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# Inquiry-based learning approach for a systematically structured conceptual design process: Design project for disabled people

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## Abstract

With the projects implemented in the 'Design for the Disabled' course in Gazi University 2019-2020 academic year, fourteen students are asked to develop solutions for the problems of disabled individuals, which is one of the real-world issues, while gaining professional knowledge such as critical thinking, idea generation and learning the conceptual design process. In addition, it is aimed to increase their learning motivation and interest in social design projects. It was learned that the students did not carry out a design project for disabled individuals in their previous projects. Throughout the semester, students developed their projects with a conceptual design matrix consisting of Data Collection, Primary Analysis, Secondary Analysis, Synthesis, Hypothesis, Preliminary Design and Final Design stages. Students were asked to present their projects at the Final Design stage. The course was conducted through online classes during the Covid-19 Pandemic for twelve weeks. Students are enabled to experience an interdisciplinary critical process. Thus, successful solutions and new models have been developed in projects in terms of product and space.

## Keywords

Design for disabled, design education, fuzzy front-end design process, conceptual design process, design toolkit

## Introduction

Industrial Design is a strategic problem-solving process (WDO, 2015). While the scale and the scope of the problem changes, the design process (DP) does not, its stages progress as repetitive and cumulative.

DP has descriptive steps and encourages an informed systematic decision-making approach by avoiding intuitive interaction (Leon and Laing, 2014). There are many different types of the DP, and they all contain analyses, synthesis, creation, and evaluation (Zimmerman et.al, 2011).

The early phase of the DP has more importance (Sanders, 2005) activities where problems and opportunities are defined (Cagan et al., 2002; Wormald, 2011; Sanders and Stappers, 2012). In the late design phase, ideas turn into prototypes and into products. Both phases require different content and format research (Sanders, 2005). Educators and researchers are looking for new methods to use in the early phase of the DP (Sanders, 2005). Much of the research conducted by designers and anthropologists since the early 1980s for the benefit of the product development industry has been related to the early design phase (Cagan et al., 2002; Wormald,

2011). The early phase of the DP is described as fuzzy front-end, as the DP and issues are ill-defined and not structured (Deschamps and Nayak 1995).

The activities in the early and late phases of the design are different. The late design requires the use of technical tools to solve well-defined problems in terms of form or structure. Conceptual design process, which is the early phase of design, is about developing new solutions and ideas. The conceptual process begins with questions and temporary design features and continues with synthesis. Good conceptual design (CD) stands for innovation, and it occurs when an innovative design consciously tries to create a design. In other words, it is the process of establishing relationships between sub-functions of design to achieve the design goal and objective through a chain of reasoning (Sturges et.al, 1993).

Correct data is needed to establish the relationships in problem-solving. Enhancing research in the early DP enables the creation of consistent cause-effect relationship between the design problem and its solutions, and increases the design quality (Payne, 2013). Archer (1965) states that in DP, creativity is the basic connection which is established in between the design idea and problem and indicates that when the solution emerges from data interaction, the design problem can no longer be ill-defined. In the 'Notes on the Synthesis of Form' by Architect Alexander, the author has adopted the idea that every decision made in the DP should be supported by data and design should be an independent process from the persons (Selau et.al,2020).

To generate design ideas, the data about the design problem area should be used (Kokotovich, 2007). The design problem should be structured before generating ideas (Mathias, 1995; Ho, 2001; Restrepo and Christiaans, 2003). Problem structuring refers to the process of reflecting the problem and its desired result (Simon, 1973).

After research and before the solution, insights that lead to design begin to emerge. It was concluded that the perceptual act underlying insight in design is more like 'bridging' the gap between the emerging problem and the solution rather than 'jumping' over a cliff (Cross, 1997; Akın, 1997). These insights can be generated by analysis and synthesis of research data, but unlike design research, this part of the DP is often ill-defined. Analysis and synthesis are underrepresented in academic and commercial literature and discussion. Although analysis and synthesis activities are extremely critical for design studies, the lack of definition means that it is difficult to teach and explain to students (Payne, 2013).

