concepts caused these difficulties. We also, came up a similar conclusion as students showed mathematical difficulties in their answers in force and motion unit. The close examination revealed that while most of the students were able to interpret line graphs, this number decreased as the question got complicated and included several steps in its solution. Most of the students were unable to answer the question that includes both interpretation of line graph and using direct proportion. The difficulties in interpreting the graphs (Capraro et al. 2005; Demirci & Uyanik, 2009; Roth & Bowen, 1999) as well as proportional concepts (Akatugba & Wallece, 1998; Howe et al. 2010a, 2010b; Lamon, 2007) was also reported in the studies that investigated students' difficulties in physics. The reason of students' difficulties in proportional concepts was explained as students' being unaware of use of proportional concepts including ratios and proportions in solving physics tasks (Akatugba & Wallace, 1999). In addition, we found that students had difficulties in applying formulas. This finding was in line with the literature that reported students had difficulties in applying formulas into physics problems (Corlu & Corlu, 2012; Karakuyu, 2008). Even science context is appropriate for developing and fostering computational fluency (Corlu et al. 2011), the students in our study showed very low achievement in the questions which included both mathematical computation skills and mathematical interpretation.

We found that unit conversion was the most problematic point for students. This finding was in line with Butuner and Uzun's (2011) study that reported science teachers' experienced difficulties in teaching concepts in force and motion unit. In their study, science teachers indicated that drawing and interpreting graphs, ratio and proportion, and unit conversion were reported mathematical difficulties in force and motion unit (Butuner & Uzun, 2011). Similarly, Kocaoğlu and Yenilmez (2010) reported students' difficulties in converting units. Specifically, we found that students had severe difficulties in unit conversion. Only very few students were able to convert the units (for instance, from km to meters). This was an interesting result because unit conversion had been taught at primary grades. Even unit conversion was learned and as an objective of fourth grade mathematic curriculum, great majority of seventh grade students had great difficulty in unit conversion in related questions.

In addition to these findings, we revealed other mathematical difficulties including applying the formula, ordering, ratio and proportion in force and motion unit. While students' difficulties in using mathematical formulas (Corlu & Corlu, 2012, Karakuyu, 2008) and ratio and proportion including direct and inverse proportion (Akatugba & Wallece, 1999; Dole & Shield, 2008; Howe et al. 2010a, 2010b ; Lamon, 2007) were reported in literature, ordering and applying formulas in force and motion unit were not widely investigated in previous studies (e.g., Butuner and Uzun, 2011). While ratio and proportion was taught at seventh grade mathematics classes, direct and inverse proportion were subject of seventh grade mathematics curriculum. Besides having difficulties in ratio and proportion which was taught in previous years, seventh grade students had confusions in direct and inverse proportion topics which they had just learned. Even though these concepts were given in sixth and seventh grades, we found that seventh grade students still had difficulties in these concepts.

As a conclusion, we can conclude that students' experienced difficulties in mathematics such as applying formulas, converting units or understanding and interpreting graphs may explain their low achievement in science. As this study was qualitative in nature, we did not aim to generalize our findings to all seventh grade students. Also, as this study was not a causal-comparative study that explores the students' low achievement in science whether caused by mathematics or not, we could not say that students' difficulties in science specifically force and motion unit was caused by their low competence in mathematics. But we can conclude that their incompetence in mathematical concepts such as ratio and proportion, unit conversion, basic mathematical computational skills may influence their understanding in science concepts. As Cetin and his colleagues (2015) found strong relationship between students' mathematics and science achievement, it is needed to explore this relationship by using multiple methods. To further analyze the relationship between competence in mathematics and understanding in science, it is needed to conduct experimental studies including implementations as well as more qualitative studies including semi-structured interviews and classroom observations.

Implications

As previous studies reported that integration of science and mathematics enhance students' achievement (e.g., Hurley, 2001; Kiray & Kaptan, 2012; Wang, 2005), students' motivation and problem solving ability (Offer & Vasquez-Mireless, 1999) and helps students to make abstract concepts more concrete, integrated curricula for science and mathematics might be useful for developing students' understanding in both disciplines as well as increase their achievement. While developing integrated curricula for science and mathematics, the role of content knowledge, pedagogical content knowledge (Frykholm & Glassom, 2005) and integrated teaching knowledge (Corlu, Capraro, & Capraro, 2014; Corlu, Capraro, & Çorlu, 2015) should be taken into consideration.

