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# Improving 7th Grade Students' Understanding of Force and Motion through History of Science Stories: A Glimpse at an Ongoing Effort

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The integration of history of science (HOS) into science teaching plays a crucial role to address many shortcomings of traditional science teaching in middle schools, due to its close relationship to the nature of science (NOS) and to its ability to reveal the interconnectedness of science to other disciplines. The purpose of this study is to improve seventh grade students' course engagement and motivation and their understanding of scientific concepts within the unit of "Force and Motion" through the use of history of science-based stories. The study was conducted according to an action research approach. Five stories based on the history of science were developed and administered by one of the researchers in their 7th grade science class. The iterative reflective practice took place over seven weeks with 15 students who met twice a week for two consecutive forty-minute sessions. Throughout this process, researcher journals, semi-structured interviews and a survey were employed for data collection. Teaching with history of science-based stories was found to be effective for students' understanding of concepts related to "force and motion." The results of the study were also positive with respect to the students' engagement and motivation. Based on the findings, it is suggested that the nature of science should be addressed explicitly through stories in future research.

## Introduction

Science education aims not only to teach about scientific concepts, principles, theories, models, and processes; but also, to help learners to make sense of the natural world around us and make informed decisions when necessary. Thus, all of these elements should be addressed in science teaching. Esra was a science teacher in a village school in north-eastern of Turkey for 4 years. She was having her master education in science education at the time of the study.

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With this in mind, Esra decided to improve the quality of her science teaching by including stories that her students would like to hear in her classroom. Moreover, she also realized that the historical development of many scientific concepts was similar to her students' preconceptions. Therefore, she decided to examine whether history of science-based stories would improve her students' understanding of scientific concepts. As such, the aim of this study was to improve seventh grade students' course engagement, motivation, and understanding of the topic of "Force and Motion" through the use of history of science (HOS) based stories.

### *History of Science*

Research has shown that students do not typically aspire to careers in the sciences or related professions (EU, 2008; Henriksen et al., 2015; Jacobs & Simpkins, 2006; Sjøberg & Schreiner, 2010). To address this concern, many developed and developing countries have taken initiatives for educational reforms by changing the teaching and learning environment. Students are expected not only to understand scientific concepts, but also to get to know the process of scientific study in greater depth and to develop the skills needed to acquire scientific knowledge. As a result, scientific literacy and science-technology-society-environmental issues have increased in importance worldwide (Solbes and Traver, 2003). In this regard, the history of science (HOS) plays a crucial role for both movements, due to its close relationship to the nature of science (NOS) and to its ability to reveal the interconnectedness of science to other disciplines (Paraskevopoulou and Koliopoulos, 2011). As the importance of teaching NOS has increased, HOS has likewise gained importance; therefore, the number of studies about teaching HOS in science education has also increased (Erdaş et al., 2016; Winrich and Garik, 2021). In this sense, Viana and Porto (2010) reported that numerous countries have integrated HOS into their updated science education curricula. There are four main reasons for doing so. One of these, embodied in the "Science-Technology-Society-Environment" curriculum established by the Ministry of National Education (MoNE) in Turkey, is to enable students to "identify and compare ideas and theories put forward about natural events in the past and today" (MoNE, 2006, p. 74). In order for students to accomplish this purpose, they need to be aware of the past and current claims and ideas relating to a scientific topic. Accordingly, HOS exposes students to past and contemporary ideas, allowing them to understand more about the development of scientific knowledge (Mantyla, 2013; Laçin Şimşek, 2019; Leona, 2014; Jardim et al., 2021).

The second reason is to address one of the drawbacks of traditional teaching, which typically addresses only discoveries and inventions. When HOS is linked to scientific concepts and processes, thereby establishing a relationship to science teaching, then an awareness of its instructional value may be formed (Mısır et al., 2018). Teachers and/or science textbooks usually address events or ideas derived from HOS, but these are generally conclusions of scientific research. This approach to using HOS in a science class is not viewed as effective (Viana and Porto, 2010) in the sense that presenting only results or inventions is not enough to provide meaningful understanding. In order comprehend scientific concepts or inventions, students need to know more about the process (Allcin, 2011; Mısır and Laçin Şimşek, 2018). Through HOS stories, students have the opportunity to follow the emergence and development of the scientific understanding of a phenomenon, thus formulizing its concepts, principles, hypothesis, laws, and theories (Yıldırım, 2011). On the other hand, if students do not gain an understanding of scientific processes, they have difficulties learning the concepts and develop negative attitudes towards science. As such, it is important to address the progressive process of science by showing students how science works (Solomon et al., 1992) and how it is developed and influenced from the social and cultural structure of the society (Solbes and Traver, 2003).

A third reason for using HOS is its capacity to reveal the importance of scientific developments in their own time, as well as their effects on culture and society (Irzik, 2015). In general, primary school students have stereotypical ideas about science and scientists, believing that scientists work all the time; that they know everything; that all of them are geniuses; and that they do not have social lives (Kahraman and Karataş, 2015). Through HOS, students have the opportunity to learn more about scientists and recognize that they are normal individuals with ordinary lives. In other words, HOS can make science more human, allowing students to relate to scientists and potentially choose science as a profession (Stephen Klassen and Cathrine Froese Klassen, 2014).

The final reason for using HOS in science classes is to allow teachers to predict where students may have learning difficulties or misunderstandings. In this sense, studies have shown that students' ideas about a phenomenon are often parallel to past scientific ideas (Dedes, 2005; Van Driel et al., 1998). To counter this, Solomon et al., (1992) suggested that HOS can help identify naïve conceptions and shape the learning of scientific concepts by drawing attention to the scientific development of an idea. Namely, when students recognize their own misunderstandings in HOS, they may become aware of their conceptual construction and development process, leading to more effective conceptual change. Thus, taking into consideration the resemblance of a student's conceptual development to the historical progress of science, HOS is a useful tool for supporting meaningful learning (Allcin, 2011; Dedes, 2005; Solbes and Traver, 2003).

