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Examining A Long-Term Activity Process for The Field of Engineering Design Skills[1]

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Abstract
This research aims to examine the effects of a long-term activity regarding science, engineering, and design skills in primary school. The intervention design, one of the mixed method designs, was used in the research. The study group includes primary school 4th-grade students and two classroom teachers. There are 77 students in the quantitative phase of the research. At the qualitative stage, 12 students were included in the study by maximum variation sampling. As a data collection tool, the Word Association Test (WAT) was used in the quantitative phase, and student and teacher interview forms were used in the qualitative phase. In the analysis of the data, ANOVA and one-way MANOVA were used for repeated measurements in the quantitative part, and content analysis was used in the qualitative part. While the study's quantitative findings showed that the student's cognitive structures improved, the qualitative findings showed that difficulties, overcoming difficulties, and awareness codes gained intensity.

INTRODUCTION

The National Research Council (NRC, 1996) established a systematic and meaningful process incorporating applied activities within scientific research in science education. The field of science teaching is multifaceted and focuses on student experience, as emphasized by the NRC (2007). In this context, Science, Technology, Engineering, and Math (STEM) education has gained significance and popularity as a new approach. STEM education is an educational approach that includes four disciplines: science, technology, engineering, and mathematics (Altunel, 2018; Basham & Marina, 2013; Çepni & Ormancı, 2018). According to Jolly (2014), STEM is a movement that provides the scientific and mathematical development necessary for individuals to compete in the workforce in the 21st century. It has been found that the majority of methods in STEM education employ project-based, problem-based, design-based, inquiry-based, and the 5E learning models (Çepni, 2018; NRC, 2014). Çepni (2018) defined design-based learning as the engineering design process in which applications are made in the educational environment. English, King and Smeed (2017, p.256) described the stages of design-based learning: "determining the scope of the problem, understanding the boundaries of the problem, generating ideas, designing and constructing, evaluating the design, redesigning and structuring, and using interdisciplinary knowledge." NRC (2014) highlighted the connection between problem-based learning and STEM education as providing students with experience about the situations they may encounter. Çepni (2018) reported that STEM and project-based learning are similar, but STEM education includes project-based learning. Jolly (2014) emphasized that inquiry-based learning is essential for individuals to gain experience regarding science. Additionally, NRC (2012, p. 41) identified eight skills, focusing on the practices of scientists and engineers. These skills are: "asking questions, defining problems, developing and using models, planning and executing inquiries, analyzing and interpreting data, using mathematics, structuring explanations and designing solutions, evidence-based discussion, and communication." Based on these, in applying STEM in education and training, specific criteria have emerged. In this regard, Jolly (2014) expressed for STEM courses criteria: "courses should include real-world problems, engineering design processes, students in the practices, teamwork, meaningfully integrated of STEM disciplines." Similarly, according to Moore, Johnson, Peters-Burton, and Guzey (2016, p.5), the STEM learning environment should have the following: "meaningful learning, gaining experience, providing motivation, developing problem-solving skills, establishing interdisciplinary connections, engineering design, presenting real-world problems, integrating science and mathematics, project-based learning, and collaborative learning methods."

