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Learning Coding and 3D Design as a Student

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ABSTRACT

Previous research states many students struggle when learning to code or 3D design. Therefore, to create a learning system that is designed to make learning 3D design and coding unchallenging, the data from a very detailed questionnaire exploring the learning experiences of a broader student group were analyzed according to the Designed-Base Research (DBR) methodology. Also, by using the designing process DBR provides we have created a program, FLL Mentorship Project, that is specifically structured to make learning these skills easier for students. After this 8 weeks long program where the lessons were given voluntarily by the students of Robert College's Robotics Team, ARC 6014, both verbal and written feedback was taken from 50 Dr. Natuk Birkan İTÜ Geliştirme Vakfı Okulları and 6 Feyziye Mektepleri Işık Okulları students who participated in the program. Furthermore, we buttressed the findings of our research conducted on our first two study groups with a smaller international study group to see if there were any discrepancies. The overall research that was conducted on a diverse group of students mainly explored the ideal age and learning medium to start learning, common areas of the usage of these skills among students, and the qualities of people interested in these topics.

Keywords: *Coding, 3D Design, Education, Learning Experience, STEM*

1. Introduction

In this paper, we will be examining the common qualities and experiences of students learning coding and 3D Design that can be used to generate a sufficient learning system by examining three different research groups. Our first data group consists of high school students from economically advantaged families from Turkey while our second group consists of middle school students with who we have as the authors of this paper conducted a mentorship program. Our last group is a small group of international high school students who are coming from different countries and economic backgrounds. We aim to analyze and reflect on the data we have gathered from these research groups via surveys and feedback forms while also connecting back them to our experience in peer-to-peer learning with the FLL Mentorship Program. As DBR methodology is used for, "test[ing] and refin[ing] educational designs based on principles derived from prior research" we chose to follow this methodology when conducting our research where we tried to idealize the educational experience according to student's needs (Collins et al., 2004, p. 15).

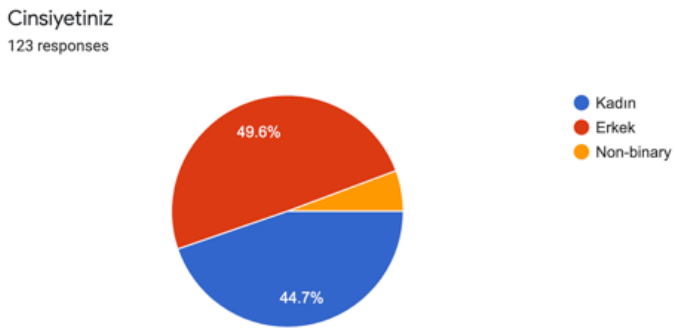
In this research, we mostly wanted to focus on the opinions of the participants instead of analyzing their academic successes such as their "mathematics access grade[s]" or "problem solving abilit[ies]" like in (Gomes & Mendes, 2008). In contrast, it was more like in (Lin et al., 2012) research which was "explor[ing] the effectiveness of application of 3D printing technology [and coding] to STEM project-based learning activities in developing students' understanding regarding engineering design process, particularly their understanding of modeling". Our ultimate aim while designing the FLL Mentorship Project was also to introduce the idea of STEM to middle school students in order to familiarize them with robotics and FIRST at an earlier age with a unique and new way of peer-to-peer learning.

1.1. General Qualities of the Attendees in our First Research Group

We conducted our research on the first research group via a questionnaire we have prepared. Our first research group consisted of 123 Turkish students who were advantaged both economically and socially.

Our first form was filled by high school students around Turkey with a gender accumulation of 49.6% males, 44.7% females, and 5.7% non-binary.

Figure 1. Gender Accumulation Pie Chart



Source: Con, Evrim Sude. Kançal, Arda. (2021). Coding and 3D Design Learning Analysis (International) [Research Survey]. Retrieved from https://docs.google.com/forms/d1Bu3HW5pF4iBi4ZXaij37lZbhDyyw0De25zhCDGnVXDQ/edit

1.1.2. The Institutions

The schools the student was from were in variety which included: Robert College, Koç High School, German High School, Lycée Notre Dame de Sion, ENKA, Lycée Saint Michel, İTÜ, Galatasaray High School, Lycée St. Joseph, Sankt Georg, and FMV Ayazağa Işık High School.