In the early stages when innovation and creativity come to the fore (Wormald, 2011), students discover the problem, try to understand it, collect data, try to make sense of the data and structure the problem (Kolko, 2010). It gains insight, establishes a relationship, and finds a solution to the problem with the data it collects (Sanders & Stappers, 2012). Focusing on the early-stage activity and developing solutions (Kokotovich, 2007) is the most challenging stage for novice designers.

Mathias (1995) found that, novice designers have no Problem Analysis (exploration of the problem area) in their processes compared to expert designers. Cross (2004) calls this 'scope of the problem' based on a focused or directed approach to collecting and prioritizing data about the problem area. Experts spend more time dealing with data and include them in their design

ideas, novice designers tend to embody the data in the design problem area independently (Mathias, 1995).

Data alone is not useful nor applicable and the creative. Students obtain knowledge by interpreting this data and jumping from raw data to insight by synthesis. This is a difficult skill to learn, and different methods should be developed to help students (Kolko, 2007). So, it is important to support design students to experience the problem structuring process in projects with different methods and techniques.

## Systematic Design Process

The DP that starts with the definition of the problem, reveals the problems, and ends with the solution (Açıcı, 2015) is a set of chronological and repetitive activities (Asimov, 1962; Bayazit 2004). From the perspective of design and technology education, the DP generally includes the steps of identifying a problem, undertaking research, generating plans of solutions, producing solutions, and evaluating the solutions (Middleton, 2005). Lawson (2005) states that the DP is infinite, prescriptive, and subjective activity carried out to meet a need. However, Selau (et.al,2020) points out that design should be an independent process from the persons.

'Design Methods Movements'(DMM) were initiated in 1950s and 1960s with the support of governments to conduct studies based on descriptive stages to define the complex DP. (Alexander, 1964; Cross, 1986; Jones, 1965; Rittel and Webber, 1973; Gedenryd, 1998). The purpose of the DMM is to understand the DP and to make it less dependent on the art and the designer. Governments have led researchers to more systematic processes within the scope of DMM. The oldest model that defines design as a systematic activity is the 'system' or 'task-oriented' approach applied by NASA (Rittel and Webber, 1984). The DP stages developed by different researchers generally as follows, understanding and defining the problem, collecting data, analyzing data, developing concepts for alternative solutions, evaluating alternatives, and choosing, testing, and applying solutions (Selau et.al, 2020).

In the 1970s systematic DP models were developed. The 'Systematic Approach' is a prescriptive model and developed by Pahl and Beitz in 1974. According to this approach, after each stage, which can be iterative, the 'decision-making stage' is carried out to evaluate the stage results, repeat the stage or move on to the next stage (Kannengiesser and Gero, 2017).

While Rittel and Webber (1973) describe the DP as a rational research task, Schön (1983) defines it as reflective practice. Archer's (1965) DP model is objective and rational (Herr, 2008). Archer's model (Figure 1), which also includes the training and experience of the designer emphasizes the importance of data collection in the DP while stating that designers should return to the data collection stage when needed after other stages. The emphasis Archer attaches to the data collection stage is the designer's or engineer's intuition or custom and practice (Davis and Gristwood, 2016).