The following points were emphasized as results in relevant studies on STEM: its benefit to science education; the improvement of the design processes of the students (NRC, 2009), providing solutions to social problems (NRC, 2012); its inclusion of all kinds of structures and product designs that concern people (Tayal, 2013), development of engineering (Pruitt, 2014), implementing thinking skills a systematically data-driven (Kelly et al., 2017). Topalsan (2018) focused on developing teaching activities for the engineering design process and the problems in his study with prospective classroom teachers. In the study, it has been reported that pre-service teachers have problems defining and understanding the problem, finding a solution, and creating a model. Ecevit, Alagöz, Özkurt, and Köylü (2022) examined the activities in the 3rd and 4th-grade science textbooks. Researchers have stated that the activities are insufficient to provide students with scientific processes, thinking, and engineering skills. Karakaya and Yılmaz (2021) reported that the students can identify the problem, present the solutions, and make sense of the information they have acquired at an interdisciplinary level whose study with ninth-grade high school students within the scope of implementing engineering design processes. However, it has been reported that the participants could not reach the desired level in the design process. Syukri, Halim, Mohtar, Le, and Soewarno (2018) conducted a study on electricity and magnetism with secondary school students using a quasi-experimental design, integrating students' problem-solving skills with the engineering design process. The study stated that it benefited students to implement engineering design process applications in their courses. When the results of Kavak's (2019) study are examined, it is stated that STEM improves students' scientific process and problem-solving skills, and they successfully offer solutions to the problems they encounter. When the research findings of Yıldız and Ecevit (2022) are examined, it is seen that the participants develop themselves in cooperation and teamwork. The study conducted by Sun, Hu, Yang, Zhou, and Wang (2021) emphasized that students' attitudes toward STEM affect their critical thinking skills and that female students' attitudes toward STEM are more favorable than male students. Kavak (2019) reported that STEM activities provide students with more permanent and easy learning. Studies on this subject indicate that students' academic achievements increase, they display positive opinions, and their attitudes and motivations are also positively affected (Öztürk, 2020).

In this context, NRC (2009) referred to scientific knowledge and stated that the use of scientific knowledge contributes to the field of engineering design. Studies have reported that societies focusing on design-based science education and mathematics obtain and produce efficient information in technology (NRC, 2012). Regardingly, the Ministry of National Education (MNE, 2013) science curriculum emphasized scientific process skills and life skills. In addition, socioscientific issues, the nature of science, the relationship between science and technology, the social contribution of science, sustainable development, science, and career awareness were emphasized. In the progress, in addition to the scientific process and life skills, science-engineering and design skills were added to the MNE (2018) science curriculum. In the fourth grade of primary school, it is emphasized that product design, presentation, and end-of-school-year science festivals should be held in this field. However, these skills are not widely implemented across all educational levels despite their effectiveness. The relevant literature highlights that the least number of studies have been carried out with primary school (1st and 4th grades) and preschool students, while the largest sample group was at the secondary school and university level (Aydın et al., 2017; Hebebci, Usta, 2017; Christensen, Knezek, 2017; Kırılmazkaya, 2017; Karışan et al., 2019; Olszewski-Kubilius et al., 2017; Uğraş, 2019; Yıldırım, 2011). Accordingly, limited studies have been conducted at the primary school level, despite the positive results. However, considering the emphasis in the literature and the MNE science curriculum on engineering design skills, it is essential to develop applications and investigate the application process. In this sense, engineering design skills should be addressed in a process supported by scientific process skills and life skills based on scientific inquiry, including the criteria in a STEM-based teaching environment. From this point of view, the study aims to examine the results of using long-term activities to acquire engineering design skills in the primary school science curriculum. For this purpose, answers to the following questions were sought.

1. How do students make sense of their experiences during the activity process?
2. What is happening in the process?
3. How are students' cognitive structures affected?

METHOD

Research Design

Şimşek and Yıldırım (2016) describe the mixed method as research in which research problems are comprehensively discussed by using quantitative and qualitative methods together. The intervention design, one of the mixed methods, is defined as applying an intervention plan by examining the experiment for the persistent problem and supporting it with qualitative data. This study was conducted using the intervention design. In this design, qualitative data can be collected before, during, or after the experiment. Following the purpose of the research, a qualitative design was used during the experiment (Creswell, 2021; p.45). Thus, the effect of the applied process on the students was examined in depth. Accordingly, long-term activities were designed and implemented for primary school 4th-grade students. In this context, it is crucial in the research to interpret the quantitative results regarding the students' cognitive structures through a process. For this reason, it was tried to deeply understand the process by collecting qualitative data during the experiment. In this way, it is aimed to make sense of the quantitative data obtained regarding the learning process and to understand the effect of the activity process on the student.