1.1.3. Age Groups of the Students

The students who have participated in this research were between 14-18 years old. The majority was 16-year-olds with a percentage of 41.5% followed by 15-year-olds with 38.2%. After that 17-year-olds were occupying 11.4% while 14 year olds were 5.7% and 18-year-olds were 3.3%.

1.2. General Qualities of the Attendees in the FLL Mentorship Project

There were 50 middle schoolers from Dr. Natuk Birkan İTÜ Geliştirme Vakfı Okulları and 6 middle schoolers from Feyziye Mektepleri Işık Okulları in the FLL Mentorship Project. The leaders of the project were Arda Kançal and Evrim Sude Con who were also instructors alongside other instructors from Robert College robotics team ARC 6014. We have used both the verbal feedback from the students and the instructors alongside the feedback form we have sent as data from our FLL Mentorship Project study group.

1.2.1. Gender Accumulation

This group of middle school students was a diverse group in terms of gender. 36% of the students were girls while 64% of the students were consisting of boys. Even though these numbers were still representing the male domination in STEM areas, we haven't observed any kind of bullying or prejudgements about gender during our lessons which were fortunate. This showed us that both of the sexes were equally interested in these STEM areas and eager to develop themselves in a given ideal environment.

1.2.2. Age Groups of the Students

This group was composed of students between the ages of 10-13 who are falling into the 5th-7th grades in the Turkish education system. The majority were the 5th-grade students while the higher grades occupied less percentage because of academic responsibilities. By choosing middle school students, we were able to observe and experience what peer-to-peer learning looked like.

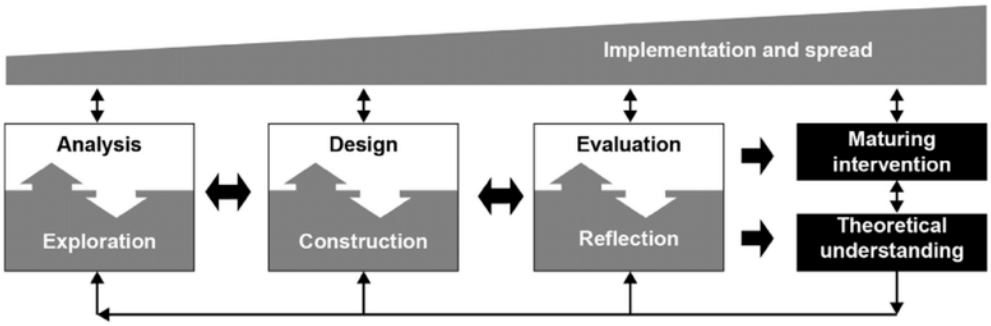
1.3. General Qualities of the Attendees in our International Research Group

Thus, for our research to be more inclusive and precise we have sent out a translated version of our form to international students who live and study abroad. Also, these students were more diverse both racially and economically.

2. Methodology

Designed-Based Research (DBR) is a well-ordered but also flexible methodology that can be used in a variety of contexts. It is commonly used for educational research as it involves a process that is suitable for creating solutions and innovative learning environments to real-life problems. There are five main characteristics of DBR that will be addressed. Firstly, "design-based research is pragmatic because its goals are solving current real-world problems by designing and enacting interventions as well as extending theories and refining design principles" (Design-Based Research Collective, 2003; Van den Akker & et al., in press). The second characteristic is that DBR methodology combines both theoretical and practical research. Thirdly, the research process is flexible and interactional. The fourth aspect is that "design-based research is integrative because researchers need to integrate a variety of research methods and approaches from both qualitative and quantitative research paradigms, depending on the needs of the research" (Wang & Hannafin, 2005, p. 11). Lastly, "design research is contextualized because research results are 'connected with both the design process through which results are generated and the setting where the research is conducted'" (Wang & Hannafin, 2005, p. 11).

Figure 2. Gender Accumulation Pie Chart



Source: McKenney, S., & Reeves, T. (2012). Generic model for conducting design-based research in education. ResearchGate. https://www.researchgate.net/figure/Generic-model-for-conducting-design-based-research-in-education-Reprinted-from-McKenney_fig3_333248547.