In order to increase students' motivation and academic achievement in both disciplines, an integrated teacher education program that consider the importance of integration of both disciplines is needed. Berlin and White (2012) indicated although there was integrated science and mathematics methods course approach, there is relatively few teacher preparation or enhancement programs for elementary and middle school levels. So, both development and implementation of these preparation and enhancement programs is strongly needed. In Berlin and White's (2012) 7-year mathematics-science and technology program for pre-service teachers, they reported regardless of the certification area, teachers showed positive attitudes and perceptions related to the value of the integration of mathematics, science, and technology education over all seven years of the program. Thus, adopting this kind of programs in pre-service teacher education programs may be helpful in developing pre-service teachers' appreciation of integration of mathematics and science as well as other disciplines. Also, both pre-service and in-service teachers that appreciate the role of collaboration and teamwork with their colleagues in numerous studies have been reported (Berlin & White, 2012; Frykholm & Glasson, 2005; Riordain et al. 2015). As Berlin and White (2012) proposed, this kind of program might be helpful in increasing the implementation of interdisciplinary teaching and learning activities. Riordain et al. (2015) reported that teachers have positive views about the benefits of integration with respect to students' learning and motivation in their study. This positive view of teachers may be helpful in designing and implementing integrated science and mathematics lessons.

As Berlin and White (2012) reported in their historical analysis of integration for one hundred years, there is a need for empirical based research about integration of science and mathematics. Thus, another important implication may be increasing the number of empirical based research about the integration of science and mathematics. The different forms of integration proposed by Hurley (2001), sequential (science and mathematics are planned sequentially), parallel (science and mathematics are planned and taught at the same time), partial (the two disciplines are partially taught together and partially taught separately), enhanced (while on of the disciplines is the major discipline of instruction, the other is used throughout the instruction) and total (two disciplines are taught evenly) forms can be employed in these kind of empirical research studies. A meta-analysis of 31 studies by Hurley (2001) revealed that science achievement is more apparent in either enhanced (mathematics used to enhance science) or total (mathematics and science totally integrated) integration models. Thus, enhanced and total integration models can be used in these empirical research studies.

REFERENCES

Akatugba, A. H., & Wallace, J. (1999). Sociocultural influences on physics students' use of proportional reasoning in a non-western country. *Journal of Research in Science Teaching, 36*(3), 305-320.

Akinci, B., Uzun, N., & Kisoglu, M. (2015). Fen bilimleri öğretmenlerinin meslekte karşılaştıkları problemler ve fen öğretiminde yaşadıkları zorluklar. *International Journal of Human Sciences, 12*(1), 1189-1215. doi: 10.14687/ijhs.v12i1.3188

Aycan, Ş., & Yumuşak, A. (2003). Lise müfredatındaki fizik konularının anlaşılma düzeyleri üzerine bir araştırma. *Milli Eğitim Dergisi, 159*, 171-180.

Basista, B., & Mathews, S. (2002). Integrated science and mathematics professional development programs. *School Science and Mathematics, 102*(7), 359-370.

Baskan, Z., Karal, N., & Karal, I.S. (2010). Physics and mathematics teachers' ideas about topics that could be related or integrated. *Procedia - Social and Behavioral Sciences, 2*(2), 1558–1562

Basson, I. (2002). Physics and mathematics as interrelated fields of thought development using acceleration as an example, *International Journal of Mathematical Education in Science and Technology, 33*(5),679-690.

Berlin, D. F., & Lee, H. (2005). Integrating Science and Mathematics Education: Historical Analysis. *School Science and Mathematics, 105*(1), 15-24

Berlin, D.F., & White, A.L. (2012). A Longitudinal Look at Attitudes and Perceptions Related to the Integration of Mathematics, Science, and Technology Education. *School Science and Mathematics, 112*(1), 20-30

Butuner, S. Ö. & Uzun, S. (2010). Fen öğretiminde karşılaşılan matematik temelli sıkıntılar: Fen ve teknoloji öğretmenlerinin tecrübelerinden yansımalar, *Kuramsal Eğitimbilim, 4*(2), 262-272.

Capraro, M. M., Kulm, G., & Capraro, R. M. (2005). Middle grades: Misconceptions in statistical thinking. *School Science and Mathematics, 105*(4), 165-174.

Cetin, S.C., Corlu M.S., Capraro M.M., & Capraro R.M. (2015). A longitudinal study of the relationship between mathematics and science: the case of Texas. *International Journal of Contemporary Educational Research, 2*(1), 13-21.