Quantitative Stage

The basis of the quantitative phase of the research is the experimental design. Experimental design is expressed as a method in which the person conducting the study can decide, direct and test the variables in situations such as the process, content, and whom the study will be conducted with (Büyüköztürk et al., 2018). This study used quasi-experimental designs, as the random assignment of participants was impossible. However, the groups were determined as random. Accordingly, two groups were determined within the scope of the control group model and selected as the experimental and control groups. Control group students were not confronted with any material and application encountered by the experimental group in the process. The Word Association Test (WAT) was applied to two groups before, during, and after the experiment. In this context, repeated measurements were made for the dependent variable in both groups.

Table 1. The quantitative stage study pattern

Group	n	Pretest	Application	Post-test
Experimental Group	42	WAT	Long-term activities WAT	WAT
Control Group	35	WAT	Teacher–centered learning WAT	WAT

The problem situation subjects in the research were covered in the primary school third and fourth-grade curriculum. In this case, while the experimental group students were trained in science, engineering, and design skills within the scope of long-term activities, the control group received training without these activities. In this respect, the difference between the groups that received and did not receive this training was emphasized when interpreting the results. The control group was determined as this design is stronger than the single-group designs. As a result, we focused on the experimental group's experiences in the long-term activity. In this context, it is aimed to compare the changes in the cognitive structures of the students who participated and did not participate in the activities.

Study group

The research study group consists of 2 volunteer classroom teachers in the selected primary school and 77 students in total (42 students in the experimental group and 35 in the control group). The distribution of these students by gender is given in Table 2.

Table 2. Quantitative stage working group

Group	Gender	Frequency (N)	Percentage
Experiment	Girl	20	47.60
	Male	22	52.40
	Total	42	100
Control	Girl	16	45.70
	Male	19	54.30
	Total	35	100
Total	Girl	36	46.80
	Male	41	53.20
	Total	77	100

When Table 2 is examined, the distribution of the experimental group students by gender is 47.6% female (n=20), 52.4% male (n=22). The distribution of the control group by gender was 45.7% female (n=16), 54.3% male (n=19); a total of 46.8% female (n=36), 53.2% male (n=41). All students attend the fourth grade of primary school. These students are educated in a public primary school in the city center.

Experimental intervention process

In the study, activities were created in line with the STEM learning environment criteria, and these activities and their contents are presented in Table 3. As can be seen in Table 3, the study was formed in 6 steps: "presenting the scientific problem situation, structuring the scientific problem situation, scientific review, scientific resource research, use of scientific resources and product design"; activities and materials were designed for these stages. In the study, a real-world problem was first structured, and students were encouraged to develop projects. To this end, the poster named "TEKNOFAS" was designed by the researchers and asked, " How do you can carry today's plants into the future?" Within the scope of the question, students were invited to the project. A scientific article review was presented to the students within the scope of the "Life from Today to the Future" activity to better structure the students' problem situation. Then, with "Journey to the Colorful World of Plants," students' scientific resource review, with the experiment application named "I am observing my bean" about the students' scientific process skills. These stages were carried out with flipped learning. In the classroom, about essential concepts in the life cycle of flowering plants, students created a word cloud activity using the "WordArt" program, and the activity "Cut, Paste, Model and Tell" also modeled this process.

Table 3. Implementation process stages, activity contents, and timeline

Stage	Activity	Contents	Timeline
Presenting the Scientific Problem Statement	Teknofas: Invitation to the project with a poster	Do You Think We Can Bring the Date Tree 2000 Years Back Today? However, Can We Preserve Today's Plants for 1000 Years? Which part can we use to store the plant? What kind of environment can we design to store this part?	1-2 Weeks
Configuring the Scientific Problem Statement	"Life From Today To The Future"	"On the Way to Become a 2000-Years-Old Date Tree."	3.- 4. Week
Scientific Resource Review	"Journey to the Colorful World of Plants"	A source of scientific information on the life cycle of plants and flowering plants Word Cloud activity.	3.- 4. Week
Scientific Inquiry	"What happened to my beans?"	Experiment and observation of flowering plant life cycle "Cut, Paste, Model and Tell" activity	Week 5
Engineering Design Skill: Design	"Seed Banks?",	Designing seed banks with suitable simple materials	Week 6
Engineering Design Skill: Product	"I Design-I Produce"	Producing seed banks with suitable simple materials	7. Week

