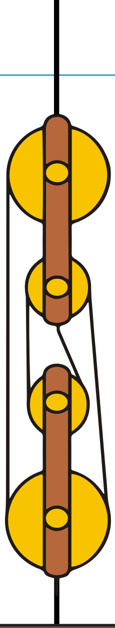

The real life application of PULLEYS in a competitive environment

Ahmet Tekbiyik

The aim of this research was to explore students' application of theoretical knowledge in real-life situations using pulley systems in a competition designed for primary school students. The study was conducted with 24 primary school students who had completed year seven, and who volunteered to participate in a summer science camp. In groups, the students were asked to design and build a pulley system using selected equipment that would hold a load of 100 grams in balance or raise it with minimum force. This was to be achieved within a time limit of 30 minutes. During the activity, the students first attempted to use the theoretical knowledge taught at their schools and designed a theoretical diagram. When they attempted to apply the diagram using real equipment, they realised that different factors (for example, pulley weights, friction, etc.) were present. Thus, they realised that the procedural problems they solved in the classroom about pulleys were different from real life.

INTRODUCTION

Most physics topics are actually about events people encounter during their daily lives. Despite this, the questions that are most frequently asked by students studying physics topics include, *"Why do I need this knowledge?"* or *"Where will I use this knowledge?"* These questions indicate a lack of understanding by students about the relevance of many physics concepts because physics has an abstract nature that is perceived to be distant from real life (Whitelegg & Parry, 1999). Due to the often theoretical and abstract structure of the physics taught in schools, students believe it comprises knowledge that is unlike real life, and has to be memorised. On the contrary, the knowledge presented in physics lessons should be in touch with real life and should facilitate the resolution of real-life problems. Having the knowledge obtained in the classroom be useful in resolving real-life problems is among the targets of current education programs (Ministry of National Education, 2013; Ministry of National Education, 2008). It is stated that if the students can associate a concept and its applications with the real world while being taught said concept, they understand that subject better (Yam, 2005). When associated with and used in real life, students will better understand the value of science that they often sense as meaningless and unnecessary, and will be more motivated about learning it (Tekbiyik, 2010). Having the students use theoretical knowledge to devise strategies in overcoming real-life problems is shown among the main outcomes of education (Bayazit, 2013).

It has been found that in science education, having students work in groups or in collaboration is much more effective than individual studies (Krajcik & Czerniak, 2014). Having students work in a group towards a goal in a manner that will create positive dependency was proved to develop many social skills (for example, communication, responsibility, etc.) (Cohen, 1994; Özer, 2005; Slavin, 1996). Even more importantly, group activities have been observed to improve the attitude and motivation of students (Gencosman & Dogru, 2012; Hanze & Berger, 2007; Springer, Stanne & Donovan, 1999; Tam, 2001; Wang, 2012). Due to the nature of physic topics that are perceived to be abstract and theoretical, having students work in groups is important for increasing their motivation. Peer interaction through cooperative learning and object-mediated learning is described among the elements for effective science teaching (Satterthwait, 2010).

CONTEXT OF THE STUDY

Pulleys are simple machines that enable students to associate physics with daily life and interpret situations through the knowledge obtained in class. Yavuz & Özdemir (2009) propose that pulley systems can be used very effectively for teaching and learning the Newtonian laws.

Research indicates that students have considerably different and alternative conceptual understandings, especially regarding pulleys and balance (Ahtee & Hakkarainen, 2007; Hakkarainen & Ahtee, 2005; Mohapatra & Bhattachaayya, 1989; Rouinfar, et al., 2012). But this research focuses on determining the mental models of student's understanding of concepts such as balance, weight or force. None of the studies required the students to design their own pulley systems and use them for balancing activities. None presented opportunities in which the students were challenged to use pulley systems in a predetermined real-life goal. However, studying simple machines can provide real-life, hands-on learning opportunities for students.