Furthermore, Roca Rosell and Grapi Vilumara (2010) expressed that in addition to supporting meaningful learning, HOS enriches students' imaginations and should therefore be included in science learning from the primary school level. In this regard, HOS can be seen as narrating the story of the changes and developments of scientific concepts. Storytelling has recently been recognized as a powerful means for improving science learning (Gamito-Marquez, 2020). With this in mind, it would be fair to state that history of science-based stories provide an opportunity for students to examine the development processes of scientific concepts and to learn meaningfully (Kahraman, 2012, Laçin Şimşek, 2019). Taking into account primary school students' age and pedagogical readiness, HOS should be administrated via short anecdotes or stories (Kortam et al., 2021).

### *History of Science based Stories (HOSBSs)*

One technique that raises students' interest in science is the use of stories in science classes. Stories have been described as short essays that address real or realistic events at a particular place and time (Arıcı, 2007). Stories can be written in accordance with scientific knowledge and used successfully in science classes for teaching science and the nature of science (Kahraman and Karataş, 2015, Walan, 2019). In this sense, Hill and Baumgartner (2009) have emphasized that stories are useful tools for organizing cognitive structure, leading to effective conceptual construction. This knowledge construction or meaning-making process occurs in such a way that new information is related to prior knowledge (Suziki et al., 2018), which leads to more successful learning. Moreover, students learn more easily when scientific concepts are related to their daily lives. In this sense, stories that address real world or realistic events are helpful for contextualizing the facts and events of everyday life (Bertiz, 2005; Dincel, 2005; Hu et al., 2021). Through such associations, scientific concepts can be constructed easily and meaningfully by learners (Hırça et al., 2011; Peleg et al., 2017).

Another advantage of using stories in classroom is to allow students to place themselves in the roles of the main characters and try to solve problems; this process is claimed to improve problem-solving skills (Bertiz, 2005; Klassen, 2009). In this sense, while reading stories, students may suggest solutions to the problems by using their prior knowledge, thus stimulating their imagination (Yiğit, 2007). Moreover, seeking answers to questions in the context of different events and situations improves not only students' imagination, but also their multidimensional thinking (Czerneda, 2010) and critical thinking skills (Yiğit, 2007).

As stated above, stories have numerous advantages, and they can illustrate both current and historical events. In this sense, HOSBSs are very effective tools when used in science education (Candaş et al., 2021; Kahraman and Karataş, 2015; Klassen, 2009; Yücel, 2009), allowing students to view scientific concepts not only through their development process, but also in terms of how others conceptualize them. Similar to other types of stories, HOSBSs help students engage with the content (Yücel, 2009) through this process, assisting them in understanding the importance of learning about particular scientific concepts (Stephen Klassen and Cathrine Froese Klassen, 2014). Thus, HOSBS enhance students' awareness, curiosity, and motivation about science and scientific knowledge in a historical context (Klassen, 2009; Laçin Şimşek, 2018) by allowing a new dimension of experience of the phenomenon (Marton, 1986). Moreover, HOSBSs facilitate the association between scientific concepts and daily life (Bertiz, 2005), thereby increasing students' interest in science class and in science itself. Because HOSBSs function as an intermediary between students' conceptions and scientific concepts (Viana and Porto, 2010), designing well-structured stories, may lead to more efficient conceptual construction (Candaş et al., 2021). In this sense, researchers have pointed out that students' naïve ideas resemble the early stages of current scientific ideas (Dedes, 2005; Van Driel et al., 1998). As such, developing stories embedded in HOS can mirror this conceptual change if designed properly. Therefore, in our case, the stories were developed via a three-step approach: first, the incorrect ideas were presented, followed by the correct answer and concepts; and finally, explanations as to why the initial ideas were wrong were embedded into the stories. In this manner, we attempted to avoid students' misconceptions by allowing them to recognize their naïve ideas and develop them through meaningful learning. In other words, within the theoretical framework of conceptual change model, HOSBSs help students become aware of the flaws in their preconceptions and understand why these ideas work in some cases and not in others (Posner et al., 1982).

### *Issues in the Classroom*

Esra (one of the authors of this study) teaches at a school in a rural area. During the course of her practice, she observed that her students' level of interest in science was low, and they were generally unwilling to participate in the classroom activities and discussions that were designed for their science courses. One of her aims is to solve this very fundamental problem in her seventh-grade classroom. After four years of teaching experience, she also realized that her students generally have difficulty understanding the topic of "Force and Motion," along with the related concepts. In this regard, research on work, energy, force, and motion has shown that students tend to memorize the definitions of these concepts, going no deeper than rote learning, and that they therefore cannot transfer their knowledge into new contexts or fields (Uluay and Aydın, 2018). On the other hand, Esra also observed that her students' interest in the coursework increased when their science textbooks addressed HOS for certain topics, including the particulate nature of matter and Mendel's studies about heredity. With this in mind, she believed that HOS could help demonstrate the development of these scientific concepts and could have a positive effect on students' interest, thus supporting their learning, as with Irwin (2000) and Solomon et al. (1992), who pointed out that HOS improves students' motivation and understanding in science learning. On the other hand, a primary concern in this process is the manner of integrating HOS into science topics. For this reason, we decided to use stories, in light of the school's conditions, cultural structure, and the literature in the field. With respect to the students' age and pedagogy, it has been asserted that HOS should be expressed through short anecdotes or stories (Roca Rosell and Grapi Vilumara, 2010). Stories are also important aspects of local culture that can be used to increase students' interest in science courses, as supported by the claim that HOSBSs can be very effective tools in science education (Stephen Klassen and Cathrine Froese Klassen, 2014).

Taking into consideration all of the above merits, we decided to conduct an action research project to improve the students' understanding and motivation in science class. The purpose of this study was to determine the effects of HOSBS on students' conceptions within the topic of "Force and Motion."