3. Findings and Results

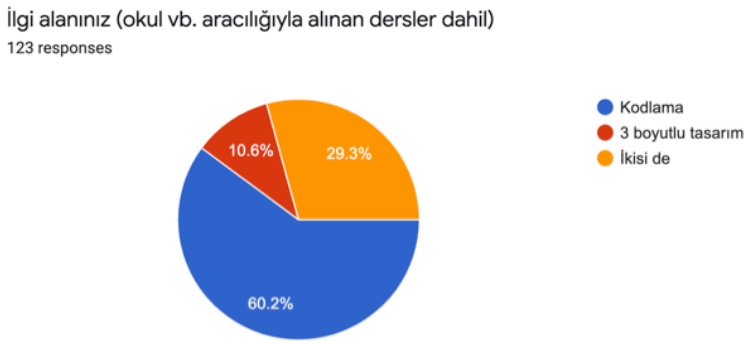
3.1. Findings from the First Research Group

This section will focus on the findings and results that were gathered from 123 students via a questionnaire.

3.1.2. Qualities of People Interested in These Groups

This group of high school students who were coming from economically benefited families had an interest in coding, 3D Design, or both with a majority of coders. 60.2% of the group was more interested in coding while 10.6% of the group told that they enjoyed 3D Design. The remaining 29.3% percent had both of them as an interest area in their lives. This data showed us that coding was more popular among these age groups while 3D Design was not a primary interest. However, most people who liked 3D Design also had a knowledge of coding which showed the relationship between these areas.

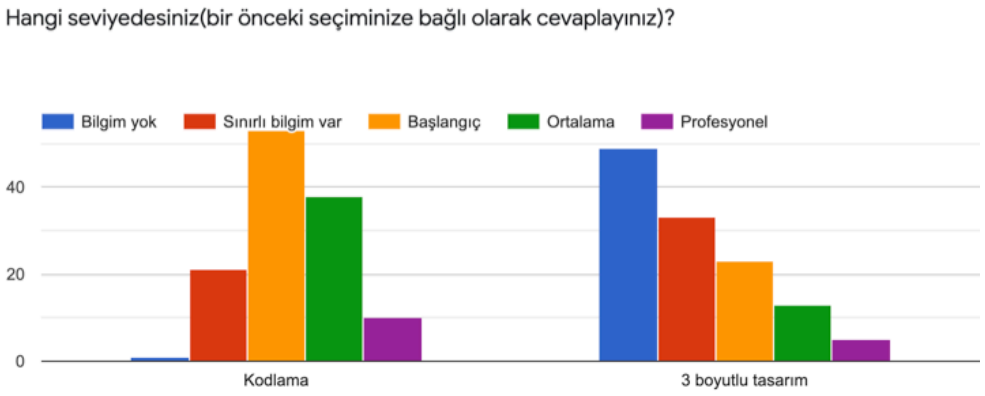
Figure 3. Interest Areas Pie Chart



Source: Con, Evrim Sude. Kançal, Arda. (2021). Coding and 3D Design Learning Analysis (International) [Research Survey]. Retrieved from https://docs.google.com/forms/d/1Bu3HW5pF4iBi4ZXaij37lZbhDyyw0De25zhCDGnVXDQ/edit

Another question in our research was about the amount the students knew about these interest areas. The results were in accordance with the previous question. While only 1 person told that they had zero knowledge in coding the people who hadn't had an idea about 3D design were much bigger with 49 votes which is nearly half of the participants. 21 people had a lacking knowledge in coding and 33 people in 3D Design. Most of the people chose being a novice in coding with 53 votes and 38 people told that they were average. A small number of people consisting of 10 attendees claimed that they were at a professional level. These numbers were much less in 3D Design. With 23 novices, 13 averages, and 5 professionals; the knowledge in terms of 3D Design was not so popular among this test group.

Figure 4. Interest Areas Knowledge Levels Graph



Source: Con, Evrim Sude. Kançal, Arda. (2021). Coding and 3D Design Learning Analysis (International) [Research Survey]. Retrieved from https://docs.google.com/forms/d1Bu3HW5pF4iBi4ZXaij37lZbhDyyw0De25zhCDGnVXDQ/edit

As we have had experience in teaching these skills to middle school students, we also wanted to know whether any of our attendees had one. 70.7% of them said they didn't which was not surprising a lot of people claimed they were beginners in these areas. However, the remaining 29.3% had one which gave us the chance to analyze different types of teaching experiences. This showed the power of sharing and peer-to-peer learning.

Figure 5. Interest Areas Teaching Experience Pie Chart

Source: Con, Evrim Sude. Kançal, Arda. (2021). Coding and 3D Design Learning Analysis (International) [Research Survey]. Retrieved from https://docs.google.com/forms/d/1Bu3HW5pF4iBi4ZXaij37lZbhDyyw0De25zhCDGnVXDQ/edit

Since there is a stereotype relating academic success with coding/3D designing, we thought it would be interesting to ask how the students that were interested in these topics would classify themselves between student options; below average, average, good, overachiever. 26.8 percent of the group considered themselves overachievers, 39.8 good students, 27.6 average students, and 5.7 below average students which were surprising since the study group was conducted on academically successful students.

