ORIGINAL ARTICLE

The Effect of the Application of STEM Based on the 6E learning model on Student Science Achievement

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Abstract: This study aims to examine the academic achievement of sixth-grade students and their perceptions of the learning process through STEM activities implemented using the 6E Learning Model in the 'Force and Motion' unit of the sixth-grade Science curriculum. In this context, to achieve the learning objectives of the "Force and Motion" unit, students participated in STEM activities guided by the 6E Learning Model for two weeks (eight lesson hours). A mixed research design was used in the study. The study was conducted in a public school located in a district of a major city. The sample was selected using purposive sampling. A total of 83 students from four randomly selected classes were included in the study, forming the experimental group (n=42) and the control group (n=41). An achievement test was used to collect quantitative data, and five open-ended questions regarding the 6E Learning Model-based STEM activities process were used to gather qualitative data. The independent-samples t-test was used to analyze the quantitative data, and descriptive analysis was employed for the qualitative data. The analyses indicated that the mean achievement scores of the experimental group were significantly higher than those of the control group. This quantitative finding was supported by the students' positive views on the 6E Learning Model-based STEM activities.

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Introduction

IT IS AN era of rapid change, development and diffusion of information and technology, which has led to the prevalence of its challenges. In fact, this situation leads to the prevalence of educational problems. For this reason, global goals also come to the fore in education, the most prominent of which are the individual's taking responsibility for their own learning, learning to make things and to do things together, and learning to live together in harmony (Nicolescu, 1999). In alignment with these goals, the main purpose of education is to prepare individuals for real-world scenarios and the complex problems they entail. Achieving this requires the simultaneous and integrated application of diverse skills across various fields (Styron, 2013). Corresponding to these evolving purposes, many new learning and teaching approaches, models and theories are being developed (Flogie & Aberšek, 2015; İnci & Kaya, 2022). These new approaches in education are based on the requirements and expectations of the 21st century (Gelen, 2017). Conventional teaching methods, where disciplines such as science, mathematics, and engineering are often taught in isolation, are insufficient to equip individuals with the 21st-century skills necessary for real-world problem-solving. Therefore, in updating new approaches, it has become important to ensure that a discipline is taught together with multiple disciplines, and many curricula are reorganized and updated according to interdisciplinary teaching (Uştu & Mentiş Taş, 2020). For example, in Türkiye, the curricula last updated by the Ministry of National Education (MoNE) in 2024, an interdisciplinary science teaching is planned in which students can make sense of themselves, their environment and the world by realizing that they are a part of the environment. Furthermore, the revised curriculum adopts an integrative teaching approach that incorporates skills and values education, focusing on an understanding based on Science, Technology, Engineering, and Design (MEB, 2024).

STEM, which is used in interdisciplinary education, is a concept that is frequently used and researched worldwide (Gonzalez & Kuenzi, 2012). STEM is an effort to solve real world problems by integrating interdisciplinary approaches with 21st century skills (Stohlmann et al., 2011). STEM instruction aims to foster essential skills such as creative, innovative thinking, and collaborative entrepreneurship (Obarski et al., 2013). Bybee (2010) stated that STEM, which generally focuses on the fields of science and mathematics, including engineering and technology, is a collaborative working philosophy based on putting knowledge into practice by providing students with comprehensive and meaningful real-life experiences. Sirajudin and Suratno (2021) stated that the STEM learning approach will lead to active and integrated learning due to the interrelationship between the four elements (Science, Technology, Engineering, Mathematics) that are needed and compatible to solve the problems presented to students, and enhances learning by helping students connect abstract concepts from different dimensions to understand the problem's core information.

Consequently, the integration of STEM into learning environments is critically important. When the literature is examined, there are many studies on the difficulties and problems experienced in the integration of STEM into curricula and learning processes. Hsu and Fang (2019), in their research on STEM, emphasized that STEM integration is one of the main challenges they face arguing that it necessitates the development of exemplary practices and targeted teacher training to help practicing teachers design their teaching plans. Kennedy and Odell (2014), in their study, mentioned the challenges of developing effective curricula that tightly integrate the four elements of STEM and providing teachers with adequate professional development trainings to help students gain STEM literacy. In Turkey, STEM research in the last 10 years has shown that the most fundamental problem is the integration of STEM fields into the curriculum, followed by the lack of STEM content knowledge of educators and problems such as equipment, lesson planning, and time management (Altunel, 2018; Örgüt, 2022).

In the studies, it is emphasized that students are less likely to use all four STEM disciplines by taking into account the knowledge and skills of all four STEM disciplines due to the fact that applied STEM activities in the general curriculum mostly focus on science and mathematics disciplines, emphasize technology and engineering disciplines less than the other two disciplines, and technology and engineering elements cannot be actively included in the process (Bybee, 2010; Hsiao, Chen, Chang, et al., 2024).

In this context, Katehi, Pearson, and Feder (2009) stated in their study that the presence of technology and engineering in K-12 applications of STEM is very low and insufficient in career planning and contributions to society, and that it is extremely important to emphasize the T (Technology) and E (Engineering) in STEM for a real innovation. Students must engage in an interdisciplinary structure to fully grasp the necessary knowledge and manage the process of solving problems that involve authentic engineering design (Moore et al., 2014). For this reason, combining activities involving engineering design and active scientific inquiry process in STEM applications will facilitate the integration of STEM into learning environments (Hacıoğlu & Gülhan, 2021; Roehrig et al., 2021). At this point, a systematic and sequential learning model is needed to lead all components of the STEM curriculum at the same time (Hsiao et al., 2024).