Corlu, M. S., Capraro, R. M., & Capraro, M. M. (2014). Introducing STEM education: Implications for educating our teachers in the age of innovation. *Education and Science, 39*(171), 74-85

Çorlu, M. A., & Corlu, M. S. (2012). Scientific inquiry based professional development models in teacher education. *Educational Sciences: Theory & Practice, 12*(1), 514–521.

Corlu, M. S., Capraro, R. M., & Çorlu, M. A. (2011). Developing algorithmic computations with the help of science: A Turkish middle and high school grades study. *The Turkish Online Journal of Educational Technology, 10*(2), 72–81.

Corlu, M. S., Capraro, R. M., & Çorlu, M. A. (2015). Investigating the mental readiness of pre-service teachers for integrated teaching. *International Online Journal of Educational Sciences, 7*(1), 17-28

Czerniak, C. M. (2007) Interdisciplinary science teaching. In S. K. Abell, and N. G. Lederman, (Eds.), *Handbook of Research on Science Education*, (pp. 537-560). New York and London: Routledge.

Czerniak,M.C., Weber, W.B., Sandmann, A.J., & Ahern,J. (1999).A literature review of science and mathematics integration. *School Science and Mathematics 99*(8), 421-430.

Demirci, N., & Uyaik, F., (2009). Onuncu Sınıf Öğrencilerinin Grafik Anlama ve Yorumlamaları İle Kinematik Başarıları Arasındaki İlişki. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 3(*2), 22-51.

Dole, S., & Shield, M. (2008). The capacity of two Australian eighth-grade textbooks for promoting proportional reasoning, Research in Mathematics Education, 10(1), 19-35, doi: 10.1080/14794800801915863

Frykholm, J., & Glasson, G. (2005). Connecting science and mathematics instruction: Pedagogical context knowlege for teachers. *School Science and Mathematics, 105*(3), 127-141.

Furner, J. M., & Kumar, D. D. (2007). The mathematics and science integration argument: A stand for teacher education. *Eurasia Journal of Mathematics, Science & Technology Education, 3*(3), 185-189.

Geary, D. C., Liu, F., Chen, G., Saults, S. J., & Hoard, M. K. (1999). Contributions of computational fluency to cross-national differences in arithmetical reasoning abilities. *Journal of Educational Psychology, 91*(4), 716-719.

Howe, C., Nunes,T., & Bryant, P. (2010a).Rational number and proportional reasoning:Using intensive quantities to promote achievement in mathematics and science. *International Journal of Science and Mathematics Education, 9*, 391- 417.

Howe, C., Nunes,T., & Bryant, P. (2010b). Intensive quantities: Why they matter to developmental research. *British Journal of Developmental Psychology*, 28, 307–329

Hurley, M.M. (2001). Reviewing integrated science and mathematics: the search for evidence and definitions from new perspectives. *School Science and Mathematics, 101*(5), 259-268.

Karaer, H. (2006). Fen bilgisi öğretmenlerinin ilköğretim II.kademedeki fen bilgisi öğretimi hakkındaki görüşleri (Amasya örneği). Erzincan Eğitim Fakültesi Dergisi, 8(2), 97-111.

Karakuyu, Y. (2008). Fizik Öğretmenlerinin Fizik Eğitiminde Karşılaştığı Sorunlar: Afyonkarahisar Örneği. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *5*(10), 147-159

Kıray, S.A., & Kaptan, F. (2012). The effectiveness of an integrated science and mathematics program: Science-centered mathematics assisted integration. *Energy Education Science and Technology Part B: Social and Educational Studies*, *4*(2), 943-956.

Kıray, S.A., Gök, B.,Çalişkan,İ.,& Kaptan,F. (2008). Perceptions of science and mathematics teachers about the relations between what courses for qualified science mathematics education in elementary schools. In Ö.Demirel& A.M.Sünbül (Eds.). *Further Education in the Balkan Countries*, 2, pp. 889-897.

Koirala, H. P., & Bowman, J. K. (2003). Preparing middle level preservice teachers to integrate mathematics and science: problems and possibilities. *School Science and Mathematics*, *103*(3). 145-154

Lamon, S. J. (2007). Rational numbers and proportional reasoning: Towards a theoretical framework for research. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 629–667). Charlotte: Information Age Publishing.

LeCompte, M. D., & Goetz, J. P. (1982). Problems of reliability and validity in ethnographic research. *Review of Educational Research*, *52*(1), 31-60.

Li, M., Shavelson, R. J., Kupermintz, H., & Ruiz-Primo, M. A. (2002). On the relationship between mathematics and science achievement in the United States. In D. F. Robitallie and A. E. Beaton (eds.). *Secondary analysis of the TIMSS data* (pp. 233-249). Kluwer Academic Publisher: the Netherlands.