In their research, Ahtee and Hakkarainen (2007) showed their Year 5, 7 and 9 students a mass and a bag hanging on either side of a pulley and asked them which was the heavier of the two. In this study, it was also separately explained that the pulley could easily rotate (that it is frictionless) and that the rope was very light. In this case, as in many others, the students were asked questions about a fairly standard pulley system. Since the students do not encounter pulley systems in real life, they have the perception that pulleys and ropes are weightless. The same scenario can be seen in textbooks in Turkey (Ministry of National Education, 2012). The textbooks are distributed to all students, free of charge, by the Ministry of National Education. Both in the course books and the teacher's guides that are commonly used in schools, pulleys and many other topics are presented theoretically and their real-life applications are not presented. It was observed that both the science and technology course book and the student study books distributed by the Ministry of National Education for use in schools, present pulleys (within the Simple Machines unit) theoretically via diagrams and that physical (hands-on) applications are not presented (Ministry of National Education, 2012, p. 90). In addition, in the assessment section, procedural problems with diagrams are also presented. For example, *"A worker is trying to pull a 500 N mass up to two metres high via the pulley system. How much force should he apply to the rope of the pulley to move the mass?"*

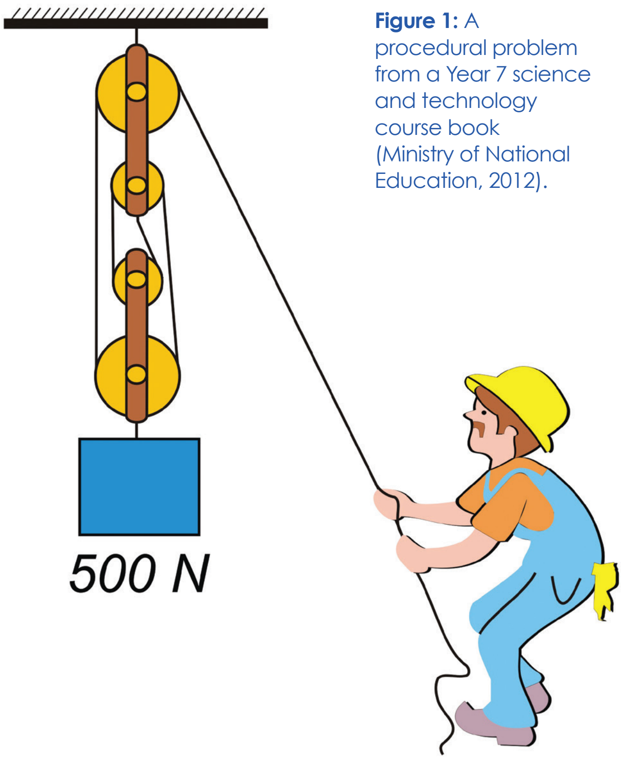

Figure 1: A procedural problem from a Year 7 science and technology course book (Ministry of National Education, 2012).

Problems using diagrams such as the one in Figure 1 are valid within predetermined limits. Even if it is not stated in the problem, there is no friction in the system, the pulleys are weightless and the angular momentums of the pulleys are being conserved. But these properties are not important for the students' solutions. The students can easily calculate the force required to raise the mass as 500/4=125 N as there are four ropes in the moving pulley. With this solution, the tension on the rope is accepted to be equal at every point of the rope. This solution is completely procedural and not conceptual at all. Furthermore, it lacks applicability to real life. Due to exclusive usage of procedural problems with diagrams in teaching pulleys, it is inevitable that students perceive a difference between the physics lessons in the classroom and their physics experiences in real life when they encounter a real physical system. This research aims to reveal how students comprehend such a situation.

Ferguson and Hegarty (1995) compared the effect of real-pulley-systems simple line diagrams on mechanical learning and problem-solving. They designed two different conditions. In the first, the students created pulley systems using real equipment. In the second, the students learned about the pulleys via diagrams. The study indicated subjects who learned, "hands-on", with real pulley systems, solved application problems more accurately than those who learned from diagrams.

Rouinfar, et al., (2012), conducted research on the topic of force in pulley systems for two weeks with students in two groups—one with real physical activities and one using a virtual education environment. They were presented with a challenge to design the best pulley system to lift a piano at the end of each week. Researchers observed them during the activities. Students in the physical group mentioned that pulleys distribute the weight of the load more frequently than those in the virtual group, but the difference was not significant.

Similarly, Rouinfar, et al., (2013) observed their students' learning about the force in pulley systems via real physical activities and in virtual environments. Later, the researchers used complex pulley systems to conduct more in-depth analysis. It was observed that students in the physical activities group were more successful in applying their knowledge when provided with real-life problems to solve when compared with the virtual group. This result was not surprising as the virtual group studied a frictionless environment.