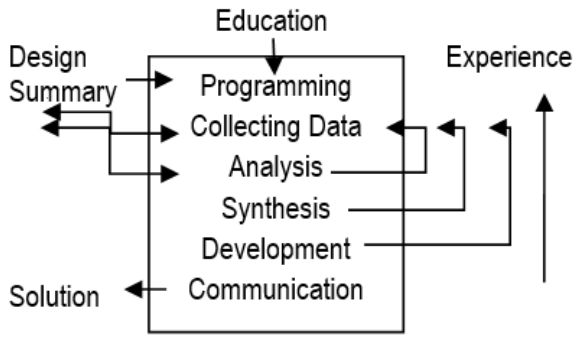


***Figure 1. Archer DP (Cross, 2008)***

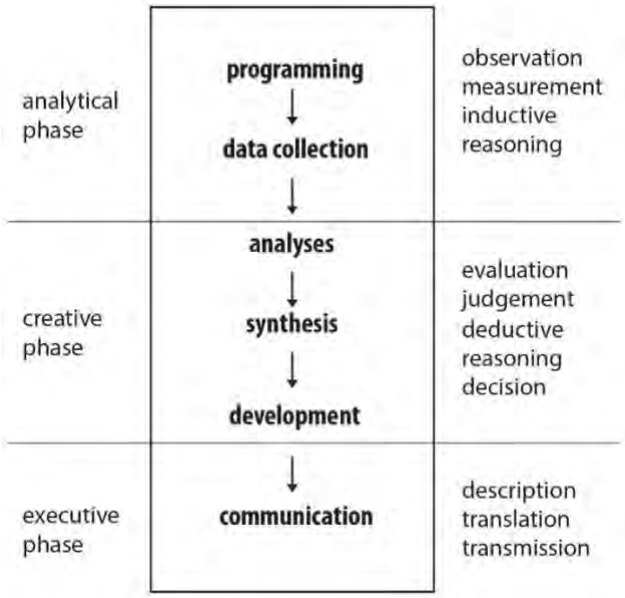


***Figure 2. Archer Systematic DP Model (Cross, 2008)***

Archer's systematic model to achieve the targeted design result (Aktaş and Çolakoğlu, 2018) is grouped as analytical, creative, and executive phase (Figure 2). In programming, the problem is defined, important points are emphasized, a business plan is made. Data is collected and organized during the data collection phase. In the analysis phase, sub-problems are determined and the product requirements, production problems and priorities are determined. In the synthesis where design ideas are produced, the suitability and applicability of the ideas are checked. The problems that need to be solved for the design idea to be implemented in the development phase are discussed. In the communication, the necessary drawings are prepared for production. In the DP model proposed by Archer, systematic observation and inductive reasoning are used in the analytical stage, while subjective and deductive reasoning is used in the creative stage (Linden et.al, 2011).

The DP stages in which different approaches are shown in Table 1 under the headings of early and late design phases. The number and terminology of the stages used to define the DP models are due to the professional design areas in which individuals are involved (Cross, 2008).

***Table 1. DP Models (Oygur, 2012)***

| | DESIGN PROCESS | |
|---|---|---|
| | EARLY PHASE of DESIGN PROCESS | LATE PHASE of DESIGN PROCESS |
| Archer (1984) | Programming > Data collection —> Analysis —> Synthesis | Development —> Communication |
| Pahl and Beitz (1974) | Clarification of the task — > Conceptual design | Embodiment—> Detail design |
| Schön (1992) | Identification of Design problem —> Decision—> Reflection | Result |

## Early design Phase 'Fuzzy Front-end': The conceptual DP

The early phase of the DP is ill-defined, while the late phase of the design is better defined (Sturges et.al, 1993). The early phase focuses more on creativity (Snider et.al 2014). While the early phase is shown as the most efficient process for the development of innovative ideas (Figure 3), it is also stated that the necessary data should be collected to make effective and efficient decisions in the innovation process (Herstatt and Verworn,2004).