## Methodology

Educational environments are impossible to recreate with their shape and ever-changing features with their unique features and human-based functioning. Qualitative research is in an effort to explain a phenomenon in depth and within its own context and limitations. Action research is considered, for some, a methodological framework within the qualitative research approach. Every teacher conducts activities or experiments or solves problems in the classroom. In this sense, a reflective practitioner is one who goes beyond solely teaching a topic, such as through engaging in action research. This process consists of a systematic method for improving the quality of the teaching and learning process, including planning, practice, gathering and analyzing data, and reflecting (Fleming, 2000). Esra, as a science teacher, observed that her students lacked understanding of the concepts relating to "Force and Motion" concepts. Moreover, she saw a need to motivate them toward science learning. Thus, collaborative action research was selected as methodological framework for this study in order to address the issues she had identified in her 7th grade class. As discussed elsewhere, collaborative action research involves a teacher and a university researcher joining together to examine and take action to deal with different issues and concerns about the teacher's practice (Capobianco and Feldman, 2006). After this initial decision, we examined the situation and identified the problem together, deciding to use HOSBSs to address this problem. Accordingly, we prepared a study plan to improve students' understanding about "Force and Motion" using HOSBSs. The participants in the study were the full class of 7th graders, consisting of eight girls and seven boys enrolled in a rural school in the North-eastern Region of Turkey. The school is located in an underdeveloped part of Turkey, so their socio-economic status was very low.

### *Research Process*

Before beginning the implementation, five HOSBSs that covered scientific concepts in "Force and Motion" unit were written. The HOSBSs were written in accordance with the story generation framework described by Isabelle (2007) as follows:

(1) The concepts with their breath and depths based on the 7th grade science curriculum were defined. It was decided to touch on the subjects of flexibility, springs, work in the sense of science, energy, energy types, energy transformations, tackles, levers, inclined plane and gear wheels in the stories.
(2) A detailed literature search was conducted about the historical development of these concepts. Information collected about springs, flexibility, work, energy, energy types,

energy conversions, tackles, levers, inclined plane, gear wheels, inventions. Scientists that work about these concepts and their working processes.

(3) Based on the literature review, scientists/thinkers involved in invention and/or discoveries of force and motion in the history of science were associated with HOSBS. In other words, the main characters in the stories were real figures from HOS. Robert Hooke as the owner of Hooke's law on the flexibility of solid bodies in the story "Robert Hooke and Flexibility" and Isaac Newton, who published important scientific studies on the gravitational force at the same time. James Prescot Joule, whose surname was determined as the unit of energy and John Dalton, a scientist working on the particulate structure of matter were assigned for the story "James Prescot Joule and the Conservation of Energy".

(4) An outline was sketched for each story, beginning with a real-life problem that the main characters tried to solve. In order to arouse the curiosity of the students and enable them to look for solutions, a problem situation based on historical foundations has been added to the stories for each story. The stories are shaped around the solution of this problem/problem. For example, in the story "Tackles and Levers", a region under siege and the efforts of people to win the war are narrated.

(5) The science concept or the relationship between the concepts that were targeted in the course were associated with the solution of the problem. Attention was paid to the fact that the concepts in the stories were capable of solving the problem encountered at the beginning of the story. For example, In the story "Tackles and Levers", the people of the city of Syracuse, which was under siege, asked Archimedes, as an inventor, to set up mechanical mechanisms during the war, enabling them to carry heavy stones and loads to the walls and to throw them to their enemies from a long distances of.

(6) Problems were designed to be attractive for students to solve by infusing a completion or a debate between the characters. A historically based problem for each story was embedded into the stories to arouse students' curiosity and seek solutions.

(7) Each story included two or more characters, with dialogues among the characters to make the story more interesting and interactive. With this strategy, the learning process of students and the difficulties they encounter while understanding the concept are reflected: Concepts that may be misunderstood or not understood well are emphasized. In the dialogues, "What do you think about this?", "How do you think the result will change?", "Let's try and see!" and similar questions were asked with aim of getting students ideas and comments on the subject by giving them a voice at these stages. A creative and attractive title was chosen to increase the students' interest in the story. The titles could be scientific concepts, topics, or anything else.

The following five HOSBSs written based on the aforementioned framework:

- Robert Hooke and Flexibility,
- James Prescott Joule and Conservation of Energy,
- Tackles and Levers,
- Inclined Plane,
- Gears.

Two professors in the Department of Science Education and a science teacher helped Esra develop the HOSBSs. The study took place over seven weeks in Esra's science class, which met twice a week in two consecutive forty-minute sessions. The teacher and the second author met every week to discuss the issues and decide how to proceed both for teaching and data collection.

### *Typical Course Outline*

Each lesson started out with one of the stories to motivate students and attract their attention and interest with respects to the concepts that they would be learning about in the lesson. The characters in the stories were assigned as roles to the students, and they read the scripts aloud. The interactive reading was intended to ensure the active participation of the students. From time to time, the teacher pauses the story to ask questions, encouraging the students to ask questions as well and leading them to find the answers (Mol et al., 2009). For instance, the teacher sometimes interrupted in order to ask questions about the dialogues and the phenomena described in the stories  e.g., "Who is right in your opinion? Why? Can you guess how story is going to go on? What do you think? In some cases, the students had different ideas about the topics in the stories. Esra allowed them to listen to each other’s ideas and discuss them. At the end of the reading of each story, Esra then asked the students to point out the main character and summarize the story. Afterward, the students were asked to do hands-on activities or experiments from their science textbooks. While the students were working on the activities, Esra asked them to associate their findings to the stories. Following this process, further association activities took place wherein examples from daily life regarding force and motion were provided. At the end of the class, Esra and students summarized the lesson, and Esra asked questions about the stories, learning activities, and scientific concepts that were addressed.