At these stages, it aimed for students to use scientific knowledge in their problem-oriented solution and design ideas. With the popular science article "Seed Banks?", students were encouraged to consider different design considerations for the engineering design process. After that, they developed different seed banks with the help of the simple materials given in the "I Design-Produce" activity and introduced them to each other in the classroom exhibition. These practices were applied to the students under the teacher's guidance during the periods determined by a booklet. In the application process, it was aimed that the students would recognize the parts of a flowering plant, recognize its life cycle, and in this way, design a product by understanding the conditions under which it should be stored for future use.

Data collection tools

The Word Association Test (WAT) was used within the scope of the quantitative research. It is stated that the Word Association Test (WAT) effectively measures individuals' knowledge and reveals their cognitive structures (Bahar, 2001; Bahar et al., 1999). Considering the study group of the research, it was deemed appropriate to choose WAT for students in terms of both significance and applicability. In this context, the key concept of "plant" was determined for activities based on science, engineering, and design skills. The pilot application of the prepared test was carried out by taking expert opinions. After the deficiencies and regulations were completed according to the results of the pilot implementation, the WAT was given its final form.

Analysis of data

The frequencies of the words associated with the key concepts by the WAT were determined for the quantitative data analysis. Therefore, directly and indirectly related concepts were evaluated as 1 point, unrelated concepts were evaluated as 0 points, and WAT scores were reached. Data distribution was performed for the word association test scores for the experimental and control groups, and descriptive statistics were examined for each measurement. Kolmogorov-Smirmov test and Q-Q plot findings were also examined, and it was decided that the pretest and intermediate test measurements of the experimental and control groups showed normal distribution. Descriptive statistics and Q-Q plot curves were considered in the post-test, and the distribution was close to normal. As the data was over 30, independence of observation and normal distribution assumptions were met, and the parametric tests were used. MANOVA results were preferred to compare groups in data analysis instead of independent samples t-test to avoid statistical errors and ensure appropriate data. Repeated measures ANOVA test was performed to compare the groups within themselves, and the results were evaluated accordingly.

Reliability and validity

The researcher first coded the answers of the experimental group students to WAT. In this process, the opinion of the relevant class teacher and also the expert opinion were taken. Then, the directly related concept, indirectly related concept, and unrelated concept status of the answers were revised. The related and indirectly related concept frequencies were used as the participants' WAT scores. Additionally, no mean score between raters was calculated. Based on this, it was considered that it did not need to calculate the fit index.

Qualitative Stage During Experiment

Working group

The interview was conducted by selecting one student from the teams of 3 and 4 people formed among the students in the experimental group through maximum variation sampling. According to Table 4, interview participants consisted of 48% female (n=5) and 52% male (n=7) students. The students were determined by considering their affective characteristics as criteria.

Table 4. Study group gender distributions

Group	Gender	Frequency (N)	Percentage
Experiment	Girl	5	48%
	Male	7	52%

Data collection tools

In the qualitative dimension, semi-structured interview forms were used for students and teachers. The semi-structured interview form was created in line with the interviewing principles. In this process, the stages of problem analysis, preparation of questions for problem analysis, and determination of the purpose of these questions were carried out. Expert opinions were obtained for the questions in this form, and arrangements were made regarding relevance and clarity for the purpose. Then, considering the student levels, interview forms were tried within the scope of pilot applications. Their final form was reached after correcting the missing or wrong parts of the interview questions. The forms were structured separately for each stage of the six-step implementation process.

Analysis of data

In qualitative data analysis, content analysis (Mayring, 2002) was done by transforming the students' answers into documents. In this process, first of all, all student responses were examined. Codes were developed from the answers given to the questions. In this direction, "difficulties, overcome difficulties, willingness to participate, positive emotion, impossibility, protection, preliminary preparation, self-awareness, teamwork, awareness" codes were created, and a coding rule was defined for each. A table has been formed with sample quotations related to these. Later, the code, definition, and related example table were developed and applied to all texts. In this way, the different stages of the student during the application process were examined using codes. Thus, student experiences are described with direct quotations obtained.