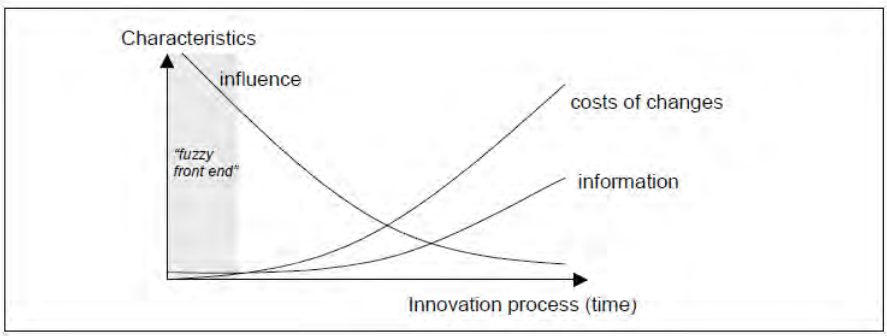


***Figure 3. Early Phase and Innovation (Herstatt and Verworn, 2004)***

The early phase of the DP is the front end of the design activities in which the design problem is defined (Cagan et al., 2002; Sanders and Stappers, 2012). CD completed in the early phase period defined as 'fuzzy front end' has the most important effect in the DP (Grierson and Khajehpour, 2002). However, the 'fuzzy front end' is the least structured phase, both in theory and in practice, and there is a need to systematize activities to increase efficiency (Herstat and Verworn, 2004). A structured process has a positive effect on student achievement (Radcliffe and Lee,1989).

CD is the most important part of a project (Gharib, 2016), dynamic and creative phase, it is the most difficult and least understood (Macmillan et.al, 2001). Good CD means innovation, and an innovative design comes about when one deliberately tries to create one (Perkins, 1981).

## Inquiry-Based learning in the conceptual design process

CD in which data collection and development of design idea is critical and is the most difficult process for students. Because the student does not know what to do and how to reason with the data obtained. Critical thinking on collected data at the early stage has a significant impact on the next stages. (Björklund, 2013).

Students should be in inquiry-based learning (IBL) style to develop their critical thinking skills. IBL is based on the philosophy of Dewey (1986), which states that education begins with the curiosity of the learner and then is the activities corresponding to learning and research. IBL is a student-centered active learning approach where the students are part of the whole research process (Herzog et.al, 2016).

IBL activities start with the creation of a research question and continue with research and development of solutions (Herzog et.al, 2016). Students create new knowledge based on the data they have within the scope of the research question. Generating new knowledge is an important part of the learning process and at the end of the process, the findings are presented (Herzog et.al, 2016, Mieg, 2019).

Wildt (2009) combines the IBL model with the Kolb learning model and describes research and experiential learning as follows:

> *The research and the learning process start with observation of problems in the real world and the concrete experience, the students are irritated by a situation or an experience. The defining of questions or problems is part two of the cycle (reflective observation) and ends with the formulation of research questions or hypothesis. The abstract conceptualization is used to develop a research concept and design. The developed concepts will be verified during active experimentation and new knowledge will be created. From these findings new learning and research cycles start. (Herzog et al., 2016).*

Kolb's Learning Style Inventory is the most widely used model for design students due to its generalized and reliable structure (Carmel-Gilfilen, 2012; Demirkan and Demirbas, 2008). According to Kolb's model (Figure 4), a learning cycle consists of four stages: concrete experience (CE) reflective observation (RO), abstract conceptualization (AC) and active experimentation (AE). Design students are in the active learners group. He argues that learning begins with experience, continues with reflection, and then becomes a concrete experience in reflection (Kolb, 1984).

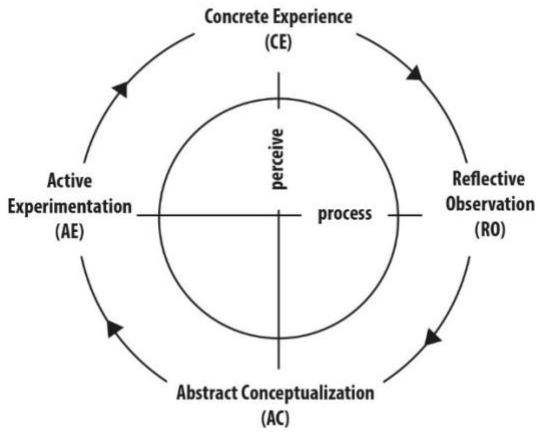


***Figure 4. Kolb ELT Phases (Demirkan and Demirbaş, 2008)***

Students can reveal a relationship between the obtained data and the new knowledge with IBL through research, in other words, the cause-effect relationship. Cause-effect express the relationship between two phenomena caused by one phenomenon behind another (Salkind, 2010).