In their research, Gire et al., (2010) created two groups and taught the first group via real physical activities and later via the virtual environment. The second group was first subjected to virtual environment teaching and later they experienced real physical activities. The analysis showed that the concepts of effort, force, distance pulled and mechanical advantage were better developed in the first group, while the concept of work was better developed in the second.

The research shows that using only linear diagrams or virtual environment activities in teaching the topic of pulleys does not create understandings of real-world usage of pulleys in students. Therefore, appropriate learning environments are required for students to apply their knowledge and to use it in a model that is close to reality. This research focuses on the observation of how students behaved in a real-life problem related to pulleys.

PURPOSE

This study aimed to investigate students' application of theoretical knowledge in real-life situations related to pulley systems through a competition designed for primary school students.

METHODOLOGY OF RESEARCH

Subjects and Design

This study was carried out with 24 Year 7 students who attend a public school. For the activities, a special practice environment was created in the Education Faculty where the researcher works. The students received formal education regarding pulleys at their school approximately six months before the research study. The activities that comprise the subject of this research were named "Benevolent Pulleys". "Benevolent Pulleys" was designed as a competition that facilitated group work opportunities for the students.

Procedure

In this study, the students were first reminded that they were taught the topic of pulleys within the Simple Machines unit during the year (while in Year 7) and that they had developed skills in calculating the balancing force that reciprocates to a load in a pulley system. A discussion about the topic was conducted with the students, which aimed at revealing some of their previous knowledge. Following this, the students were separated into groups of four and each group was given the same materials. The materials were: a pulley set, balancing sticks and connection parts, a set of weights, and fishing line. The groups were asked to design a pulley system that would keep a mass in balance or raise it with minimum force. It was stated that the group that could accomplish this with the minimum weight would be rewarded. A time limit of thirty minutes was given for the activity, which was organised as a competition to make sure that the groups carried out the task. The students attempted the task in six groups of four.

In the study, three practical activities were implemented every second day. In each activity, the mass required to be balanced and the equipment to be used (pulleys, balancing sticks, etc.) were different. In this way, the theoretical knowledge of students was challenged with real-life situations and practical experience. During the practical activities, the efforts of each group were recorded by the researcher using an observation form.

Data Collection

Interview

Following the activities, three female and three male students, one chosen from each group at random, were included in semi-structured interviews regarding how they used the theoretical knowledge gained in the "Benevolent Pulleys" competition and their opinions regarding its application. Content analysis was conducted on the obtained qualitative data. In the content analysis, the responses were consolidated under applicable themes and were presented in tables.

Observation

Due to the nature of the research, how the students behaved during the practical activities and what processes they utilised were important. Therefore, the kind of work conducted by each

Figures 2 & 3: Students attempting the given tasks.

group was recorded in five-minute periods using an observation form. The groups were named A to F in the observations.

Worksheets

During the activities, each group was given worksheets to remind them what they had to do, to self-record how they completed the given task, and to draw the balanced pulley system that was created.

RESULTS OF RESEARCH

Findings Obtained from the Observations

During the study, the researcher recorded the way the groups behaved in each five-minute period during the 30-minute practical activities using an observation form. During the first task, the groups usually spent the first five minutes of the given time getting to know the task provided or the materials. They began taking action in the following period. Some of the groups first created a theoretical model using their theoretical knowledge, and attempted to set up a system in accordance with this model. Other groups immediately began to set up the pulley systems. When the groups that created a theoretical model realised the effect of the weights of the movable pulleys and the friction in the system, they reviewed their models and decreased the number of movable pulleys (because the movable pulleys introduced additional load to the system). During this process, they realised that the diagrams they had created with their theoretical knowledge were not valid in application. They rearranged the systems by moving away from their sketches and established balance through practical, hands-on application. At the end of the first task, it was observed that three groups could establish a load balancing system while three groups had failed to accomplish it.