Figure 6. Academic Success Pie Chart

Source: Con, Evrim Sude. Kançal, Arda. (2021). Coding and 3D Design Learning Analysis (International) [Research Survey]. Retrieved from https://docs.google.com/forms/d/1Bu3HW5pF4iBi4ZXaij37lZbhDyyw0De25zhCDGnVXDQ/edit

3.1.2. Common Areas Of Usage Of These Skills Among Students

There were multiple programs that these high school students used both in terms of coding and 3D Design. A huge majority of 84.6% said they used Python and 64.2% said they used Scratch which are both well-known coding platforms. These were followed by Java with 31.7% and C# with 12.2% students. As expected, 3D Design programs were less common among these students. However, still, 30.1 % of the students knew TinkerCad, which is a beginner-level platform for 3D Design learning. Also, 11.4% of the participants knew Fusion 360 and even Solid Works with 5.7% which are more advanced platforms used professionally. There were other added choices on the list such as C++, HTML, CSS, Blender, JavaScript, and Geogebra for functions, etc. We also wanted to learn whether these people were learning these skills just as a hobby or were they planning on choosing a future path depending on this knowledge. So we asked them if they were planning on using these skills in their professional lives or only for personal growth. 44.7% of the attendees said that they were planning on integrating these areas into their professional job lives which was a significant sign that Gen Z might shape future job opportunities depending on coding or 3D Design which are essential STEM areas. People thinking about studying these areas was also a sign how teens were encouraged to plan their future accordingly so that they can be ready for life as an adult in the future world which is set to be more developed and competitive than ever. The other 55.3% of the group said that it was only for personal growth which is also positive. They want to learn this out of pure interest and they feel like this could develop them in some way as a person. After this more general question, we wanted to get a more detailed answer for these areas so we asked the students how much they think these skills would help them in both academic, professional, and daily lives. 44 people thought that they would use coding beneficially in their academic lives while 44 people believed that they would use 3D Design a bit in their academic life. The majority of the students agreed that they would probably use both of these skills at some point in their academic lives. The votes for “highly beneficial” increased significantly for professional life. 51 students thought they would do a lot more than their academic lives, which was probably because they believed it would be their area of expertise in the future. Even though these numbers were a little less in terms of 3D Design, it was shrill more than the expectations from academic life. As expected, the numbers were the lowest for daily life. However, the numbers for 3D Design were higher than coding which was unexpected.

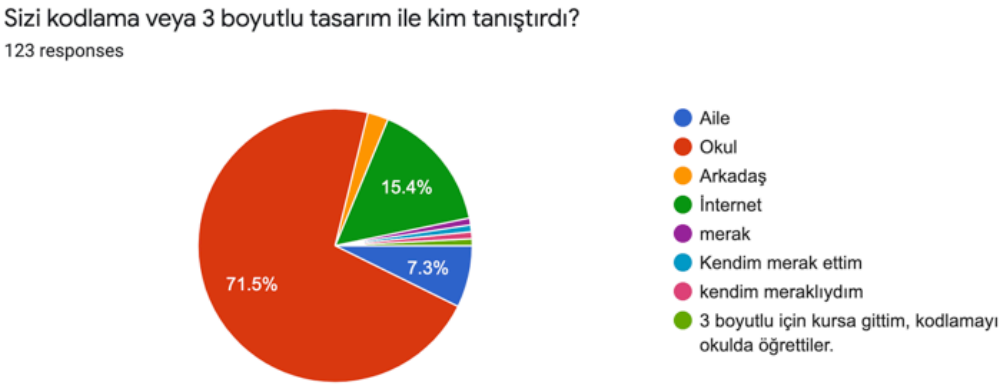
Figure 7. Benefits of Coding and 3D Design Graph

Source: Con, Evrim Sude. Kançal, Arda. (2021). Coding and 3D Design Learning Analysis (International) [Research Survey]. Retrieved from https://docs.google.com/forms/d/1Bu3HW5pF4iBi4ZXaij37lZbhDyyw0De25zhCDGnVXDQ/edit

3.1.3. Ideal Age and Learning Medium to Start Learning

Of course, there should be an origin for this interest or hobby. 71.5% of the students claimed that they started learning about either coding or 3D Design at their school which was the vast majority of the group. This showed that schools in Turkey were seeing this knowledge as essential skills and had a part for them in their curriculums. Even though it is only at the beginner level, this gives young kids a great chance to explore different skills and areas which might lead them to something bigger in the future. 15.4% said that it was a result of the Internet and 7.3% said that they started learning with a family member. The remaining students' answers consisted of friends, wonder, and outside courses that they have taken.