### *Data Collection and Analysis*

Action research aims to improve the quality of teaching and learning. To achieve this goal, the teacher, as researcher, systematically works to gain insightful understanding about student learning (Capobianco, 2007). In order to achieve this, researcher’s journals, semi-structured interviews and a survey were employed in this study.

Researcher journals: Esra kept a reflective journal using a word processor. Twice weekly, right after each class meeting, she wrote her observations and her own ideas about the lesson process. The students’ behaviours, feelings and ideas about the stories, learning activities, and concepts were noted in the research journal. In addition, she described the problems that emerged in the course of teaching, as well as her action plans to eliminate these problems. The journal entries were then analysed inductively. Qualitative data analysis is an analytic progression from describing to explaining. This is usually an arduous process intended to explain a phenomenon satisfactorily to the point that it is well-understood (Miles and Huberman, 1994, p. 91). Accordingly, Esra read the journal entries several times before beginning to code them. The emergent codes were then used to interpret the students’ learning and their interest in both the scientific concepts and the HOSBSs. As a result of the analysis five categories were emerged including class attention, attention to stories, active participation, making inferences from the stories and associated activities, and responding to the questions. These categories were used to describe the class in general. Three of Esra’s journals also coded by two researchers in science education. For reliability, the percentage of agreement between the coders and Esra were calculated as 92% and 87%. It is considered very high consistency between the interrater.

Semi-Structured Interviews: After teaching each of the topics associated with the story, semi-structured interviews were conducted with three students. The students were selected based on their science achievement, including low, medium, and high achieving participants. After each simple machine section was finished, the students at different learning levels were interviewed about that section and these interviews were voice recorded. Esra asked them questions relating to the scientific concepts, stories, and learning activities. A few sample questions are as follows: “What do you know about elastic limit?”; “What was the story about?”; “What results did you get from the experiment?" and so on. One of the aims of conducting the interviews was to determine the students' understanding and whether they had any difficulties in conceptualization. Another aim was to determine whether the students were able to associate the stories with the scientific concepts that they encountered in the activities. All of interviews were first transcribed, and then inductive and descriptive analysis were used to analyze the transcripts (Miles and Huberman, 1994). For the analysis of the data obtained from the semi-structured interviews, the categories used by Abraham et al (1992) and Karataş et al. (2003) were taken into consideration. The students' responses to the interview questions were grouped in 3 categories: "Understanding," "Partially Understanding," and "Not Understanding and Missing." The scoring criteria for the comprehension levels used in the analysis of the data are given in Table 1.

Table 1. Categories Used to Analyse the Open-ended Questions

| Understanding Levels | Scoring Criteria |
|---|---|
| Understanding | The responses cover all aspects of the valid answer. |
| Partially Understanding | The responses cover one, but not all aspects of the valid answer.<br>The responses may include some incorrect explanations along with some aspects of the valid answer. |
| Not Understanding and Missing | No response.<br>Repeating the question verbatim.<br>Unintelligible or unclear response<br>Responses contain irrational or inaccurate information. |

Questionnaire: A questionnaire was employed in order to identify the students' ideas and feelings about the stories, as well as to determine any learning difficulties relating to the stories. The questionnaire included two open-ended questions: "Is there anything that you could not understand in the story? Please respond in detail;" and "What do you think about the effects of the stories that were used in the "Force and Motion" unit on your understanding of the unit?" The students' responses to the questionnaire were also analysed by describing the general patterns of the responses (Miles and Huberman, 1994).

In the analysis of the data obtained from the questionnaires, three categories were assigned according to the students' summaries of the story and their descriptions of the "Force and Motion" concepts with respect to the content of the stories. The evaluation criteria for the questions are shown in Table 2.

Table 2. The evaluation criteria of the responses to the questionnaire

| Level of Inclusion of Concepts | Analysis Criteria |
|---|---|
| Yes | All or almost all of the necessary explanations are included. |
| Partially | Included in about half of the necessary explanations |
| No | Very few or no explanations are given. |

## Results and Discussion

The analysis of the data that were obtained from the researcher journals, the semi-structured interviews, and the questionnaire were sorted into three main themes: students' conceptions and views about force and motion, views about HOSBSs, and evolution of the research process.

***Students' Conceptions and Views about Force and Motion***

The main topics covered in the “Force and Motion Unit” are flexibility and springs, work and energy, and simple machines (lever and tackle, inclined plane and gears). The analysis of the data from the teacher journals showed that the students enjoyed the topic of flexibility and springs the most, and they were willing to participate in the related activities and experiments. For example, while they were conducting an activity about the thickness of springs and their elongations, they indicated enjoying it very much. When they saw that thick springs also elongated, they were curious and added more weights to observe the limits. In the process of these activities, they were also talking about them with their peers: e.g., “Look! It extends a lot. Let’s add one more weight” and “The aluminum spring expands more than the iron one.” The students also answered questions about the activities, such as, “Is there any relationship between the elongation of a spring and the pendant weight?” or “What can we say about the relaxed force constant of springs?” and so on The students demonstrated that they could interpret the activities about the reaction force (tension) of springs; the relationship between the elongation of a spring and the pendant weight; the thickness of the springs and their elongations; or the brand of the springs and their elongations; giving examples from the activities.

In the related story, the overload force (weights) caused the spring to expand too much, leading it to fail. A class discussion took place about this to decide whether the spring failure would only occur when it expanded. Most of the students expressed that the springs would fail only if they were expanded, demonstrating that they did not consider that the springs could also fail if they were over-compressed. Similarly, while talking about the example of the springs, the students mentioned that equally expanded springs have more flexibility potential energy than compressed springs. This view reflects Yıldız’s (2008) report that students believed that “expanded and compressed springs that have equal elongation do not have equal energy.” This could account for the students’ belief that springs fail only when they are expanded, because spring expansion has more flexibility potential energy than compression.