Reliability and validity

At the qualitative stage, the first coding was done for the interviews with the teachers and students. The answers for coding are listed as documents. Then, codes were created and defined by the researcher. The Code Definition, Related Examples table, developed in this way, was examined with another field expert, and a consensus was reached. The coding process was carried out on all data with quotations from the answers given for the later definitions. After the other expert rechecked the coding at the end of this stage, the analysis was completed as agreed.

FINDINGS

Findings Related to the Results of the Experimental Study

Within groups comparing

The repeated measurement ANOVA results of the data set obtained with the WAT measurements of the experimental group are presented in Table 5.

Table 5. Repeated measurement ANOVA results of the experimental group

Variable	Mean ($\bar{X}$)	Standard Deviation (SD)	N
Pretest	14.67	8.192	42
Midterm test	15.93	6.88	42
Final test	26.43	5.89	42

	df	Mean Squares	F	p	Partial Eta Square (η^2)
Cognitive Structure	1.767	1982.76	48.46	0.00	0.542
Error	72.427	40.916			

According to Table 5, it was found that there was a significant difference between at least two of the measurement results [F (2-82) = 48.46, p < 0.05]. Considering the repeated measurement results, the midterm and final test WAT's mean increased compared to the experimental group's pretest mean. In the post-test, it was concluded that the mean ($\bar{X}$ = 26.43) was the highest. Pairwise comparison findings regarding the significance of the differences between these measurement results are given in Table 6.

Table 6. Pairwise comparison of experimental group concept measures

(I) Concept	(J) Concept	Mean Differences	Std. Error	p	95% Confidence Interval	
					Lower Limit	Upper Limit
Final test	Pretest	11.762	1.371	0.00	8.34	15.184
	Midterm test	10.500	1.016	0.00	7.965	13.035

When Table 6 is examined, it is seen that there is a statistically significant difference between the third measurement and the first measurement ($p < 0.05$) and between the third measurement and the second measurement ($p < 0.05$). Accordingly, it was found that there was a significant increase in the students' word association test mean.

Repeated measurements ANOVA test results of WAT measurements of the control group at the same time interval are given in Table 7.

Table 7. Repeated measurement ANOVA results of the control group

Group	Variable	Mean ($\bar{X}$)	Standard Deviation (S)		N
Control Group	Pretest	14.06	6.32		35
	Midterm test	13.94	7.28		35
	Final test	14.89	6.58		35
	Df	Mean Squares	F	p	Partial Eta Square
Cognitive Structure	2	9.27	0.361	0.698	0.542
Error	68	25.66			

The Repeated Measurement ANOVA results were examined, and it was found that there was no statistically significant difference between the pretest, midterm test and final test WAT mean scores of the control group [$F(2\text{-}68) = 0.361$, $p > 0.05$]. When the means of the control group's measurements ($\bar{X} = 14.05$; $\bar{X} = 13.94$; $\bar{X} = 14.88$) are examined in repeated measurements, it is seen that the measurements are very close to each other.

Between groups comparing

The MANOVA results for examining the pretest, mid-test, and post-test averages of the experimental and control groups are given in Table 8.

Table 8. Descriptive statistics

	Teaching_Method	Mean ($\bar{X}$)	Standard deviation	N
Pretest	Control Group	14.06	6.32	35
	Experimental group	14.67	8.19	42
Midterm test	Control Group	13.94	7.28	35
	Experimental group	15.93	6.88	42
Final test	Control Group	14.89	6.58	35
	Experimental group	26.43	5.89	42

	Wilks' Lambda	F	Hypothesis df	p-value	Partial Eta Square
Teaching_Method	0.474	26.978	3.000	0.000	0.526