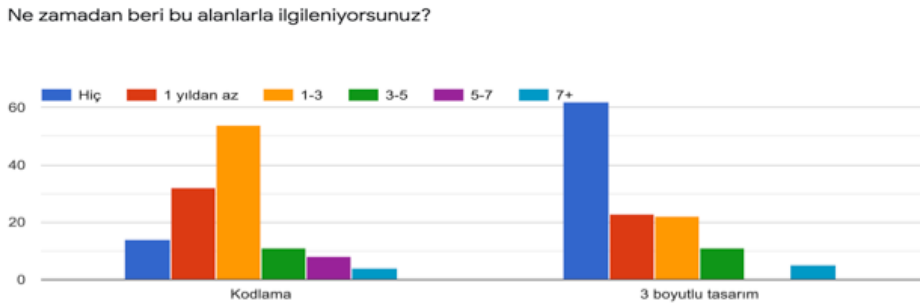
Figure 8. "Who Has Introduced To You?" Pie Chart



Source: Con, Evrim Sude. Kançal, Arda. (2021). Coding and 3D Design Learning Analysis (International) [Research Survey]. Retrieved from https://docs.google.com/forms/d/1Bu3HW5pF4iBi4ZXaij37lZbhDyyw0De25zhCDGnVXDQ/edit

A huge majority of coders(54 votes) said that they have been learning coding for 1-3 years now and it was followed by 32 votes for less than a year. This explained the number of beginners in our data and showed that this wonder of them started in high school. 11 people said that they have been into this for 3-5 years, 8 people said 5-7 and 4 people have been fond of coding for 7+ years. This requires a lot of dedication and time which was hopeful even though it was a small part of the group. The situation was again a little less hopeful in 3D Design as expected. 62 people had never done 3D Design and 23 people had been doing it for less than a year. 22 people had been learning it for 1-3 years while 11 people had been in this ship for 3-5 years. 5 people said that they have been interested in 3D design for over 7 years which was again magnificent.

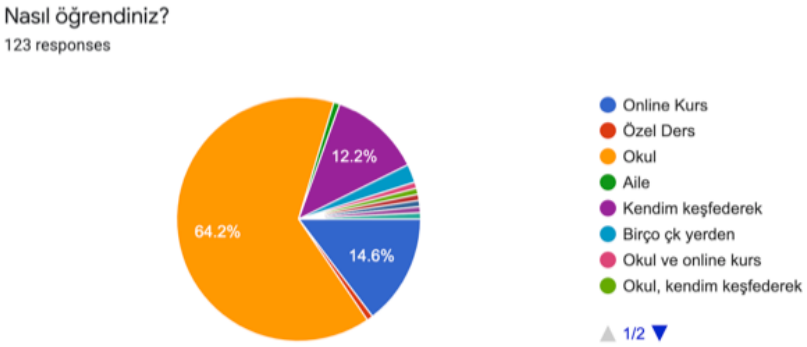
Figure 9. "How long have you been interested?" Graph



Source: Con, Evrim Sude. Kançal, Arda. (2021). Coding and 3D Design Learning Analysis (International) [Research Survey]. Retrieved from https://docs.google.com/forms/d/1Bu3HW5pF4iBi4ZXaij37lZbhDyyw0De25zhCDGnVXDQ/edit

Even though information about the origin of their interests was collected, it was essential to look at how they continued learning about the subject. 64.2 percent of students said that they learned these skills in school in contrast to 71.5 which was the percentage of students that were introduced to these skills. This discrepancy shows that even though introducing kids to these skills is impactful they tend to continue their learning journeys through different mediums. 14.6 percent of the group continued their learning experience through online courses and 12.2 percent have explored the subject by themselves. Another important point that was discerned from this question was that students tended to turn to the internet and would prefer to work by themselves when they wanted to learn 3D Design or coding.