As a learning model that can integrate STEM practices into the curriculum, the 6E learning by DeSIGN Model was proposed by Barry N. Burke of the International Technology and Engineering Educators Association (ITEEA) in 2013. This model is derived from R. Bybee's (1997) 5E learning cycle model, which is based on constructivist learning theory in which students gradually build a framework of knowledge in the learning process and use discovery, discussion, research and application activities. The 6E Learning Model is utilized to enhance students' design and technological inquiry abilities and to implement interdisciplinary STEM practices through student-centered activities. Furthermore, it specifically emphasizes the importance of individual motivation and the desire to learn, factors that significantly influence learning performance (Lin et al., 2020; Sanjayanti, Rustaman & Hidayat, 2019). The 6E learning model has an effective design that emphasizes real-world problems, successfully solves the problem of the lack of a serial and sequential STEM curriculum (Burke, 2014; Hashim et al., 2018; Hsiao et al., 2024). In this respect, the 6E model places more emphasis on the transfer of learned knowledge compared to the 5E model. The sequential steps of the 6E model help students to reinforce their learning one after the other and to think and develop ideas (Lin & Chiang, 2019).The 6E learning model is both a practical model that provides educators with strategies that can be implemented at the classroom level, and a framework for policy makers that has the potential to improve learning outcomes and develop 21st century skills (Hsiao et al., 2024).The six steps of the 6E model are as follows:

1. Engagement: Arousing students' curiosity, interest and engagement by creating connected experiences through real-life situations.
2. Explore: Providing opportunities for students to explore themselves, to build their own understanding of the problem as they collect data about it, and to make sense of the data they collect.
3. Explain: Enabling students to rethink what they have learned and to construct knowledge, realizing this through their own explanations.
4. Engineering: To clarify concepts through practical work and integrate knowledge and skills. To be able to understand and solve a problem in greater depth.
5. Enriching: Providing students with the opportunity to enrich their knowledge by exploring what they have learned in depth and applying what they have learned to more complex problems.
6. Evaluation: To evaluate students' learning using alternative assessment techniques. Keep students and teachers informed of students' learning progress in order to facilitate future improvement (Burke, 2014).

Research on 6E-STEM applications has consistently shown their effectiveness in improving students' learning performance, efficiency, attitude, motivation, creativity, hands-on performance, practical skills, and willingness for self-discovery (Hsiao et al., 2023; Lin et al., 2020; Şahin & Kılıç, 2023). Sanjayanti, Rustaman, and Hidayat (2019) emphasized that learning with STEM Applications based on the 6E Model can improve logical thinking and reasoning skills, and allow for process-oriented and gradual deepening of learning. Şahin and Kılıç (2023) found that students improved their research skills (including data collection, analysis, and solution generation), developed a positive attitude toward collaboration, and perceived the model as both effective and enjoyable. Furthermore, Yazıcı, Hacıoğlu, and Sarı (2023) stated that the engineering and technology dimensions used consciously in STEM Applications based on the 6E Model contributed to students' STEM attitudes and STEM career interests. Lin et al. (2020) conducted a comparative study between 6E-focused STEM applications and Problem-Solving (PS)-based STEM applications, focusing on middle school students' attitudes toward technology and technological inquiry skills. They found that the 6E model's effect was more pronounced in students with high levels of prior knowledge, particularly regarding attitudes toward technology. While the research concluded that both the 6E model and the problem-solving approach are effective in classroom STEM applications, it suggested that 6E activities should be more selectively designed for optimal efficiency. They also noted that the 6E model offers more guidance for teachers during the process, whereas PS-based STEM activities are more flexible and time-based.

The aim of this study is to investigate the effect of 6E Learning Model-based STEM activities on students' academic achievement and to explore students' perceptions of this learning environment. This research is significant as it provides an empirical example of the 6E model's application—a model designed to integrate STEM disciplines into the curriculum—and examines the effectiveness of this specific integration on student learning outcomes.

Method

In this study, sequential explanatory design, one of the mixed method research designs, was used. In this design, quantitative data are collected and analyzed first, followed by the collection and analysis of qualitative data. The goal is then to interpret the relationship between the two datasets and establish their supportive nature (Baki & Gökçek, 2012). For the quantitative dimension, a pre-test/post-test quasi-experimental control group design was utilized to investigate the effect of 6E Learning Model-based STEM activities on student achievement related to unit learning outcomes. Comparative analysis of the collected data was made in SPSS program. The qualitative dimension of the research was carried out with a case study design and students' opinions and ideas about learning environments containing 6E Learning Model Based STEM Practices were taken. The analysis of qualitative data was carried out using thematic analysis method. The analysis followed a rigorous process based on a coding framework developed by the researcher. First, meaningful expressions were identified from the student opinions. Next, these expressions were comparatively grouped by two researchers based on similar characteristics to generate initial codes. Finally, these codes were organized into higher-level structures, which served as the themes. An inductive approach was adopted during coding, ensuring fidelity to the data set. Each code was substantiated with sample quotes (opinions), and their frequency distributions were calculated and reported. The resulting codes, themes, and sample opinions are presented in the Findings section (Çarıkcı et al., 2024).

Study Groups

The population of the study consists of middle school students in a public school in a district of a large city. One public school in the district was selected for the study through purposive sampling. Two of the sixth-grade groups at the school were randomly selected as the experimental group (42 pupils) and two as the control group (41 pupils). A total of 83 pupils were included in the study.

The research was conducted with the necessary ethical and administrative approvals obtained from the relevant institutions and authorities. Prior to the start of the study, all participants and their legal guardians were informed about the purpose and procedures of the research, and their informed consent was obtained on a voluntary basis.

Data Collection Instruments

In the study, a 20-item achievement test developed by Özer (2019) within the scope of the 6th grade "Force and Motion" unit was applied to students in the experimental and control groups as a pre-test and post-test. The necessary permissions for the use of the achievement test were received via e-mail. For the validity of the achievement test, it was evaluated by two faculty members from Ege University in terms of content validity and measurement and evaluation criteria. The difficulty levels (Pj) and discrimination indices (Rjx) of the items in the achievement test were analyzed, and the Pj values of the test items ranged from 0.33 to 0.80. When the question difficulty levels were grouped; 3 items ($Pj \leq 0.40$) were determined as difficult, 9 items ($0.40 < Pj < 0.60$) were determined as medium difficulty, and 8 items ($Pj \geq 0.60$) were determined as easy. The KR-21 value for the reliability of the achievement test was calculated as 0.82, and since this value is greater than 0.70, it has an appropriate reliability (Büyüköztürk, 2018).

In the qualitative part of the study, after content validity was established based on the opinions of two academics, data were collected by asking four open-ended interview questions to students in the experimental group. The collected qualitative data were coded by two researchers, and an intercoder reliability coefficient of 0.92 was reported using Cohen’s Kappa (Қ).

Table 1. Experimental Group - 6E Learning Model Based STEM Practices.