When the equality matrix of covariance matrices from the MANOVA results was investigated, it was observed that equality was achieved (Box's M = 7.179; $p = 0.334$). Wilks' Lambda results from the multivariate test result were considered in this direction. When Wilks' Lambda results were examined, it was determined that the teaching method variable differed significantly between the groups [F (df = 3) = 26.97; p<0.05]. While the mean scores of the experimental and control group students were closer to each other in the pretest and midterm test, it was determined that the mean of the experimental group ($\bar{x}$ = 26.46) in the final test was higher than that of the control group ($\bar{X}$ =14.89). The main effect results regarding the significance of the differences between these measures are given in Table 9. It was found that there were no significant differences between the groups' pretest (F (1) = 0.13; p = .72) and the midterm test (F (1) = 1.51; p = 0.22) results. When the post-test was examined (F (1) = 65.92; p = 0.00), it was revealed that there was a significant difference. As a result, according to the word association test findings of the experimental and control groups, there was no significant difference at the beginning between the experimental and control groups without any intervention. At the end of the intervention process, it was determined that there was a significant increase in the cognitive structure of the experimental group compared to the control group.

Table 9. Main effect results

Source	Independent variables	df	Mean Squares (K mean)	F	p	Partial Eta Square
Teaching Method	Pretest	1	7.09	0.13	0.72	0.00
	Midterm test	1	75.28	1.51	0.22	0.02
	Final test	1	2543.63	65.92	0.00	0.47

In this context, in the process carried out with STEM-based long-term activities, there are significant positive differences in the cognitive structure regarding target concepts.

Findings Related to the Results of the Qualitative Study

In presenting the scientific problem situation in line with the answers given by the students, "impossibility" and "protection" codes appear. The "impossibility" code includes quotes that express seeing the solution of the given problem as impossible. Quoting about it:

> *"The earth came to my mind. Then we cannot bring back the date tree 2000 years ago."* (S1)

However, the code of "protection" means not allowing the code to be altered, carrying it into the future as it is, and keeping it intact. Quote for this:

> *"It reminds me that plants can be more for protection. For example, he says, can we bring the date tree 2000 years ago? For example, it seemed more like a protection thing to me. Then, when we protect the plants, they give us oxygen…."* (S12)

It has been determined that the codes of "difficulties, overcoming difficulties" occur at the stage of scientific inquiry and application of scientific resources review and product design. The difficulties code includes quotations expressing the situations that require manual dexterity in the activity process and the stages (observation, experiment, data recording) based on scientific inquiry. Quote for this:

> "*I had a hard time putting it in a sunny spot. Because our house does not get much sun*." (S11)
> *"I have never been challenged anywhere. I just had a little trouble sticking it."* (S10)

Product design includes quotations that express reasoning, analysis, creative thinking, cooperation, teamwork, getting support, reflecting terms, using the internet, researching, examining, gradual progress, being programmed, and drafting. Quoting about it:

> *"So first, we put the seeds squarely on the foil, one by one. Then we brought the pen. We divided it as plus (+). Then my friend said, "Can I do it too?" and I said OK. We did it together.*" (S8)
> *"I researched on the Internet how to design, how to make something for plants." (S10)*

At the scientific review stage, it was determined that "preliminary preparation" and "awareness" codes were formed. The preliminary preparation code includes quotes that express preparation before the event, creating a draft, working regularly, and being planned. Quote for this:

> *"We thought as a group, at home. Some of my friends had phone numbers. We thought a lot together. I even made one at home. To understand how it is done." (S5)*
> *"I had planned on paper. I had prepared a sketch. I followed that path."* (S4)

The code of "awareness" was used for observation, experimentation, data recording, and more. It includes expressions such as to sense, understand, and distinguish. Quote for this:

> *"I noticed my bean being a little brown and cracked."* (S7)

The codes of "positive emotion, willingness to participate, teamwork" are formed when presenting the scientific problem situation, scientific inquiry, scientific resource review, and product design (all steps). Positive emotion code includes quotes about the process experienced, expressing having a good time, having fun, and loving. Quoting about it:

> "*I am pleased. I felt happy. I enjoyed it"* (S9)
> *"I loved science very much. It is my favorite class so far. I loved the life cycle topics of these plants. I think it's fine now. But it will be better if it is increased over time."* (S5)