The concept of energy is important to the understanding of the physical, biological, and technological world and bears on many situations in daily life. As such, the teaching of these concepts starts in early grades in school (Rizaki and Kokkotas, 2013). In this regard, the “Force and Motion” unit includes topics on mechanical, kinetic, and potential energy; the transformation of energy; and the transition of energy.

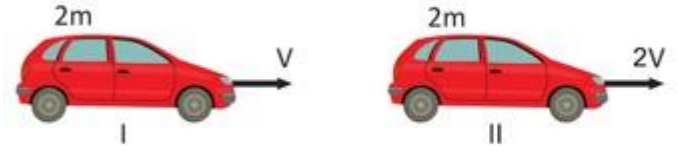
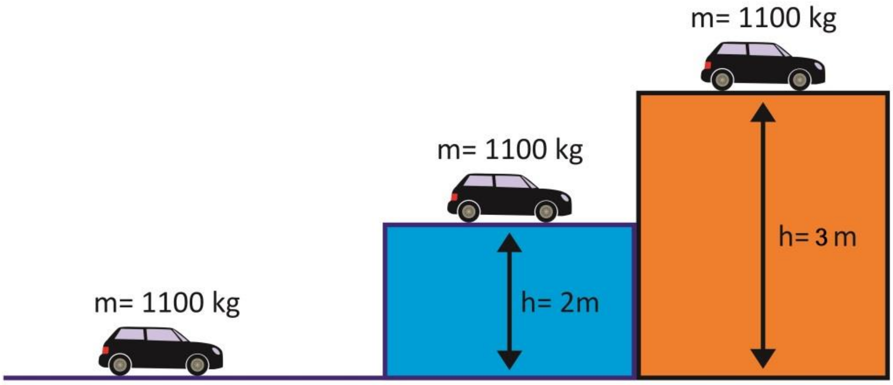



Figure 1.a. Cars with different velocity




1.b. Cars with different heights

1.c. A kid on a slide

Esra noted in her journal that "the students could interpret Figure 1.a, in that when a car runs, its kinetic energy increases; or Figure 1.b, in that a car on floor which is 4m height has more potential energy than another one on the floor that is 2m height. However, while discussing Figure 1.c, most of the students only mentioned that the character's potential energy decreases; they did not express changes in mechanical energy."

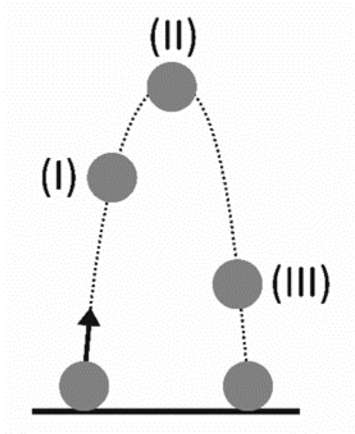



Figure 2. Vertical projectile motion

They also failed to explain the transformation of energy while a ball is thrown up and then falls down, as shown in Figure 2. While talking about this, the students looked confused when it was indicated that the speed of the ball is zero at the top (II) of the upward movement. For example, in the interview, participant Salih could express the transformation of kinetic and potential energy in the situation where a girl slides down a slide, but he could not give the correct answer that there was no energy conversion in the plane flying at a constant speed.

> Teacher: How does potential and kinetic energy change for a plane which is at constant speed?
> Salih: Potential energy changes according to gravity and height. Potential energy increases with rising height. When potential energy increases, kinetic energy decreases. Mechanical energy remains constant.

As the example shows, Salih could explain the transformation of kinetic and potential energy, but he could not associate these changes with mechanical energy. In this regard, science courses and textbooks generally focus on computational exercises, and most of these exercises pertain to frictionless situations. Thus, students may believe that mechanical energy always remains constant. Kurnaz (2007), for example, pointed out that students could not describe mechanical energy and expressed that mechanical energy can occur only if there is kinetic or potential energy. This problem may emerge from the approach to teaching the concept that energy is related to "work." When students do not understand the concept of work, they consequently have difficulties learning about energy (Hırça et al., 2011; Kurnaz, 2007).

In the lesson that included the story "James Prescott Joule and Conservation of Energy," titled, "In what conditions do we consider we are doing work?" the students easily understood the idea that applying force to an object is not considered "work" unless it moves the object, but they were puzzled and felt doubtful when an example of "walking with backpack" was presented. Kerem, for instance, asked, "We apply force to the backpack, and it moves, so why is this not work?" Esra explained the difference in terms of the direction of force and motion using drawings, as well as giving different exemplary scenarios. She deduced from the students' expressions that most of them understand the explanations, but she noted that a few students who stayed silent and had confused looks could not assimilate it. In a similarly situation, Avcı et al. (2012) found that many students mistakenly believe that "if an object moves, we are always doing work."

In the case of the concept of friction, the students believed that when friction is equal to the force applied to an object, the object would remain stable, as reported in the existing literature (Demir, 2010; Özsevgeç, 2007). In other words, many students do not believe that when friction and applied force on an object are equal, it can move at a constant speed. On the other hand, according to Aristotle's explanation, as a stationary entity continues its movement, the force which sets it in motion should continue (Yıldırım, 2011). In this case, the students' ideas about the scientific concept were very similar to those depicted in HOS (Dedes, 2005). As such, we may be able to predict the misconceptions that students might have according to HOS, thus facilitating the teaching of scientific concepts and the process of concept transition. In this regard, Solomon et al. (1992) likewise expressed that when students review the development of scientific knowledge, their conceptual development process becomes easier. They may also begin to understand that scientific knowledge is changeable, which is a tenet of the nature of science. While we did not specifically focus on the nature of science in this study, having a sound understanding of the nature of science is claimed to have positive effects on students' understanding of scientific concepts and the scientific process (Lederman, 2006). Thus, the nature of science should be deliberately integrated into the design of future research.