	Engage	Explore	Explain	Engineer	Enrich
Week 1	Students are encouraged to think about the observable effects of force through in-class applications.	Students are encouraged to explore concepts such as balanced force and composite force by playing the 'Rope Game'.	Discussions lead to clarification of concepts by drawing attention to errors with student explanations.	Bridge Design STEM Group Work	Developing design bridges over new situations
Week 2	Making and flying paper airplanes, question and answer work on their movements	Speed experiment with 'Handkerchief Grab' game	By drawing attention to errors with student explanations, discussions lead to clarification of concepts.	Balloon Rocket Design STEM Group Work	Design rockets work on developing new cases

Table 2. Control Group - 5E Learning Model.

	Engage	Explore	Explain	Elaborate	Evaluation
Week 1-2	Question-answer through examples for the concepts of force and motion	Experiments through examples for the concepts of force and motion	Student explanations draw attention to errors and lead to clarification of concepts through discussions.	Solution of sample problems related to the concepts learned and question-answer	Process-oriented study questions

Application Process

Before starting the research process, a 6E Learning Model Based STEM Practices lesson plan (**Table 1**) for the experimental group and a 5E lesson plan (**Table 2**) for the control group were prepared in line with the relevant outcomes of the selected scientific subject. Then, the total duration for the application process of the research was determined as 3 weeks (2-weeks application, 1-week pre-test, post-test, and interview process).

Before the lesson plans were applied to the experimental and control groups determined for the research, the achievement test was applied as a pre-test. Then, the application was carried out in line with the lesson plans. In the first lesson, after the end of the implementation process of the lesson plans, the achievement test was applied to the experimental and control groups as a post-test. The answers given to the achievement test and interview questions were evaluated by the researcher through descriptive content analysis. The data collection process is given in **Table 3**.

Table 3. Data Collection Process.

Experimental Group	Pre-Test (Force and Motion Academic Achievement Test) (1 Class Hour)	6E Learning Model Based STEM Practices (2 Weeks)	Post-Test (Force and Motion Academic Achievement Test) (1 Class Hour)	Experimental Group Interview Questions (1 Class Hour)
Control Group				

Table 4. Tests of Normality.

	Groups	Kolmogorov-Smirnova			Shapiro-Wilk		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Pre-Test	**Total**	0.084	83	0.200	0.978	83	0.160
	Experimental Group	0.142	42	0.033	0.951	42	0.071
	Control Group	0.126	41	0.100	0.974	41	0.461

Data Analysis

Within the scope of the research, normal distribution test was first performed for the data obtained in the achievement test. For the normality test, some researchers suggest using the Shapiro-Wilk test when the number of experimental and/or control groups is below 50 and the Kolmogorov-Smirnov test when the number is above 50 (Razali & Wah, 2011), while some researchers argue that this number should be 30 (Mayers, 2013). Since the experimental group in our study consisted of 42 students and the control group consisted of 41 students, we used both Kolmogorov-Smirnov and Shapiro-Wilk tests and the analysis values showed normal distribution for both tests (P=020>0.05 and P=016>0.05).

Content analysis was performed for qualitative data. In this process, the data were first coded, themes were created, codes and themes were organized, and the findings were defined and interpreted (**Table 4**).

Findings

The results of the analysis of the data obtained through data collection tools are presented under two main headings.

Table 5. Pre-Test of Independent Samples t-test Results.

Pre-test	Levene's Test for Equality of Variances		t-test for Equality of Means					95% CI	
	F	Sig.	t	df	Sig. (2-tailed)	Mean	Std. Error	Lower	Upper
Equal Variances Assumed	2.39	0.12	-0.47	81	0.63	-1.98	4.16	-10.25	6.29
Equal Variances not Assumed			-0.48	79.1	0.63	-1.98	4.15	-10.24	6.27

Table 6. Post-test of Independent Samples t-test results.

Post-test	Levene's Test for Equality of Variances		t-test for Equality of Means					95% CI	
	F	Sig.	t	df	Sig. (2-tailed)	Mean	Std. Error	Lower	Upper
Equal Variances Assumed	0.352	0.555	2.82	81	0.006	12.4	4.39	3.66	21.15
Equal Variances not Assumed			2.82	80.8	0.006	12.4	4.38	3.67	21.14

Findings from the Achievement Test

Since the achievement test data showed normal distribution, it was decided to use the independent group's t-test, one of the parametric hypothesis tests. As a result of the t-test analysis conducted to understand whether the achievement of the students in the experimental and control groups on the scientific subject before the application of the 6E Learning Model Based STEM Practices and 5E learning model were equivalent to each other, it was seen that the groups were equivalent to each other. The mean pre-test score of the experimental group was 46.19 and the mean post-test score of the control group was 48.17. There is no statistically significant difference between the pre-test mean scores of the experimental and control groups (t=-0.476, p=0.635>0.05). This shows that the students of both groups have equivalent prior knowledge of the "Force and Motion" unit (**Table 5**).

The average post-test score of the experimental group was 71.31 and the average post-test score of the control group was 58.90. There is a statistically significant difference between the post-test mean scores of the experimental and control groups (t=2.824, p=0.006<0.05) (**Table 6**). This situation

Table 7. Effect Size Calculated According to the Posttest Results

Test Type	Group 1 (Experiment)	Group 2 (Control)	Difference Between Averages	Pooled SD	Cohen's d	Effect Size
Posttest	71.31	58.90	12.41	20.00	0.62	Intermediate

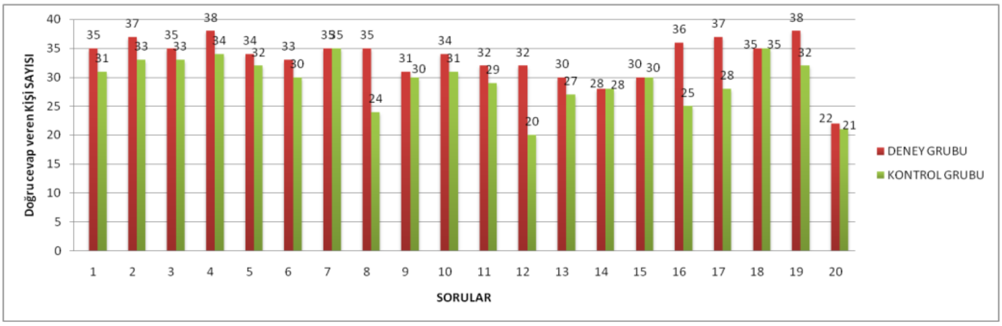

Figure 1. Number of Students Answering Correctly to the Achievement Test in the Experimental and Control Groups.

shows that 6E Learning Model Based STEM Practices are more effective than 5E learning model in students' learning the subjects within the scope of the "Force and Motion" unit.