The groups that succeeded in establishing the load equaliser mechanism in the first practical activity were observed to perform this work in a shorter period in the latter practical activities. The observation findings from Group A, which succeeded in establishing a load-balancing system in the first activity, are shown in Figure 4. Group A had made a draft drawing of how to balance the load by using their theoretical knowledge in the first practical activity, and then started the second with similar work. Afterwards, they had changed the size of the balancing load using a trial and error method, then providing the balance by establishing a proper system. This process was completed successfully in 25 minutes on the second practical activity and in 20 minutes on the third.

The groups that were not successful in the first practical activity were observed to change their method during the latter activities (activities 2–3). The observation findings from the three activities conducted by Group D can be seen in Figure 5. In the first practical activity,

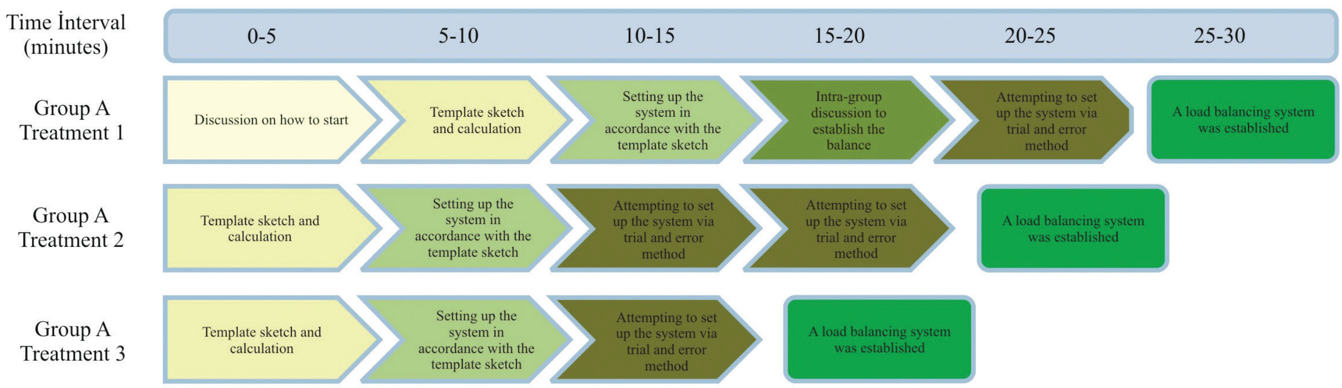

Figure 4: The observation findings from Group A during three practical activities.

Group D started the activity without creating a diagram or drawing using their theoretical knowledge. They spent most of the time trying to balance the load using a trial and error method. As a result, they failed to establish the load equaliser mechanism. Group D also started the process for the second practical activity in a similar manner; however, they then decided to make a draft drawing to calculate how to balance the load. They aimed to build a pulley system in accordance with the draft drawing and spent the remaining period occupied with this. They did not establish a load-balancing system in the second practical activity. In the last activity, Group D took advantages of their experience in the first two practicals. They created a draft drawing using their theoretical knowledge and then started to build according to their drawing. However, this procedure failed to produce an effective solution. They then switched to using a trial and error method. By this means, they were observed to achieve the load balance in 25 minutes.

The Findings Obtained in Interviews

After the practical activities, semi-structured interviews were conducted with three female and three male students chosen at random from each group about their opinions of the practical activities. The male students in the interviews were coded as MS1, MS2 and MS3, while the female students were coded as FS1, FS2 and FS3. The content analysis of the students' responses to the questions is given below.

Question 1: Did you have difficulties in balancing the loads using the pulleys? If yes, why?

The findings from the students' responses to question number 1 are provided in Table 1.

STUDENTS	DIFFICULTY OF BALANCING THE SYSTEM	REASON
MS1	Difficult	As the pulleys have weight, we tried to use the least number of moving pulleys
MS2	Difficult	As the pulleys have weight, we tried to use the least number of moving pulleys
MS3	Partially difficult	Too much friction in the pulleys
FS1	Difficult	Too much friction in the pulleys
FS2	Partially difficult	Too much friction in the pulleys
FS3	Difficult	As the pulleys have weight, we tried to use the least number of moving pulleys

Table 1: Findings regarding the students' responses to Question 1.

From Table 1 it can be seen that all the students stated that they experienced difficulties in keeping the system they established in balance. The students stated that the reasons for this were too much friction in the pulleys and the weight of the pulleys.