Figure 10. "How did you learn?" Pie Chart



Source: Con, Evrim Sude. Kançal, Arda. (2021). Coding and 3D Design Learning Analysis (International) [Research Survey]. Retrieved from https://docs.google.com/forms/d/1Bu3HW5pF4iBi4ZXaij37lZbhDyyw0De25zhCDGnVXDQ/edit

In order to gain more information about the ideal age to begin coding or 3D designing according to students, the group was asked the ideal time that these skills would be introduced. The ideal time to start learning was divided into 7 categories which consisted of preschool (0-4), kindergarten (4-7), elementary school (7-10), middle school (10-14), high school (14-18), university (18+) and professional life (18+). For coding, 33.3 percent of the group believed that elementary school would be ideal whereas 56 percent believed that middle school would be ideal to be introduced to the topics. For the same question 1 person chose preschool, 6 students chose kindergarten and also 6 chose high school as the ideal time. When the question was asked for 3D designing it was seen that 35.8 percent chose elementary and 50.4 percent chose the middle school as the ideal time gap. Furthermore, 4 people chose kindergarten, another 4 chose preschool, 7 chose high school and 2 chose university. When compared 3D Design has a broader dataset which could show how people perceive 3D design and the lack of knowledge.

Figure 11. Ideal Age Graph

Source: Con, Evrim Sude. Kançal, Arda. (2021). Coding and 3D Design Learning Analysis (International) [Research Survey]. Retrieved from https://docs.google.com/forms/d/1Bu3HW5pF4iBi4ZXaij37lZbhDyyw0De25zhCDGnVXDQ/edit

We observed that the learning environment is a big factor in the students' experience and enthusiasm, thus, we wanted to find out the best learning conditions that could be provided when giving a 3D design or programming lesson. According to our questionnaire, 22 students believed that getting the lesson from a peer (+- 2 years) would be highly beneficial for their learning, 46 believed that it would be beneficial and 34 thought it wouldn't affect while only 20 students believed it would affect their learning negatively. Another question we asked was about how the presence of a teacher/counselor being present would affect their learning and the results were: 22.1% negatively, 31.1% neutral, 28.7% beneficial, 18% highly beneficial. Also, students were asked how these lessons being conducted outside of school would affect their learning experiences and the results were; 7.3% negatively, 39.8 neutral, 35% beneficial, 17.9% highly beneficial. Our last question regarding the learning environment explored how having a socially interactive environment in contrast to a regular school lesson would affect their learning experience and the results were; 1.6% negatively, 13.8% neutral, 26.8% beneficial, and 56.9% highly beneficial.

3.2. Findings from the International Research Group

As this research was conducted on a limited number of students that come from an advantaged background, we knew that the results may not have applied to bigger focus groups. Thus, for our research to be more inclusive and precise, we have sent out a translated version of our form to international students who live and study abroad. Also, these students were more diverse both racially and economically. We have decided not to go over each question extensively as we did with our main form since the purpose of this international form was to see if there were any discrepancies between the two study groups, thus we will compare the results of these forms.
In the international form, the students were approximately the same age and they consisted of more people that were interested in only 3D design. They had similar background information about these topics; however, the number of coders that considered their knowledge professional level was lower. The percentage of students who were introduced to these topics via school was significantly lower while the percentages of learning via family and the internet were higher. The results regarding the question aiming to find the ideal age to start learning about this topic were almost exactly the same; however, the percentage of students who believed 3D design should be introduced in kindergarten was higher.
Most of the students from this group wanted to use their skills for personal development in contrast to the main study group. Similar results were taken from the question exploring in which areas the students believed these skills would benefit them the most with the exception of coding in academic life. However, this discrepancy was expected and perfectly normal as the academic system of the two groups are different. This group had no experience in teaching these skills. Also, one of the most essential parts of our research that focused on the learning environment had very similar results which showed these findings could be applied to students all over the world without minding their differences.

To conclude; even though there were some minor differences between the results of the two groups, they were all negligible which was surprising since there are broad differences in the groups regarding economic status, country, race, and academic systems. This proves that our research can be applied to almost any group of students without minding the differences.

3.3. Findings from the FLL Mentorship Project

At the beginning of the summer of 2020, we came up with the idea of mentoring students from FLL teams of middle schools in order to introduce them to FIRST and STEM and to give them lessons about the basics of coding and 3D design. Firstly, Arda Kançal contacted his former school and asked them if they would be interested in a project like this and he made some meetings with his contact about what they would be interested in. Then, Evrim Sude Con, got into contact with her former school's FLL Team's mentors in order to ask them if they would also be inclined to participate in these weekly lessons.