The request to "participate" code includes quotations that include the wishes of individuals during the activity and their demands for such activities. Quote for this:

> "*The project on the poster looks like an excellent project. I also looked and studied with my friends. It is a project to protect plants, and I am thrilled to participate in this project"* (S12)

The "teamwork" code includes team spirit, togetherness, making up for deficiencies, helping each other, mutual determination, and being productive. Quoting about it:

> *"Yes. I was able to work efficiently with my groupmates. I consulted with my friends. For example, how can we do it, how can we show it. I think it has been productive."* (S12)

It has been concluded that the codes of "protection, positive emotion, difficulties, overcoming difficulties, willingness to participate, preliminary preparation, self-awareness, teamwork" are formed in the product design step. It has been determined that the resulting codes occur at a higher rate in the product design phase than in other steps. Protection for this excerpt about the code:

> *"I understood how we can save the seeds. Then I realized what kind of place it is to preserve the seeds. It brought many things. My hand skills have improved, then we do many things at home. I also learned how to create a word cloud. It has been perfect for me, too."* (S7)

Excerpt about teamwork code:

> *"I was a little overwhelmed. I had a hard time doing it with aluminum foil. Then the people in my group told me how to do it. They told me how to wrap it. Then I learned how to do it too."* (S10)

Excerpt about the difficulties overcoming code:

> *"I did a little research. From the papers you gave me and a little bit of the internet. Let's say I tried to liken it to a seed bank."* (S12)
> *"With help from my friend, then took an inch of the middle strips. We used a ruler." (*S9)

Excerpt about preliminary preparation code:

> *"I had planned on paper. I had prepared a sketch. I followed that path." (*S4)

Excerpt about the willingness to participate code:

> *"You can improve more by doing more of these things. We can do more difficult things; it can be more comfortable. It may take longer." (*S6)
> *"I researched on the Internet how to design and make something for plants." (*S10)
> *"I think, we can do 2-3 or 5-10 more events. Because it is fun and beneficial." (*S8)

Quote about positive emotion code:

> "*I am pleased. I felt happy. I enjoyed it"* (S9)

However, the code of "self-awareness" includes quotes such as developing imagination and creativity, discovering one's talent, and turning to science. Quoting about it:

> *"Yes. Because here I understand the importance of group work. My hand dexterity is improving, and my imagination is expanding. It is also fun."* (S4)
> *"It allowed me to develop my sense of design. For example, nothing came to my mind before. As I thought and researched, I started finding more beautiful things and created my sketch. Afterward, I tried to reflect it together with the materials."* (S12)

In the interview with the teacher, it is seen that the codes of willingness to participate, positive emotion, and teamwork are formed when presenting a scientific problem situation, scientific examination, scientific resource review, and product design. Quote from willingness to participate:

"They were excited, they actively participated. They were curious." (Teacher)

Quote for positive emotion code:

"It was a fun activity for children, and I believe it was beneficial." (Teacher)

Excerpt about teamwork code:

"Students raised their friends as a group. They supported each other." (Teacher)
"Their communication was good. They tried to improve the passive students and make up for their deficiencies." (Teacher)

It has been concluded that the codes of "difficulties" and "overcoming difficulties" are included in the scientific review, use of scientific resources, and product design steps. Excerpt for the challenges code:

"*While some of our students wanted to be meticulous, they were upset when they over-watered the plant, which rotted psychologically. In addition, because the class was so crowded, it was difficult to pay close attention to them during the experimentation process. Other than that, there was not much of a problem.*" (Teacher)

Excerpt from the code for difficulties overcoming:

"They thought repeatedly about the activities he was doing. They coped by trying to get support from their friends, teachers, parents." (Teacher)
"*The parents have been contacted. That way: the problem was solved.*" (Teacher)

When the qualitative findings were examined, it was concluded that the students and the classroom teacher had positive emotional and cognitive views on science, engineering, and design skills in long-term activities.