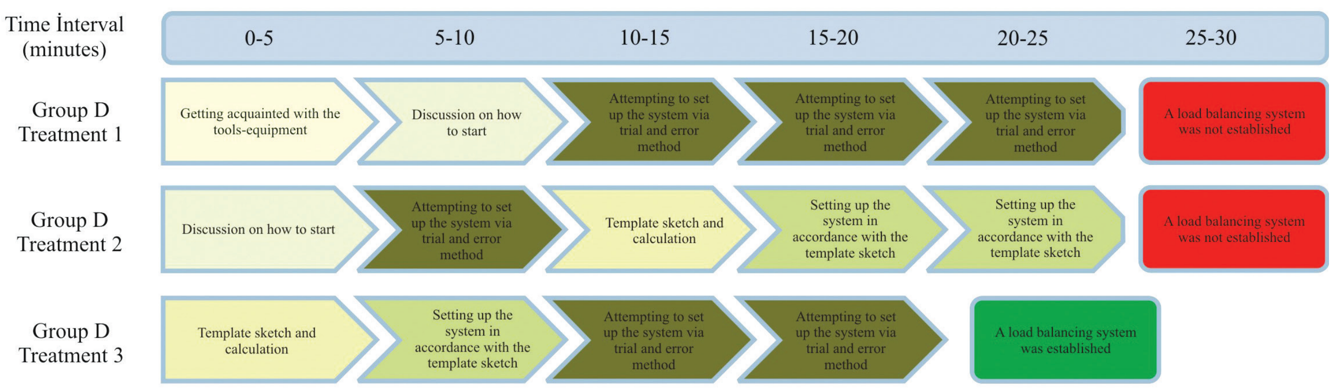

Figure 5: The observation findings from Group D during three practical activities.

Question 2: Were there differences between the knowledge learned in the classroom and the knowledge you applied here? If there is, how?

The findings from the students' responses to question number 2 are provided in Table 2.

STUDENTS	DIFFERENCE BETWEEN THE THEORETICAL AND APPLICABLE KNOWLEDGE	SOURCE OF THE DIFFERENCE
MS1	Different	Weight of the pulleys
MS2	Different	Weight of the pulleys, friction
MS3	Not different	-
FS1	Different	Friction
FS2	Partially different	Weight of the pulleys
FS3	Different	Weight of the pulleys, friction

Table 2: Findings regarding the students' responses to Question 2.

According to Table 2, five of the students who participated in the interviews stated that there were differences between the theoretical knowledge obtained in the classroom and the knowledge they tried to apply during the activity. They stated the weight of the pulleys and the friction in the system were the sources of this difference.

The statement of a student, as provided below, clearly shows the difference between the procedural problems they encountered in classroom lessons and the real-life applications:

> *MS2: …While we were solving the problems in the courses, we obtained the balancing force when we divided the load by the number of ropes in the pulley, but when we did a similar computation here, we could not balance the load. We understood that we had to factor in the pulley weights as well…*

The findings obtained from the interviews show that the students had difficulties in creating systems when using never-used-before tools and equipment. And although they could theoretically calculate the force to balance the load, as the pulleys are frictionless and weightless in classroom learning, in application they used the minimum number of movable pulleys due to the weight of the movable pulleys.

Findings Obtained from the Worksheet

The groups were asked to draw on the worksheet the balanced pulley systems they created at the end of the activities. As three groups could not complete the task for the first practical activity, they did not draw anything. Two of the three groups that correctly set up the system used only one movable pulley to balance a 100-gram load with 70 grams. The winning group (Group E) used a set of pulleys to balance a 100-gram load with a mass of 25 grams. The sketches of Group E are presented in Figure 6.