When the students performed the activity about gravitational potential energy, they realized that the change in potential energy depends on mass of the object, as well as on gravity. In their textbook, it is noted that "gravitational potential energy changes according to magnitude of the object and its ground clearance." One of the students asked, "why is it like that?" Esra then asked the class if someone could explain. A few students were willing to offer an explanation, but most of them were unable to distinguish the concepts of mass and weight. One student even stated explicitly said that weight is the same as mass. The reason for this misunderstanding may be that there is limited alignment between language in daily life and in science, leading students to apply the concepts incorrectly (Atasoy and Akdeniz, 2007). A further example of this issue came from Adem during the interview, he expressed that an inclined plane does not benefit from work: "On an inclined plane, we do more work, as the length of the ramp is increased, so it is tiring." In other words, Adem did not think of the concept of "work" as a scientific matter (e.g., mechanical energy), but rather applied the everyday usage of the term.

### *The Effects of HOSBSs on Students' Learning Progress*

One of the most important benefits of using stories in science education is their ability increase students' attention. Therefore, it is recommended that stories should be included at the beginning of a lesson (Yücel, 2009). Another advantage of HOSBS is illustrating to students the reasons that they should learn about a scientific concept (Klassen, 2009). For this reason, as well, we preferred to use stories at the beginning of the lessons. During the lessons, most of the students asked questions about stories; they were also willing to read them, answer the questions and work on the activities. Furthermore, they expressed that the HOSBS were both funny and educational. For instance, as Fatma reported, "I think the stories were good. It made a difference for the lesson and made it easier for us to understand the subject." Likewise, Ebru expressed, "I think the stories affected the lesson positively. They helped us understand the subject better. Thanks to the stories, I learned about the events and inventions in the history of science, and it added a lot to the lesson for me." Another student, Kerem, also indicated that "the stories affected the lesson positively and helped us understand the topic." Moreover, the responses to the questionnaire revealed that the students wanted stories to be used more often, both in science class and in other classes (e.g., mathematics and social science). Only two students expressed that science courses are enjoyable with or without HOSBS. Also asking questions about the stories, raising their hands more often to attend, class examining the figures and making comments, making jokes about the stories by showing them to each other, and laughing are always an indication that the interest in the stories is at a very good level. As such, we can state that the HOSBS increased the students' interest and participation in the science class, as with other researchers who found that stories increased students' interest and motivation in science courses (Dincel, 2005; Frisch, 2010; Klassen, 2009; Robertson and Blake, 2011).

During the lessons, the students were asked to think about the examples from daily life given by the teacher or the textbook. For example, the story of "James Prescott Joule and Conservation of Energy," narrated how a paper vibrates when it gets close to boiling pot. After they read this story, some of the students looked at the curtain hanging over the radiator and tried to observe movement. Similarly, in the "Gears" story, an example was narrated relating to the size of a wheel and the number of rotations. Afterward, many students gave the example of a tractor that has two different tire sizes, noting that the smaller tires of a tractor rotate more often than the large tires while in motion. Based on these observations, we can say that HOSBSs are effective for relating scientific concepts to daily life, supporting the existing research that recommends that abstract scientific concepts such as work, force, and/or energy should be related to daily life (Hırça et al., 2011; Uluay and Aydın, 2018). In this sense, the students were able to interpret the events that took place in their lives based on scientific knowledge and transfer their knowledge to different situations, indicating that meaningful learning took place.

In the stories, we also added some alternative ideas to the scientific concepts in the dialogues between characters. The students were allowed to have discussions about these alternative ideas and performed related activities. At the beginning, most of the students thought these alternative ideas were factual. For example, in the story of the "Inclined Plane," some workers carried huge stone blocks on a short inclined plane, while others used a longer inclined plane of the same height while building a pyramid (see Fig. 3.).

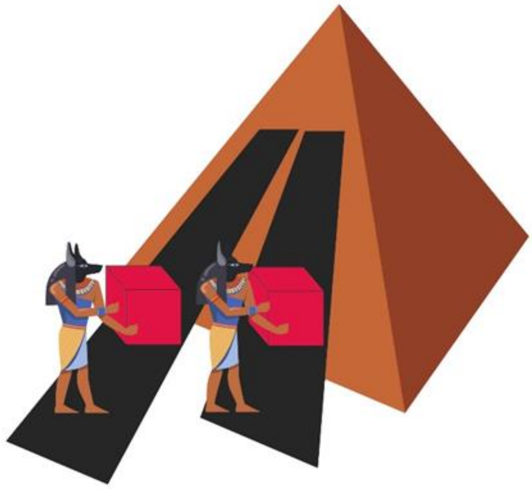


Figure 3. A depiction of the pyramid building process

In the story, it was stated that the supervisor realized that the workers on the short-inclined planes became exhausted more quickly than those on the longer one. Thus, he decided to use only long inclined planes. The main character then asks, "How can it be possible? Long inclined planes mean a longer way to travel, so this should cause the workers to get tired." While reading the story, almost all members of the class affirmed this idea by nodding their heads or saying, "Yes", or "He is right". However, after completing the activities, the students changed their minds and were able to explain why short inclined planes require more force, even though the distance is shorter. Emine, for instance, pointed out that, "When the path is short on the inclined plane, the slope is a lot higher, so too much force is required, like a very steep slope. The longer the road, the less force is applied, because the slope decreases." In this manner, we tried to prevent misconceptions and supported the students with meaningful learning. Similarly, Mantyla (2013) pointed out that seeing old and new ideas about the same subject helps students in the meaningful construction of concepts construction process. As such, Laçin Şimşek (2019) likewise asserted that teachers opt to use HOSBSs in their teaching to explain how information/knowledge has evolved.