Maxwell, J. A. (1994). *Qualitative research design: An interactive approach: An interactive approach*. Thousand Oaks, CA: Sage Publications.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation* (2nd ed.). San Francisco (CA): John Wiley & Sons.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage Publications.

National Council of Teachers of Mathematics (NCTM) (2000). *Principles and standards of school mathematics*. Reston, VA.

National Research Council (NRC) (1996). *National Science Education Standards.* Washington, DC: The National Academies Press.

NGSS Lead States (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Offer, J., & Vasquez-Mireles, S. (2009). Mix it up: Teacher's beliefs on mixing mathematics and science. *School Science and Mathematics*, *109*(3), 146-152.

Oon, P. T., & Subramaniam, R. (2011). On the declining interest in physics among students—from the perspective of teachers. *International journal of Science education*, *33*(5), 727-746.

Orton,T., &Roper, T. (2000).Science and mathematics: A relationship in need of counselling? *Studies in Science Education,35*(1), 123-153

Park-Rogers, M. A., Volkmann, M.J., & Abell, S. K. (2007). Science and mathematics: A natural connection. *Science and Children, 45*(2), 60-61.

Ríordáin, M., Johnston, J., & Walshe, G. (2015): Making mathematics and science integration happen: key aspects of practice, *International Journal of Mathematical Education in Science and Technology*, doi: 10.1080/0020739X.2015.1078001

Roehrig, G. H., Moore, T. J., Wang, H.-H. and Park, M. S. (2012) 'Is Adding the E Enough? Investigating the Impact of K-12 Engineering Standards on the Implementation of STEM Integration', *School Science and Mathematics, 112*(1), 31-44.

Roth, W. M., & Bowen, G. M. (1999). Complexities of graphical representations during ecology lectures: An analysis rooted in semiotics and hermeneutic phenomenology. *Learning and Instruction*, *9*(3), 235-255.

Sahin, E., & Yagbasan, R. (2012). Determining which introductory physics topics pre-service physics teachers have difficulty understanding and what accounts for these difficulties. *European Journal of Physics*, *33*(2), 315.

Sulun, A., Oktay-Ciminli, E., & Sanalan, V. (2014). Öğrenci ve öğretmenlerin fen ve teknoloji dersinin yaşamimizdaki sürat konusundaki matematik becerileri üzerine görüşleri. *Erzincan Üniversitesi Fen Bilimleri Enstitüsü Dergisi,* 7(1), 37-55. doi:http://dx.doi.org/10.18185/eufbed.83955

Venville, G., Rennie L., & Wallace, J. (2004). Decision making and sources of knowledge: how students tackle integrated tasks in science, technology and mathematics. *Research in Science Education*, 34, 115-135

Wang, J. (2005). Relationship between mathematics and science achievement at the 8th grade. *International Online Journal Science Math Education, 5,* 1-17.

Westbrook, S.L. (1998). Examining the conceptual organization of students in an integrated algebra and physical science class. *School Science and Mathematics, 98*(2), 84-92.

Cebesoy, Ü. B., & Yeniterzi, B. (2014). Investigation of Science and Technology Exam Questions in Terms of Mathematical Knowledge. Procedia - Social and Behavioral Science, 116, 2711-2716

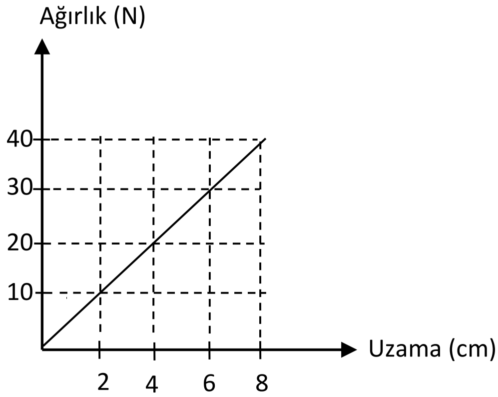
Yildirim, A. & Simsek, H. (2009). Nitel araştırma yöntemleri (6th ed.). Ankara: Seckin Publishing

APPENDIX

Sample Questions Types

Question 1.

The graphing representing of the relationship between the length and mass of a spring was given below.



Based on the graph given above, find the elongation which is caused by 30 N.

Related Area: *Reading Line Graphs*

Question 3 (A Follow up question for students by using same graphs)

Based on the graph given above, find the difference in the elongation of spring in meter when 60N is applied.

Related Area: *Rate-Ratio, Unit Conversion and Reading Line Graphs*