We, as the leaders of this project, took international 3D Design lessons and programming courses in order to broaden both our knowledge and to transfer them to the other instructors of this project.

We had a very surprising amount of participation requests like 120 students even though we only planned this project for 10-15 students. We quickly made some zoom meetings and decided to take

this project to the next level and make it possible for 50-55 students to attend. We had our very first lesson where we met with the students and briefly explained what we are going to do on the 26th of December and these lessons lasted till the 13th of February with 8 lessons both on coding and 3D Design.

3.3.1. Findings from the FLL Mentorship Project by Verbal Feedback and Observations

Throughout the process of the FLL Mentorship Project, we have gathered lots of verbal feedback from both the instructors and the students also, we have made some significant observations ourselves. We thought that it was essential to have this section since we had a chance to gather data from a real learning experience, not just hypothetical questions.

Firstly, the students were unsatisfied with the level of coordination between the instructors of different classes and weeks, thus, we have created a weekly meeting session which solved this issue. From this experience, we have found out that communication between instructors/teachers is very essential to have a fulfilling learning experience.

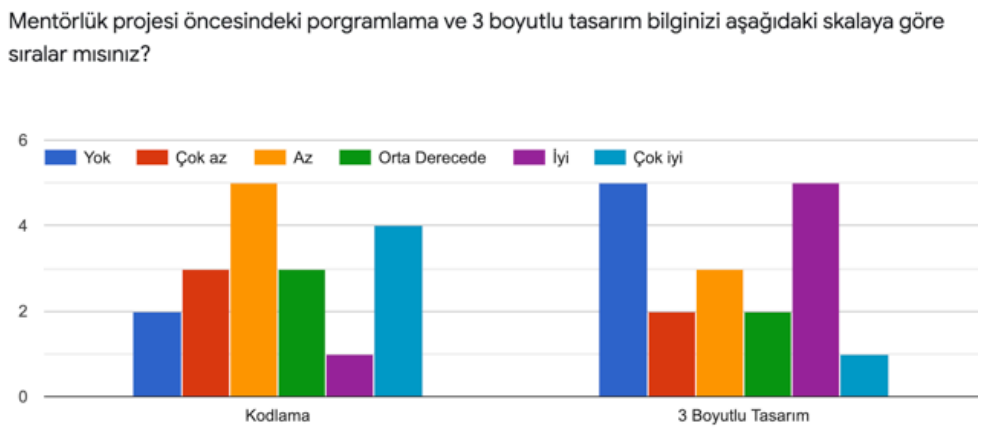
Secondly, as the age of the students was really low their attention span and motivation could wane throughout the hour-long online lessons. As a solution to this problem, we adjusted our curriculum to be more socially interactive and also incorporated a few projects that the students could do by themselves and see the results. This change was really beneficial as we got positive feedback both from the students and the instructors.

Lastly, we have observed that students were less motivated when they had to learn 3D designing tools and operations shown on mechanical components. Thus, we started to ask the students about the things they wanted to model so that we could teach the platform more effectively. The results were highly positive in 3D designing and also in programming when they programmed some basic functions they could use in their lives. From this experience, it could be said that student interests should be incorporated into the lessons and also that the lessons must use relatable objects and examples to achieve the ideal learning experience.

3.3.2. Findings from the FLL Mentorship Project by Feedback Form

After coming to the end of this journey, we wanted to get some feedback on our program; thus, we prepared a feedback form for the attendees to fill out. This form had multiple similar questions with the First Form we have conducted on our First Research Group which allowed us to make comparisons between high school students and middle school students.
Since the aim of this project was to increase the knowledge in terms of coding and 3D Design with the help of peer-to-peer learning, we first wanted the students to rate their prior knowledge on these areas. The majority of the group told that their knowledge was either non-existent or limited in both of the areas while there were also a group of students who also claimed they had an excessive knowledge on both of these areas. These different levels were noticeable during lessons; however, it did not affect our flow significantly as the students were mostly really respectful towards the environment.