According to the posttest results, the mean score of the experimental group (M = 71.31) is significantly higher than the mean score of the control group (M = 58.90) (p = 0.006). According to the posttest results, the calculated effect size was found as Cohen's d = 0.62 (**Table 7**). This shows that STEM applications based on the 6E learning model have a moderately positive effect on student achievement compared to the 5E learning model (Cohen, 1988). This finding suggests that the 6E model contributes to students' more active participation in the learning process and their deeper learning.

When the responses to the achievement test were analyzed individually, the questions showing the largest differences in the number of correct answers between the experimental and control groups were questions 8, 12, and 16 (**Figure 1**) (see **Appendix I**: Sample Questions of the Achievement Test). This may be attributed to the fact that the problem situations in these questions were the focus of the 6E Learning Model-Based STEM Applications in the experimental group, with extensive activities facilitating concept

Table 8. Student views on the learning contribution of 6E Learning Model Based STEM Practices.

Code		Sample	N	%
Effective & Permanent Learning		S17: I think I have grasped the subject, it is more memorable, we can do these things and always remember them rather than writing them in a notebook and reading them.	10	23.8
Ease of Learning	By design and implementation	S8: It helped me to understand the subject more easily with the activities we did (making rockets).	10	23.8
	Having fun	S27: Yes, it was both instructive and very fun, especially making rockets was fun.	5	11.9
	In cooperation	S3: Yes, we learned both the subject and how to learn through cooperation.	7	16.7
Contribution to Thinking Skills		S39: It helped thinking and generating ideas.	10	23.8

learning. The experimental group answered questions 4 and 19 correctly most frequently (38 students), whereas the control group most frequently answered questions 7 and 18 correctly (35 students). Notably, the control group did not outperform the experimental group on any question. The most challenging question for the experimental group was question 20 (answered correctly by 21 students), while the control group struggled most with questions 12 and 20 (see **Appendix I**: Sample Questions of the Achievement Test), possibly due to difficulties with unit conversions in the mathematical content of the questions.

Findings Obtained from Interview Questions Regarding 6E Learning Model Based STEM Practices

After the 6E Learning Model Based STEM Practices, the students in the experimental group were asked 4 open-ended questions to analyze their opinions about these experiences. The first question "Did teaching in this way contribute to your learning? Briefly explain", all of the students' opinions were positive. The codes for their explanations were "effective and permanent learning" (23.8%), "ease of learning" (52.4%), and "contribution to thinking skills" (23.8%) (**Table 8**).

When the students were asked the question "How did you feel while teaching in this way, how does it feel to teach in this way?", 97.6% of the answers consisted of positive emotions. The most common response was "Excited and joyful" with 50%, followed by "Willingness to learn" with 33.3%. Only one of the experimental group students (2.4%) mentioned a negative emotion such as "Being challenging" (**Table 9**).

Table 9. The emotional states about 6E Learning Model Based STEM Practices Lesson.

Theme	Code	Sample	N	%
Positive Emotions	Excited & Joyful	S41: I felt excited while teaching, I felt like an engineer.	21	50
	Willing	S17: I felt that my desire to learn increased, this is a very nice feeling	14	33.3
	Surprising	S29: It was very nice to cooperate with my friends and surprisingly I never wanted the lesson to end.	6	14.3
Negative Emotions	Challenging	S5: It was very difficult for me to work with the group in this way.	1	2.4

Table 10. The benefits of group work during 6E Learning Model Based STEM Practices Lesson.

Theme	Code	Sample	N	%
Communication & İnteraction	Idea Sharing	S4: Since everyone thought differently, we shared and thought about the ideas in the group.	5	12
	Active Resting	S22: We learned both teamwork and taking turns to listen to each other even though it was difficult (active listening).	5	12
Social Skills	Cooperation	S1: We also learned to work together and we succeeded together (cooperation).	22	52.3
	Conflict Resolution	S38: First, we had many ideas, but then we combined these ideas and created the best idea (conflict resolution).	4	9.5
Fun & Positive Experience	Enjoyment	S9: It was fun, we learned very well (enjoyment while learning).	6	14.2

Table 11. The Negative Aspects of 6E Learning Model Based STEM Practices Lesson.

Theme	Code	Sample	N	%
Negatives Exist	Technological challenges in product creation	S42: We could not adjust the weight of our rocket and the balloon exploded.	6	14.3
	Tiredness	S33: We tried too much, I got a little tired	2	4.8
	Disharmony among groupmates	S15: The work of some people in group work was not sufficient	7	16.5
	Physical conditions of the learning environment	S18: There was a lot of noise	1	2.4
No Negatives			26	62

When the students were asked the question “What are the benefits of group work while teaching in this way?”, the themes of “Communication and Interaction”, “Social Skills” and “Fun and positive experience” were reached as a result of their answers. The frequency of occurrence of the codes belonging to these themes is explained in **Table 10**.

When the students were asked the question “What are the deficiencies/negatives you have seen or experienced while learning in this way?” 62% of the experimental group students answered that there were no negative situations. Of those who thought that there were deficiencies/negatives situations, 14.3% stated "technical problems in product creation", 4.8% "fatigue", 16.6% "incompatibility within the group", and 2.3% "physical conditions of the environment (sound)" (**Table 11**).

Conclusion and Discussion

The theoretical framework of this activity is based on the classical thesis of 'learning by doing' (Dewey, 1952), which is also reflected in constructivism (Piaget, 1969; Vygotsky, 1978). In constructivist learning theories (Bruner, 1986, 1990; Piaget, 1969), learning is the construction of the whole process in which a person is involved and experiences. Moreover, according to Bloom's taxonomy (Forehand, 2005), education based on 'learning by solving problems' paradigm is considered as the most effective process of acquiring knowledge (Burbaite et al., 2012). In this study, 6th grade students were asked to make a real design related to the subject and to develop their designs by experimenting in order to fulfil a task involving the process of 'learning by problem solving' in STEM Applications based on the 6E learning model during the teaching of the concepts of the 'Force and Motion' unit within the scope of the science course, and the effects of the process on the students' academic achievement levels and their views on the application process were examined.