It can be understood from the observations that Group E first set up the pulley system using template sketches and they determined the load-balancing mass via theoretical calculations. When Figure 6 is examined, it can be seen that the load was balanced by a 25-gram weight. But in procedural calculations, as there are five ropes in the movable pulley system that balances the load, 20 grams of weight

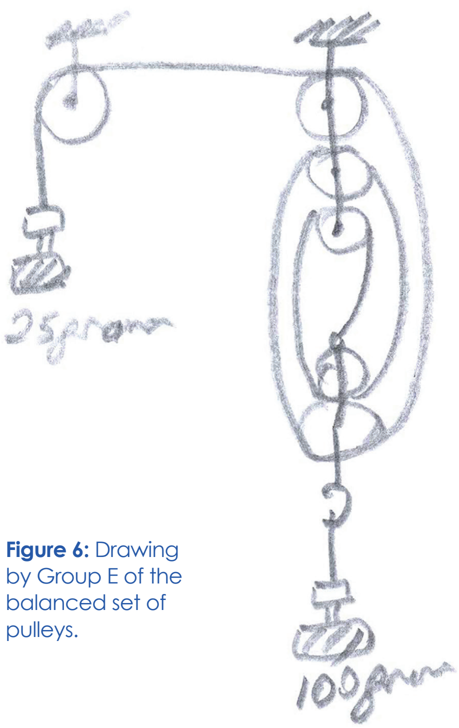

Figure 6: Drawing by Group E of the balanced set of pulleys.

is expected to balance the load (100 gr/5 = 20 gr) and 25 grams of weight is expected to accelerate the load upwards. Since the system has friction, the movable pulleys have weight, and angular momentum is not conserved. The 100-gram load was balanced with a 25-gram load.

DISCUSSION AND CONCLUSIONS

This research observes how students use their theoretical knowledge in the study of pulleys in real-life situations through a contest designed for primary school students. The students worked in groups and used pulleys to set up a real system in order to solve the given problem. During this process, the students first attempted to use the theoretical knowledge taught at their school and created a theoretical diagram. When they attempted to apply the diagram using real equipment, they realised that different factors (pulley weights, friction etc.) were involved. Thus they realised that the procedural problems they solved in the classroom about pulleys were different from real life. During the first practical activity, while some groups managed to overcome this new situation, some groups failed to devise alternative paths when faced with the problem.

The groups that successfully established the load-balancing mechanism were observed to perform this in a shorter period in the latter practical activities. These groups (for instance, Group A) had created the draft drawings before starting to work on the mechanism. However, they had used the drawings only to start creating the mechanism. In the remaining period, they created the mechanism using a trial and error method. In other words, they were observed to realise that the theoretical knowledge did not work.

The groups that were unsuccessful in the first practical activity (for instance Group D) were observed to use different methodology. These groups did not make any draft drawings in the first practical activity. They only created drawings with theoretical knowledge in the second activity and they aimed to establish the mechanism using this. However, they finally balanced the mechanism through trial and error as they observed that the theoretical approach did not work. All of the students in these groups were observed to realise that the drawings they created with theoretical knowledge were not valid in reality. This situation is confirmed with the findings gained from the interviews. Almost all of the students indicated that establishing the mechanism was quite hard when they performed the activity for the first time. According to the students, the reason for this difficulty and the pulley systems not working was because the theoretical knowledge they had learned during lessons did not work because of the effect of friction and the weight of the pulleys (see Tables 1 and 2).

Students do not know how to approach the problems they are faced with in real life without real-life experiences and practical application in the education setting. Ferguson and Hegarty (1995) found that students who study the topic of pulleys using real equipment solve the problems more accurately compared with students who learn solely via diagrams. However, they found that using diagrams and procedural problems during lectures and only later confronting the students with real-life problems caused issues for the students in transferring knowledge.

The main goal of the current Turkish science curriculum is to develop skills in using scientific knowledge in solving natural problems (Ministry of National Education, 2013). It is therefore imperative that real-life applications are presented during the teaching, not after it. Provision of practical, hands-on activities in real-life contexts helps develop student thinking about abstract scientific concepts and the ability to apply their theoretical knowledge in practical situations.

During the practical activities provided through the "Benevolent Pulleys" competition, the students enjoyed using their physics knowledge in a competitive environment—and were inclined to develop positive attitudes. This can be clearly observed in the interviews and the observations that took place during the practical activities. However, this development should be analysed in more detail in future research. This study reveals the need to research the effects of competitive (contest) environments on students in more detail.

ACKNOWLEDGEMENT

The author wishes to acknowledge that this study was conducted within a project supported by The Scientific and Technological Research Council of Turkey (TUBITAK) (Project Number: 110B033). Any opinions, findings or conclusions expressed in this paper are those of the author and do not necessarily reflect the views of the Scientific and Technological Research Council of Turkey (TUBITAK).

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