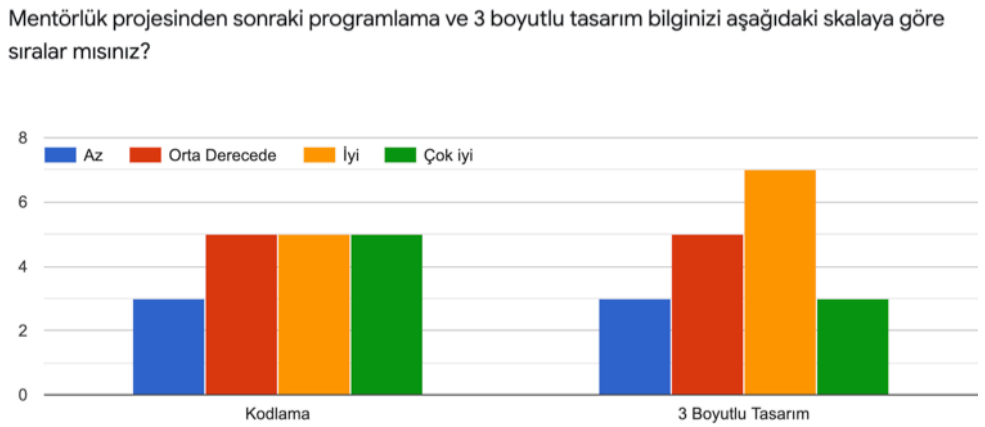
Figure 12. Prior Knowledge Graph



Source: Con, Evrim Sude. Kançal, Arda. (2021). FLL Mentorship Feedback Form (Feedback Form) [Research Survey]. Retrieved from https://docs.google.com/forms/d/166rG06FvVbKSoAsJqVN4sGugiLeJKNK6PAPodGx5_Rc/edit

After learning the initial state of their knowledge in these skills, it was time to see how much they feel like they have evolved. Fortunately, the numbers were significantly improved. Most of the students thought they gained an average, good, or very good knowledge in both of the areas with some exceptions of limited knowledge. This was proof that our project was successful and it made us really happy to see that the participants thought they learned a lot while we were also learning new things every day with them.

Figure 13. Post-Knowledge Graph



Source: Con, Evrim Sude. Kançal, Arda. (2021). FLL Mentorship Feedback Form (Feedback Form) [Research Survey]. Retrieved from https://docs.google.com/forms/d/166rG06FvVbKSoAsJqVN4sGugiLeJKNK6PAPodGx5_Rc/edit

We mainly wanted our program to be a unique learning experience that we both as a student and instructor would enjoy. A few of the unique qualities we tried to integrate into our project were interactivity, peer-to-peer learning without teachers, and a course apart from academic life.
All of these areas were highly appreciated and liked by the students participating in our program which showed us that a new more engaging learning model could be designed to entertain the students even more by still giving the needed content.

Figure 14. Unique Qualities Graph

Source: Con, Evrim Sude. Kançal, Arda. (2021). FLL Mentorship Feedback Form (Feedback Form) [Research Survey]. Retrieved from https://docs.google.com/forms/d/166rG06FvVbKSoAsJqVN4sGugiLeJKNK6PAPodGx5_Rc/edit

4. Conclusion

Acknowledgment

We would like to primarily thank Mr. Ergin for making this research possible for us and giving us the opportunity to reflect on our journey of mentoring FLL students. This was a huge project that we have conducted with the help of our Robotics Club - ARC 6014 - and our mentors. The cooperation of the mentors of FLL Teams we have got into contact with which were from Dr. Natuk Birkan İTÜ Geliştirme Vakfı Okulları and 6 Feyziye Mektepleri Işık Okulları made our journey undeniably easier and smoother. Mrs. Ünlü Ergin being the bridge between us and Mr. Ergin as well as participating in all of our sessions during the teaching period was really valuable for us. Gürkan Akçay, the mentor of the Işık Middle School FLL Team, being always in contact with us and making it possible for us to get feedback was also a huge help. We would like to thank all of our teammates who have participated in this course as an instructor and all of the students who have been eager to learn since the first day till our last lesson as they brought joy and success to this voluntary project. Lastly, we would like to thank all of those who participated in our forms

and surveys who made it possible for us to broaden our perspective and analyze the current situation in terms of the learning process of coding and 3D design among students.

This paper is an output of the research project done by Evrim Sude Con and Arda Kançal who are Robert College ARC 6014 Robotics Club Mechatronics Members and FIRST Outreach Assistants. This paper focuses on the learning experience of both high school and middle school students in coding 3D design and it aims to find the ideal learning environment with the help of the Designed-Based Research (DBR) methodology. This paper examines three research groups which consist of economically advantaged high school students from Turkey, international high school students from different economical and social backgrounds, and FLL Mentorship Programme participants.

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