In this context, in the study with experimental and control groups, it is seen that there is no significant difference between the pre-test scores of both experimental and control groups, the groups are equal in terms of achievement level, and when the post-test scores after the lessons are examined, it is seen that the achievement scores of the experimental group students are significantly higher, and 6E Learning Model Based STEM Practices affect learning more positively. STEM practices based on the 6E model are likely to have increased the learning effects of the experimental group students (Love & Deck, 2015; Štuikys & Burbaitė, 2018), because students' ability to think systematically and integrate content into the design process in a purposeful and informed way provided a student-centered framework for teaching (Burke, 2014; Hashim et al., 2018). While students generally carry out hands-on, task-oriented activities such as creating a design in design-based or project-based STEM Practices, with 6E learning model-based STEM Practices, students learned how to use and develop their designs by integrating the knowledge they learned into their designs in practice, and this facilitated the learning and application process of students by strengthening the interdisciplinary connection (Burke, 2014; Hsiao et al., 2022).

There are many experimental studies in the literature that support this research result. In their study, Hsiao et al. (2022) used robot-based applications based on the 6E model in teaching "Arduino electronic components" in

6th graders and concluded that learning performance, motivation and application skills showed significantly more improvement in students who were subjected to 6E-oriented applications.

Lin, Lin, Wang, and Wu (2023) investigated the effects of applying 6E Learning Model Based STEM Practices to VR lessons on learning outcomes, motivation, creativity, and learning satisfaction of middle school students with different cognitive styles. They drew attention to the effect of 6E Learning Model Based STEM Practices on cognitive styles and stated that serialist learning style (active, deep, and sequential learning) is more advantageous in this context and that they show higher performance as learning achievement. Çakmak (2007) mentioned in his study, systematic guidance of cognitive resources through activities and supporting them with effective teaching materials provide active participation and meaningful learning by balancing the cognitive load. In this context, learning efficiency can be increased by balancing the cognitive load during the transfer of complex STEM concepts to students in the 'Explanation' and 'Deepening' steps of the 6E model. Şahin and Kılıç (2023) used the 6E Learning Model to examine the effects of the 6E Learning Model on the learning skills, opinions and values of first-year university students in the "Character Development and Values Education" course and stated that there were significant positive changes in students' learning skills and acquisition of new values. In this context, it can be said that the 6E learning model integrates the "T and E" of STEM better than the different teaching models that have been used for years, and since 6E has a systematic and holistic structure, teachers can easily develop and implement STEM activities in the 6E model (Yazıcı, Hacıoğlu, & Sarı, 2023).In addition, Burke (2014), while defining the Engineering step of the 6E Learning model, underlines that students use inquiry-based learning approaches to make informed design decisions in their solutions and systematically integrate this with engineering concepts.

Within the scope of the research, after the achievement levels of the students were examined, the opinions of the entire experimental group about the 6E Learning Model Based STEM Practices were taken and, in this direction, it was seen that the students emphasized the positive aspects of this course such as that it was fun, caused effective and permanent learning, and facilitated learning through collaboration and design. These views expressed by the students are in line with Styron's (2013) statement that the use of models that encourage students to engage in interdisciplinary learning develops communication skills, collaboration, creativity and positive feelings about learning. Moreover, in Şahin and Kılıç's (2023) study on the effectiveness of the 6E model, students stated that they were satisfied with making products and that they found the model effective, exciting and fun. While STEM applications based on the 6E learning model increase students' motivation and encourage their active participation in learning, they also contribute to the development of self-regulated learning skills through their student-centered structure and systematic stages (Burke, 2014; Sanjayanti et al., 2019; Yazıcı, 2019). This synergy between motivation and self-regulated learning can positively affect students' learning success in the STEM field and their views on the learning environment.

In another study Yazici, Hacıoğlu, and Sari (2023), students' views on 6E-based STEM activities were stated that the activities made the learning process fun and effective, increased their interest in the course and improved their various skills. Like in our study, although the majority of the students who expressed their opinions in the study mentioned the positive aspects of the activities, a few negative opinions were also expressed, such as process-oriented strain, tiredness, in-group conflicts and environment-oriented noise level.

These opinions expressed by the students can be seen as the reasons for these difficulties, as stated in Yazıcı's (2019) study, that they are experiencing 6E-oriented STEM activities for the first time and that students lack time management and teamwork. If these design-oriented activities are implemented sequentially and frequently in the curriculum, students will gradually ease the complexity of applied tasks, and their knowledge and skills will gradually strengthen, enabling them to produce easier products (Hsiao et al., 2024).

Another notable finding of the study is the responses of the experimental group students, which indicate their acceptance of the 6E Learning Model-based STEM practices, even though they were performing these activities for the first time and encountered some difficulties. In contrast, it was found that, despite recognizing several positive effects—such as increased effectiveness, enjoyment, and facilitation of collaborative learning—teachers were reluctant to integrate these applications into their lesson plans. Previous studies suggest that this reluctance may be due to challenges such as ineffective time management, deficiencies in measurement and evaluation planning, difficulties incorporating design and engineering activities into lessons, and concerns about classroom management (Nuangchalerm, 2018). In the 6E model, the student has a role that investigates questions and experiences (Şahin & Kılıç, 2023). However, as Harman and Yenikalaycı (2021), stated in their study, it takes both time and experience for teachers to effectively plan and implement each stage of the model. This may create an extra burden on the teacher in terms of classroom management and the time allocated to the program.

As a result, the 6E Learning Model Based STEM Practices made a positive difference in the success of the students and created positive feelings and thoughts towards the process. The fact that students remained active in each step of the 6E learning model facilitated STEM applications and played an important role in increasing success by providing a design-oriented approach to daily life problems in line with the concepts they learned.

Limitations of the Study

There are some limitations that should be considered when interpreting the findings of this study. Firstly, as the sample was limited to a single state school with only 83 sixth-grade pupils, the generalizability of the results is restricted. Furthermore, the intervention period was relatively short (two weeks) and covered only the 'Force and Motion' unit; therefore, the long-term effects and learning retention of 6E-based STEM applications could not be examined. The fact that the intervention was conducted by a single teacher can be considered another limitation that may have affected the teaching practice and classroom management. Qualitative data were collected using only five open-ended questions, limiting the depth and diversity of students' views. Finally, the fact that students were experiencing 6E-based STEM applications for the first time suggests that process-related difficulties such as group inconsistency, noise levels, and time management may have affected the learning experience.