As the above discussion proves, it is concluded that a new methodology that combines the conceptual DP with an IBL model and contributes to students' professional skills can be useful in design. Guided questions encourage critical thinking about aspects of the problem that need to be addressed to develop a successful design.

## Design for the disabled

Disability is the condition of preventing one's full and effective participation in society on an equal basis with others, due to imperfection (lack of psychological-physical functions), dysfunction (inability to work compared to a healthy person) and disability (inability to perform normal activities due to disability) (Koca, 2010; WHO, 2011; Börklü et.al, 2018), or long-term physical, emotional, mental or sensory impairments (CRPD, 2020).

Design for the Disabled is defined with the terminologies' Universal Design ', Accessible Design', 'Barrier-Free Design', 'Design for All' in the fields of architecture and design, and it is aimed to make more inclusive designs. Universal Design means the design of products, environments, programs, and services that can be used by everyone without the need for special design (UN Human Rights, 2020).

Industrial designers are expected to take responsibility for the disabled, the homeless, and the unemployed, as well as designing products for profit (Papanek, 1995; Yavuzcan et.al, 2019). Norman (2009) also reveals the lack of education by stating that the disabled are not a small group deprived of their rights and represent all individuals, therefore what needs to be done is education, awareness, and empathy.

Apart from the concept of accessibility in physical environments, social, emotional, cognitive, and physical needs of persons with disabilities should be met within their skills and abilities. Considering these requirements, the terminology 'Design for Disabled' has been used to prevent the project from being accessibility oriented.

### Methodology - Conceptual DP with IBL

According to the discussions, auxiliary toolkits are required for students to learn the conceptual DP defined as 'fuzzy front end'. Therefore, a toolkit focused on IBL learning that can be used in teaching the conceptual DP has been developed. Fourteen students attending the Gazi University 2019-2020 Distance Education Academic Year Fall Semester Design for Disabled course, were asked to use new teaching toolkit. This toolkit consists of the CD Learning Tool and its Matrix. The main purpose of the toolkit is to guide design students to develop design solutions consistent with the design problem and develop critical thinking skills by learning the conceptual DP defined as the 'fuzzy front end' of design with a systematic and inquiry-based structured toolkit. The new tool developed encourages critical thinking about the aspects of the problem that need to be addressed to develop a good design idea, with guided questions in the process stage.

The new learning tool (Figure 5), Archer systematic design model (Cross, 2008), IDEO Design Thinking, Scientific Project Stages, City of Toronto Accessibility design guidelines, 5W1H tools used in scenario and fiction development, and lecturers' self-knowledge were created. The Archer model and the IDEO Design Thinking model cover the entire DP and research questions are omitted. The City of Toronto Accessibility design guide focuses on 'Accessibility', hence the physical barrier. 5W1H research questions are mostly used in developing scenarios and fiction.

Systematically structured New CD (Figure 5) guide consists of 3 main phases and 8 consecutive steps: Analytical Phase (Programming, Data Collection), Creative Phase (Primary Analysis, Secondary Analysis, Synthesis, Hypothesis), and Visualization Phase (Preliminary Design, Final Design). A New CD Matrix (Figure 6) was created by using the New CD tool for the students to process the decisions they make in each step. Students were asked to develop projects with this process matrix.

The content of each stage in the newly designed CD learning tool is detailed in Figure 5.