In a similar vein, while they were reading the story "Gears" in the classroom, the students asked "(were) wheels invented like that?" showing surprise on their faces. Based on this reaction, a discussion took place about how scientists generate scientific knowledge. Most of the students confidently expressed that scientists develop knowledge by conducting experiments in laboratories, a traditional and stereotypical idea that many students hold concerning the scientific process (McComas, 1997). This idea may be rooted in experiences from science books or media (Karataş et al., 2011). To change this misconception, we should allow students to investigate scientific the development process; as Klassen (2009) and Solbes and Traver (2003) point out, HOSBSs provide an effective means to demonstrate that science consists of attempts derived from needs and curiosity.

In some cases, while reading the stories, Esra stopped or asked the students to stop in order to inquire about their views, asking questions like, "Who is right?" "What do you think about that?" "What will the result be?" "If you were (one of the characters in the story), what would you do?" The students took time to think and shared their ideas, which allowed them opportunities to solve the problems presented in the stories. In this manner, the students put themselves into the roles of the scientists to look at the cases from different perspectives. Through this interactive process, the students became active, rather than passive listeners, creating their own questions and solving problems (Mol et al. 2009). We believed that this improved the students' questioning and problem-solving skills, as well as their comprehension of the concepts (Alcantara et al., 2020; Bertiz, 2005; Dincel, 2005; Hill and Baumgartner, 2009; Klassen, 2009; Leona, 2014; Şimşek, 2006). As such, it can be said that HOSBS enhanced the quality of the teaching.

A further advantage of the stories consists of providing appropriate role models for students in the form of scientists (Tayşi, 2007). For example, during the "My Extraordinary Machine Project" provided in the science textbook, the students attempted to create a machine that transforms one type of energy into another type. Although similar activities had been provided in previous chapters to improve students' creativity, they were not interested in doing them. While studying the previous units, the students had asserted that they could only confirm already-known ideas or build replicas; they did not think they could produce something new. As such, they did not want to complete the activities; however, in the current study, the students were willing to do the extraordinary machine project. We believe that this change is related to the HOSBSs. In other words, when the students recognized Robert Hooke, Isaac Newton, John Dalton, James Prescott Joule, and other scientists in the stories, they identified with them scientists and felt inspired by them. This circumstance may encourage students to conduct projects or research.

### *Flaws in the Research Process and Readjustments*

Action research as a methodology relies on constant change and improvements to the process. In the present study, we rigorously kept track of the teaching and learning activities and attempted to correct flaws whenever it was necessary. The flaws we observed, as well as our adjustment attempts, are discussed in this section.

Esra met with her class twice a week, on Wednesday mornings and Thursday afternoons. The HOSBSs were employed at the beginning of the lessons on Wednesdays. Esra realized that after each story section, some of the students were distracted. This generally happened during the afternoon classes. To address this situation, she decided to start the class with stories on Thursday afternoons to raise students' attention.

Esra also realized that the HOSBSs increased the students' motivation, so she often associated and addressed the subjects/concepts depicted in the stories while teaching. For example, while explaining that simple machines did not provide benefits from total work, she mentioned Archimedes' statement that "Tackles makes soldiers' work easier; they can lift heavier objects they could not have lifted before" from the related story.

Another issue that Esra needed to address was the students' motivation and anxiety while reading the HOSBSs. In the first class, the students read the stories paragraph by paragraph, but they did not read with emphasis and intonation. This diminished their attention to the stories, so the approach to reading was altered from the paragraph-by-paragraph approach to character ownership. In other words, a character or a role was assigned to a student, and each student read his/her part of the story. This led to motivation and excitement in the students, and they became eager to read the stories. Almost all of the students raised their hands to ask Esra to assign a role for them. One note from the classroom observations illustrates this: “Teacher, may I be Archimedes, please?” or, “I want to be Joule”. By having roles assigned to them, they not only became eager to read the stories, but also felt closer to their characters who were scientists.

During the lessons, Esra also addressed the students’ view of the NOS and realized that they had “mythical” ideas, such as, “Scientific knowledge is absolute and unchangeable,” and “Scientists work only in laboratories.” The HOSBSs included a few examples illustrating that scientific knowledge is tentative and can change over time in light of innovative technology and research. The stories also revealed that scientists can work either inside or outside of a laboratory. In addition to the information in the stories, Esra also explained explicitly that these ideas were incorrect, using different examples. However, we did not have the specific aim of improving students’ views about the NOS. Thus, our efforts remained limited as a reaction to the students’ views during the instructional process (see Appendix 1).

## Conclusion and Suggestions

The purpose of this study was to improve students’ understanding of the concepts of “Force and Motion” by integrating HOSBSs into the teaching process. Based on the discussion, the following conclusions and suggestions have been derived. However, readers may be concerned with the limitations of the action research methodology. In this regard, Esra’s professional experience as a teacher and a researcher shall not be considered as personal and subjective, because her efforts were always monitored by the second author of this study. The following excerpts should be considered taking this into account.

(1) The HOSBSs increased students’ interest and motivation in the science course. Using these stories at the beginning of lessons helped the students recognize why they should learn these scientific concepts. The stories also improved the students’ understanding about science, scientists and the scientific process (Irwin, 2000; Solbes & Traver 2003). Laçin Şimşek (2019) also achieved that science teacher candidates believe that HOS based stories will have a positive impact on meaningful learning, interest, and motivation in the course, and understanding how science and scientists work. To further support students’ development on these topics, the nature of science should intentionally be integrated into the stories.

(2) The student interviews showed that the HOSBSs had a positive effect on students’ learning and helped them transfer the concepts of “Force and Motion” to everyday settings, as they generally cited the stories while explaining a phenomenon relating to this topic. Similarly, Jardim, Guerra & Schiffer, 2021 and Leona, 2014 achieved that HOSBSs helped meaningful learning and transfer science concepts everyday settings.