Recommendations

Based on the findings of the study, the following recommendations can be made:

- As the application period was short, future studies should be planned to examine long-term effects and learning retention.
- As the study was limited to the 'Force and Motion' unit, the scope could be expanded to include the outcomes of other science units.
- As this study was conducted only on Year 6 students, it could be diversified to evaluate learning effects in different age groups.
- The demographic characteristics of students, such as socio-cultural and economic factors, could be included in the study to examine the effects in different contexts.
- The literature shows that the 6E learning model is not limited to STEM fields; it can be successfully adapted to various disciplines, values education, entrepreneurship education, and general student-centered approaches. The structured stages of the model provide a flexible framework for achieving different educational goals by encouraging student participation. Therefore, it is recommended that studies on the 6E learning model be expanded.

References

Altunel, M. (2018). STEM eğitimi ve Türkiye: Fırsatlar ve riskler [STEM education and Turkey: Opportunities and risks]. SETA. Available at: https://www.setav.org/stem-egitimi-ve-turkiye-firsatlar-ve-riskler/

Baki, A., & Gökçek, T. (2012). Karma yöntem araştırmalarına genel bir bakış [An overview of mixed method research]. Elektronik Sosyal Bilimler Dergisi, 11(42), 1–21. Available at: https://dergipark.org.tr/tr/pub/esosder/issue/6156/82721

Burke, B. N. (2014). The ITEEA 6E Learning ByDesign™ model: Maximizing informed design and inquiry in the integrative STEM classroom. Technology and Engineering Teacher, 73(6), 14–19. Available at: https://eric.ed.gov/?id=EJ1049196

Büyüköztürk, Ş. (2018). Sosyal bilimler için veri analizi el kitabı (24. baskı) [Handbook of data analysis for social sciences (24th ed.)]. Pegem Akademi Yayınları.

Bruner, J. S. (1986). Actual minds, possible worlds. Cambridge, MA: Harvard University Press

Bruner, J. S. (1990). Acts of meaning. Cambridge, MA: Harvard University Press.

Burbaite, R., Stuikys, V., & Marcinkevicius, R. (2012). The LEGO NXT robot-based e-learning environment to teach computer science topics. Elektronika ir Elektrotechnika, 18(9), 113–116. https://doi.org/10.5755/j01.eee.18.9.2825

Bybee, R. W. (1997). Achieving scientific literacy: From purposes to practices. Heinemann.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. Technology and Engineering Teacher, 70(1), 30–35. Available at: https://eric.ed.gov/?id=EJ898909

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Çakmak, E. K. (2007). Çoklu ortamlarda dar boğaz: Aşırı bilişsel yüklenme[Bottleneck in multimedia environments: Excessive cognitive load].Gazi Üniversitesi Gazi Eğitim Fakültesi Dergisi, 27(2), 1–24. DOI: https://doi.org/10.17152/gefd.54187

Çarıkcı, K., Meral, H., Berkil, S., Çalışır, A., Önala, L., & Arslan, Ö. (2024). Nitel araştırmalarda tematik analiz [Thematic analysis in qualitative research]. Socrates Journal of Interdisciplinary Social Researches, 10(37), 127–140. DOI: https://doi.org/10.5281/zenodo.10509707:contentReference[oaicite:1]{index=1}

Dewey, J. (1925). Experience and nature. Chicago: Open Court Publishing Company.

Flogie, A., & Aberšek, B. (2015). Transdisciplinary approach of science, technology, engineering and mathematics education. Journal of Baltic Science Education, 14(6), 779–790. Available at: https://oaji.net/articles/2016/987-1479544205.pdf

Forehand, M. (2005). Bloom's taxonomy: Original and revised. In M. Orey (Ed.), Emerging perspectives on learning, teaching, and technology (pp. 41–47).

Gelen, İ. (2017). P21-Program ve öğretimde 21. yüzyıl beceri çerçeveleri (ABD uygulamaları) [P21-21st century skills frameworks in curriculum and instruction (U.S. practices)]. Disiplinlerarası Eğitim Araştırmaları Dergisi, 1(2), 15–29. Available at: https://dergipark.org.tr/tr/pub/jier/issue/33877/348852

Gonzalez, H. B., & Kuenzi, J. J. (2012). Science, technology, engineering, and mathematics (STEM) education: A primer. Congressional Research Service, Library of Congress. Available at: https://sgp.fas.org/crs/misc/R42642.pdf

Hacıoğlu, Y., & Gülhan, F. (2021). The effects of STEM education on the students' critical thinking skills and STEM perceptions. Journal of Education in Science Environment and Health, 7(2), 139–155. DOI: https://doi.org/10.21891/jeseh.771331

Harman, G., & Yenikalaycı, N. (2021). STEM Eğitiminde Mühendislik Tasarım Sürecine Dayalı Etkinliklere Yönelik Fen Bilgisi Öğretmen Adaylarının Görüşleri [Opinions of pre-service science teachers on engineering design process–based activities in STEM education]. Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi, 53(53), 206-226. DOI: https://doi.org/10.15285/maruaebd.729672

Hashim, H., Ali, M. N., & Shamsudin, M. A. (2018). Enhancing an entrepreneurial mindset in secondary school students by introducing the green-STEM project via the integration of the 6E instructional model. Journal of Science and Mathematics Education in Southeast Asia, 41(2), 173–192. Available at: https://eric.ed.gov/?id=EJ1247020

Hsiao, H. S., Lin, Y. W., Lin, K. Y., Lin, C. Y., Chen, J. H., & Chen, J. C. (2022). Using robot-based practices to develop an activity that incorporated the 6E model to improve elementary school students' learning performances. Interactive Learning Environments, 30(1), 85–99. DOI: https://doi.org/10.1080/10494820.2019.1636090

Hsiao, H. S., Chen, J. C., Chen, J. H., Chien, Y. H., Chang, C. P., & Chung, G. H. (2023). A study on the effects of using gamification with the 6E model on high school students' computer programming self-efficacy, IoT knowledge, hands-on skills, and behavioral patterns. Educational Technology Research and Development, 71(4), 1821–1849. DOI: https://doi.org/10.1007/s11423-023-10216-1

Hsiao, H. S., Chen, J. H., Chang, T. I., & et al. (2024). A study on the effects of using the 6E model and a robot teaching assistant on junior high school students' STEM knowledge, learning motivation, and hands-on performance. Journal of Science Education and Technology, 33(5), 759–778. DOI: https://doi.org/10.1007/s10956-024-10119-7

Hsu, Y. S., & Fang, S. C. (2019). Opportunities and challenges of STEM education. In Asia-Pacific STEM teaching practices (pp. 1–16). Springer, Singapore.