CONCLUSION, DISCUSSION AND SUGGESTIONS

The research was conducted with 42 fourth-grade students for seven weeks within the scope of long-term activities for applying science, engineering, and design skills. The results revealed that there was a significant positive difference in the cognitive structures of the students in the experimental group as indicated by the WAT scores [$F(2\text{-}82) = 48.4$, $p<0.05$]. However, there was no significant difference in the cognitive structures of the control group. Karışan and Yurdakul (2017) stated that these long-term activities positively affect the students in their studies in which plants and animals are included in the content, making observations, drawing graphics, and designing processes. On the other hand, in their study with secondary school students on socioscientific issues, which also includes 35 long-term activities, Öztürk, Altan and Tan (2020) stated that positive results have emerged in terms of cognitive, affective and design creation for students. In this respect, it is seen that the emergence of a significant difference in the results of the study coincides with the results in the literature. Experimental phase findings include long-term activities and course units within the scope of a science lesson, affecting students positively in terms of remembering concepts. In the applications made within the scope of this study, there are activities related to engineering design skills based on scientific inquiry. This context includes Web 2.0 applications, modeling activities, and scientific resource reviewing applications. The application process developed approximately the STEM learning environment (Jolly, 2014; Moore et al., 2016; NRC, 2012), which not only supports creating designs and products based on scientific knowledge about the problem but also supports concept learning.

The qualitative results have provided evidence for every research stage, a comprehensive comprehension of both student and teacher experiences. The coding that emerged at various points during the planned six-stage implementation procedure has reflected the diverse circumstances encountered in each stage. The codes "impossibility" and "protection" were revealed during the presentation of the scientific problem situation, while "difficulties" and "overcoming difficulties" were identified during the scientific review, use of scientific resources, and product design stages. The codes "positive emotion, teamwork, willingness to participate" were observed at all stages. The "awareness" code also occurred during the scientific review and inquiry stages. The highest occurrence of "preliminary preparation" codes was determined during the scientific inquiry and product design phases. These results were interpreted that although the beginning phase of a STEM-based application may present some difficulties, it can also lead to positive results in dealing with them. In different studies in the literature, there are findings that students cannot reach the desired level in some stages where difficulties are experienced for different stages of STEM activities processes (Karakaya & Yılmaz, 2021; Topalsan, 2018). The result showed that this process affects the students positively and that the practices can be done in primary school students. The code of awareness, which comes to the fore in scientific inquiry and product design stages, strengthens the idea of connecting the engineering design process with scientific inquiry. When teachers' views on science, engineering, and design skills are examined, it is concluded that they show a positive effect in line with the student's views. Accordingly, the finding reveals that students are affected positively regarding teamwork, cooperation, use of scientific process skills, communication, research, discovery, awareness of what they can do, holistic approach to events, collaboration, tolerance, working like a scientist, and efficient time use. Similarly, studies in the literature stated that implementing engineering design process applications in science teaching benefits students (Syukri et al., 2018).

The results obtained with the qualitative findings show that during the design and product development stage the students understood the scientific concepts related to the flowering plant's life cycle and associated it with the solution to the problem. The statements about the seed and its storage conditions are in the quotations. These findings support and explain the cognitive structure obtained at the quantitative stage.

In summary, when long-term activities are applied with appropriate tools and instructions at the primary school level, it positively affects students' cognitive structures in terms of remembering concepts and bringing together related ones. This process differs significantly from students who receive an education not supported by STEM-based long-term activities. This quantitative data is positively affected by the questioning learning environment reached with the qualitative findings and the awareness that emerges during the product design stages. Of course, it should not be overlooked that codes such as positive emotions, cooperation, and awareness, which are effective throughout the activity process, contribute to creating a positive learning atmosphere. The materials and instructions presented to the students in the research helped them overcome the difficulties they faced. The positive effects of communication and cooperation should be considered in long-term activities for students at this education level. Ecevit et al. (2022), finding that textbooks are limited in this regard, support the importance of preparing guide materials for teachers and students. The findings of this study provide evidence that it is possible to carry out STEM-based long-term activities for science engineering design skills in an inquiry teaching environment in primary schools.

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