(3) Solbes & Traver (2003) expressed that in one of the reason HOS should be included in science lessons, HOS has played a role in solving tools, diseases and many problems that will make life easier. They realize that these problems are not solved by science alone but cannot be solved without science. The HOSBSs helped the students to recognize how simple machines have been developed in accordance with human needs.

These examples also enabled them to make connections between the concepts and daily life, promoting more meaningful learning.

(4) In some cases, everyday language and the language of science may have different connotations. This may lead to learning difficulties due to confusion about the meaning of terms such as mass, gravity and work. As such, it is necessary to use teaching techniques that allow students to focus on and associate daily life with scientific concepts.

(5) The students were highly interested in the HOSBSs, and they enjoyed learning in this context. They also noted that they would like to benefit from stories in other classes, as well as science. With this in mind, further studies should be conducted in other fields to integrate stories into other subjects.

(6) The action research approach allows classroom teachers to critique their instructional process. In each learning environment, teachers come across different problems. Thus, in order to identify, evaluate, and improve their practice, teachers should know more about action research. This approach should therefore be addressed in pre-service teacher training programs.

**Conflict of Interest**
On behalf of all authors, the corresponding author states that there is no conflict of interest.

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## Appendix 1. An Example of Regular Course Plan (Inclined Plane)

**Attracting Attention:** When I entered the class with the materials of inclined plane activities, the whole class began to examine what I had. After a short repetition of the previous lesson, the stories were distributed to the class.

**Motivation:** One of the few students who watched the movie "The Mummy" as soon as they got their hands on the story said, "Teacher, is this the Scorpion King in the movie The Mummy? she asked. "Yes." Another said, "Are these names real?" she asked. I said that I had chosen from among the names of important people during the Egyptian period. Emine said, "Teacher, I read somewhere that even plants grow faster than normal inside these pyramids. Is that the pyramid? How is this happening?" she asked. I shared with them some of the information I know about the pyramids. Meanwhile, the students asked, "Teacher, is that how ramps were invented?" they asked. All the students were very eager to read the characters in the story.

**Review:** We started reading by distributing the characters in the story to the students. While the story was being read, I paused where I thought necessary, read it in accordance with the emphasis and intonation, and then asked questions to the students. For example; In the story, "Each of the stones weighed an average of 2.5 tons (about a shuttle van)." After the sentence, he drew attention to this part and said, "How do you think it can be carried under the conditions of the day?" I posed the question. Usually, the voices of "So heavy stones cannot be carried" were heard, while a student in the class said, "Are they on the ramps, are they in the picture?" said. Continuing after answering "yes", "Ramps of different lengths were made to carry stones to the heights. Workers were working on both long and short ramps to move stones of the same height." I asked them to review the picture after the part. "Why do they work on ramps of different lengths, use shorter ones if they're going to go a little higher," one student said. "Why should the prepared ramps be empty, if they use all of them, their work will be finished in a shorter time." I explained. Horus said, "Is it okay? Long ramp means long road. The longer they carry those huge stones, the more tired they get." When I asked what they thought about his comment, most of them agreed with this idea, they said that they thought they would get more tired on long journeys. When they read the rest of the story, they were surprised, the students looked at each other and me and said, "Is it okay?, How so? They were asking questions like I said let's try and see with the activity we are going to do. On the one hand, while setting up the inclined plane assembly on the table with the materials, "Who will summarize the story for me?", "What was being told in our story?" When I asked, almost half of the class raised their hand to answer. I gave 2 students the right to speak. After the students' explanations, when I asked them how did you like the story, some of the answers were; "Yes, I liked it very much." I like." was in the form.

**Learning Activities:** We did a simple activity using glass plates, wooden wedges, dynamometers and books. First, we created inclined planes by placing 5 books on top of each other and placing long glass plates on one and short glass plates on the other. We drew identical wooden wedges on both inclined planes with the help of dynamometers and noted the readings of both dynamometers on the board. What were we thinking when we first read the story when we saw that the force in the long inclined plane is smaller than the force in the short inclined

plane in the objects raised to the same height?, Who was right in the story?, Why? When I asked them, they stated that they saw at the event that the foreman was telling the truth. We added 3 more books to the bottom of the long glass plate and increased it to a total height of 8 books, and made a new measurement with a wooden wedge and dynamometer and noted the value we reached on the board. When I asked them to evaluate the forces applied on the inclined planes that we created from the long glass plate with 5 books and 8 books, after comments such as "The higher the force is, the greater the force", we all came to the conclusion that the applied force increases as the height increases in the inclined planes of the same length. Drawing two paths on the board, "There are two slopes to go to the upper quarter, which one is more difficult to get out in front of you?" when I asked him, "It is more difficult to go up a steep slope, the force was more when there were 8 books." i got the answer. I emphasized that the inclined plane is a simple machine that causes loss of path while gaining strength, so that more force is applied on short inclined planes than on long inclined planes. After explaining that the force applied to the object increases as the height increases in the inclined plane, I drew an inclined plane on the board and solved an example by explaining the inclined plane formula on the figure. While explaining on the figure in the book that the ax is an example of a simple machine consisting of two inclined planes, I added that the bottom of the ships is formed by the combination of two inclined planes, and this feature makes it easier to move through the water. I unscrewed it from one of the student desks and showed the screw, indicating that the screw was an inclined plane wrapped around a rod. By showing the screw to the students, I showed them the way on the board and asked them to watch me as I put it in the queue. They saw how many times I turned the screw so that it took a very short path, "What would change if it were a nail and not a screw?" "It would sink right away, but we used to apply a lot of force with a hammer, not with our hands."
**Evaluation:** "What kind of a simple machine is the inclined plane?", "What is the relationship between the length of the inclined plane and the applied force?", "What is the relationship between the height of the inclined plane and the applied force?" questions were asked and the students answered correctly. Then, the students solved the 3 questions I asked the class about calculating the force or load on the inclined plane. Almost the entire class was raising their hands to stay on the board for the solution of the questions. The lesson ended with the bell sound.