İnci, S., & Kaya, V. H. (2022). Eğitimde Multidisipliner, Disiplinlerarası Ve Transdisipliner Kavramları [Multidisciplinary, interdisciplinary, and transdisciplinary concepts in education].Milli Eğitim Dergisi, 51(235), 2757-2772. DOI: https://doi.org/10.37669/milliegitim.905241

Katehi, L., Pearson, G., & Feder, M. (2009). Engineering in K-12 education: Understanding the status and improving the prospects. National Research Council.

Lin, C., & Chiang, J. K. (2019). Using 6E model in STEAM teaching activities to improve university students' learning satisfaction: A case of development seniors IoT smart cane creative design. Journal of Internet Technology, 20, 2109–2116. Available at: https://jit.ndhu.edu.tw/article/view/219

Lin, K. Y., Hsiao, H. S., Williams, P. J., & Chen, Y. H. (2020). Effects of 6E-oriented STEM practical activities in cultivating middle school students' attitudes toward technology and technological inquiry ability. Research in Science & Technological Education, 38(1), 1–18. DOI: https://doi.org/10.1080/02635143.2018.1561432

Lin, Y.-H., Lin, H.-C. K., Wang, T.-H., & Wu, C.-H. (2023). Integrating the STEAM-6E Model with Virtual Reality Instruction: The Contribution to Motivation, Effectiveness, Satisfaction, and Creativity of Learners with Diverse Cognitive Styles. Sustainability, 15(7), 6269. DOI: https://doi.org/10.3390/su15076269v

Love, T. S., & Deck, A. (2015). The ocean platform engineering design challenge: Flooded with STEM content and practices. Science Scope, 39(3), 33–40. DOI: Available at: https://www.jstor.org/stable/43691479

Mayers, A. (2013). Introduction to statistics and SPSS in psychology. Pearson Education Limited.

Milli Eğitim Bakanlığı (2024). Türkiye Yüzyılı Maarif Modeli Fen Bilimleri Dersi Öğretim Programı ve Kılavuzu (3,4,5,6,7 ve 8. sınıflar)[Turkey Century Maarif Model Science Curriculum and Guide (Grades 3–8)]. Ankara, Türkiye: Talim Terbiye Kurulu Başkanlığı.

Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A., & Stohlmann, M. S. (2014). A framework for quality K-12 engineering education: Research and development. Journal of Pre-College Engineering Education Research (J-PEER, 4(1), 1–13. DOI: https://doi.org/10.7771/2157-9288.1069

Nicolescu, B. (1999). The transdisciplinary evolution of learning. Talk at the American Educational Research Association (AERA), Annual Meeting, Montréal, Canada, April 1999, Round-Table "Overcoming the Underdevelopment of Learning: A Transdisciplinary View".

Nuangchalerm, P. (2018). Investigating views of STEM primary teachers on STEM education. Chemistry: Bulgarian Journal of Science Education, 27(2), 208–215 Available at: https://chem-bjss.org/chemistry-bulgarian-journal-science-education/2018/27-2/208-215

Obarski, K., Boyce, A., Cloran, K., Driesen, R., Jordan, B., Latimer, S., & Peskett, J. (2013). Implementing STEM: STEM in the virtual environment. Florida Virtual School. Available at: https://www.flvs.net/docs/default-

source/research/STEM_White_Paper.pdf
Örgüt, M. (2022). Türkiye'de STEM eğitimi araştırmalarının incelenmesi ve STEM eğitimi model önerisinin sunulması [Examination of STEM education research in Turkey and proposal of a STEM education model] (Master's thesis). Amasya Üniversitesi, Fen Bilimleri Enstitüsü.
Özer, İ. E. (2019). 6. sınıf kuvvet ve hareket ünitesinde gerçekleştirilen Algodoo temelli etkinliklerin öğrencilerin tasarım becerilerine ve akademik başarılarına etkisi[The effects of Algodoo-based activities on students' design skills and academic achievement in the 6th grade forces and motion unit] (Master's thesis). Aksaray Üniversitesi, Fen Bilimleri Enstitüsü, İlköğretim (Fen Bilgisi Eğitimi) Anabilim Dalı.
Piaget, J. (1969). The intellectual development of the adolescent. In G. Caplan & S. Lebovici (Eds.), Adolescence: Psychosocial perspectives (pp. 22–26). New York: Basic Books.
Razali, N. M. & Wah, Y. B. (2011). Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. Journal of Statistical Modeling and Analytics, 2(1), 21-33. Available at: https://www.nrc.gov/docs/ML1714/ML17143A100.pdf
Roehrig, G. H., Dare, E. A., Ring-Whalen, E., & Wieselmann, J. R. (2021). Understanding coherence and integration in integrated STEM curriculum. International Journal of STEM Education, 8(2), 1–21. DOI: https://doi.org/10.1186/s40594-020-00259-8
Sanjayanti, A., Rustaman, N., & Hidayat, T. (2019). 6E learning by design in facilitating logical thinking and identifying algae. AIP Conference Proceedings, 2194, 020109. DOI: https://doi.org/10.1063/1.5139841
Sirajudin, N., & Suratno, J. (2021, March). Developing creativity through STEM education. In Journal of Physics: Conference Series (Vol. 1806, No. 1, p. 012211). IOP Publishing.
Stohlmann, M., Moore, T. J., McClelland, J., & Roehrig, G. H. (2011). Impressions of a middle grades STEM integration program educators share lessons learned from the implementation of a middle grades STEM curriculum mode. Middle School Journal, 43(1), 32–40. DOI: https://doi.org/10.1080/00940771.2011.1146179
Štuikys, V., & Burbaitė, R. (2018). Smart STEM-driven computer science education: Theory, methodology and robot-based practices. Cham: Springer.
Styron, R. A. (2013). Interdisciplinary education: A reflection of the real world. Systemics, Cybernetics and Informatics, 11(9), 47–52.
Şahin, Ş., & Kılıç, A. (2023). Proje tabanlı 6E öğrenme modelinin etkinliği[Effectiveness of project-based 6E learning model]. Avrupa Açık, Uzaktan ve E-Öğrenme Dergisi, 25(1), 31–48. DOI: https://doi.org/10.2478/eurodl-2023-0003
Uştu, H. ve Mentiş Taş, A. (2020). Disiplinlerarası öğretim: İlkokullarda stem eğitiminin bütünleştirilmesine yönelik yaklaşımlar[Interdisciplinary teaching: Approaches to integrating STEM education in primary schools]. Çukurova Araştırmaları, 6(2), 248-257. DOI: https://doi.org/10.29228/cukar.44209
Vygotsky, L. (1978). Interaction between learning and development. Readings on the Development of Children, 23(3), 34–41.
Yazıcı, Y. Y. (2019). 6E öğrenme modeline dayalı FeTeMM eğitiminin girişimcilik, tutum, meslek ilgisine etkisi ve öğrenci görüşleri[Effects of STEM education based on 6E learning model on entrepreneurship, attitude, career interest, and student opinions](Master's thesis). Kırıkkale Üniversitesi, Fen Bilimleri Enstitüsü, Kırıkkale.
Yazıcı, Y. Y., Hacıoğlu, Y., & Sarı, U. (2023). Entrepreneurship, STEM attitude, and career interest development through 6E learning byDeSIGN™ model based STEM education. International Journal of Technology and Design Education, 33(4), 1525–1545. DOI: https://doi.org/10.1007/s10798-022-09780-z
Yılmaz, M., & Yalçın, N. (2021). 6E öğrenme modeline dayalı öğretimin öğrenci başarısı ve tutumlarına etkisi [Effects of teaching based on 6E learning model on student achievement and attitudes]. Uluslararası Eğitim Programları ve Öğretim Çalışmaları Dergisi, 11(2), 75-90.

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Appendix I: Sample Questions of the Achievement Test

Question 8.
The forces acting on the bodies at rest are shown below. Which of the information given about these bodies is incorrect?

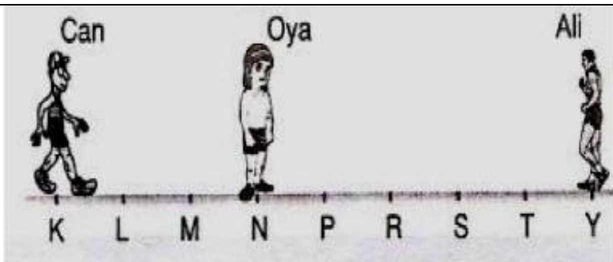
a)
← 2N 7N →
The object is under balanced forces.

b)
← 1N 6N →
The object moves.

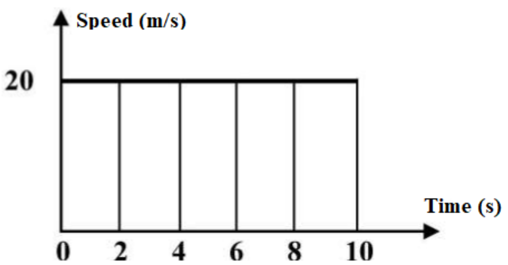
c)
← 18N 2N →
The object moves in the direction of the 18N force

d)
← 4N 4N →
The net force acting on the object is zero

Question 12.
Can, Oya and Ali, who are moving at the same time with speeds of constant magnitude, reach point R at the same time. Since the distance between the points is equal, which of the following is the fastest and slowest of Can, Oya and Ali?



	the fastest	the slowest
a.	Can	Oya
b.	Ali	Can
c.	Can	Ali
d.	Oya	Ali

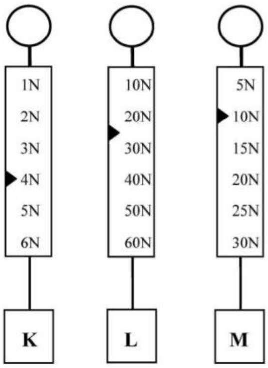


Question 16.
The speed-time graph of a vehicle with a speed of 20 m/s is shown on the right. How many meters is the distance traveled between the 4th second and the 10th second?
a) 80 m/s, b)120 m/s, c) 160 m/s, d) 200 m/s

Question 4.
1.A runner running at a constant speed
2.The movement of a stopped car
3.The book on the table
Balanced in which of the above situations, which ones involve unbalanced forces?

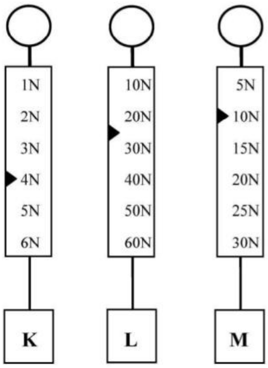
1	2	3

a) Balanced - Balanced - Unbalanced
b) Unbalanced - Balanced - Balanced
c) Unbalanced - Unbalanced - Unbalanced
d) Balanced - Unbalanced - Balanced



Question 19.
Which object exerts the most force?
a) L b) K c) M d) K & M

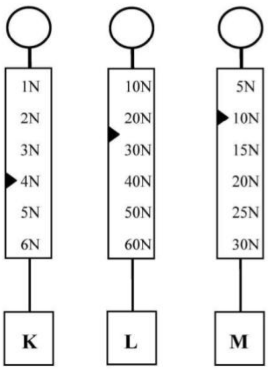
Question 7.
Two forces act on the following object, which of the following is incorrect?
a) The resultant force acting on the object is 10N.
b) The object moves in the direction of 2N.
c) The direction of the combined force is in the direction of 12 N.
d) The object moves.



Question 18.

Find the force values of objects suspended on a dynamometer?

	K	L	M
A)	4	35	10
B)	4	25	10
C)	6	30	30
D)	6	60	30



Question 20.

Which dynamometer can we better measure an object weighing 200 grams?

a) M   b) L   c) K   d) K & M