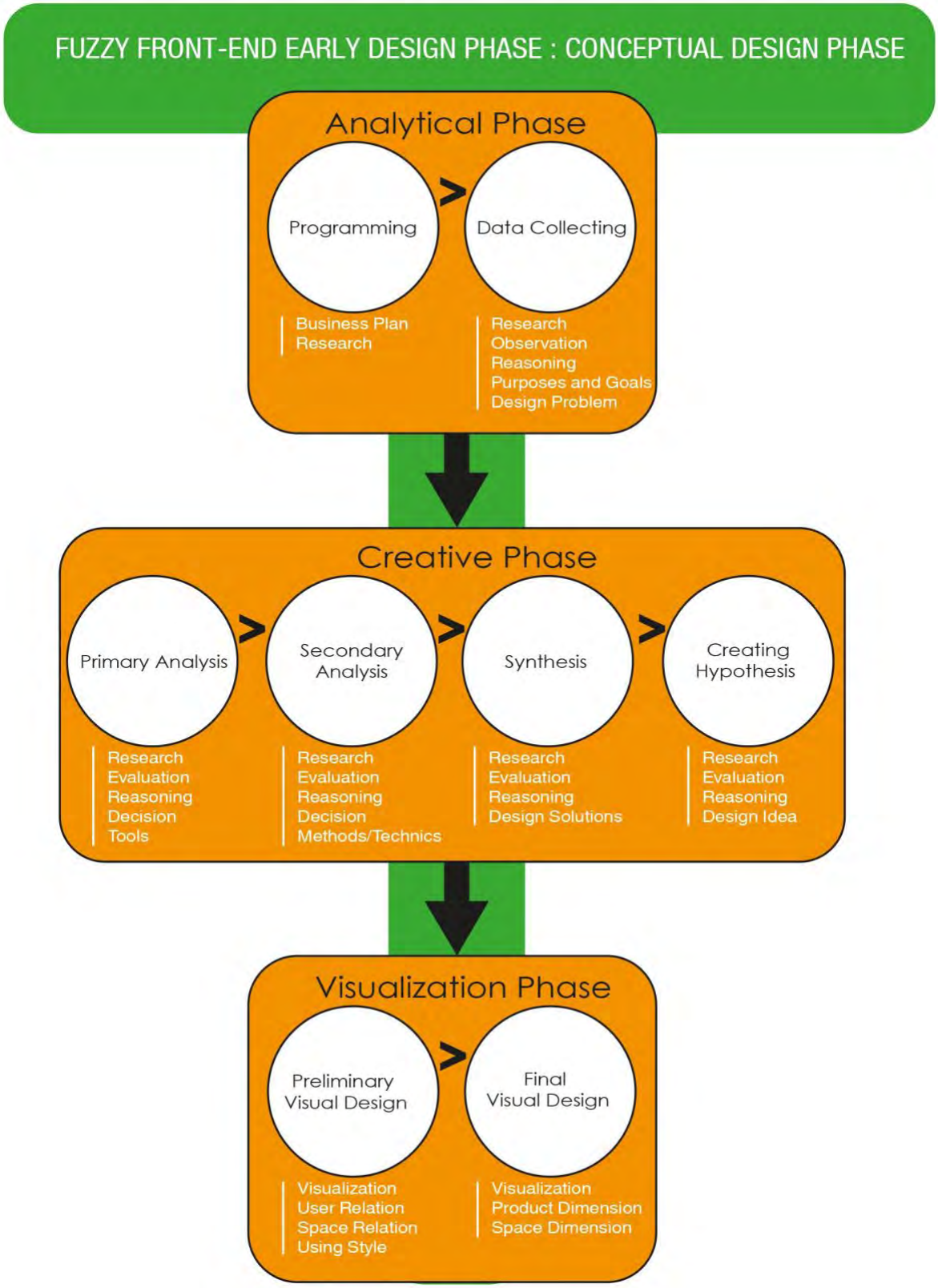


***Figure 5. Teaching Fuzzy Front-End and Early Phase of Design: Systematically Structured Phases of The New Teaching Tool for Conceptual DP***

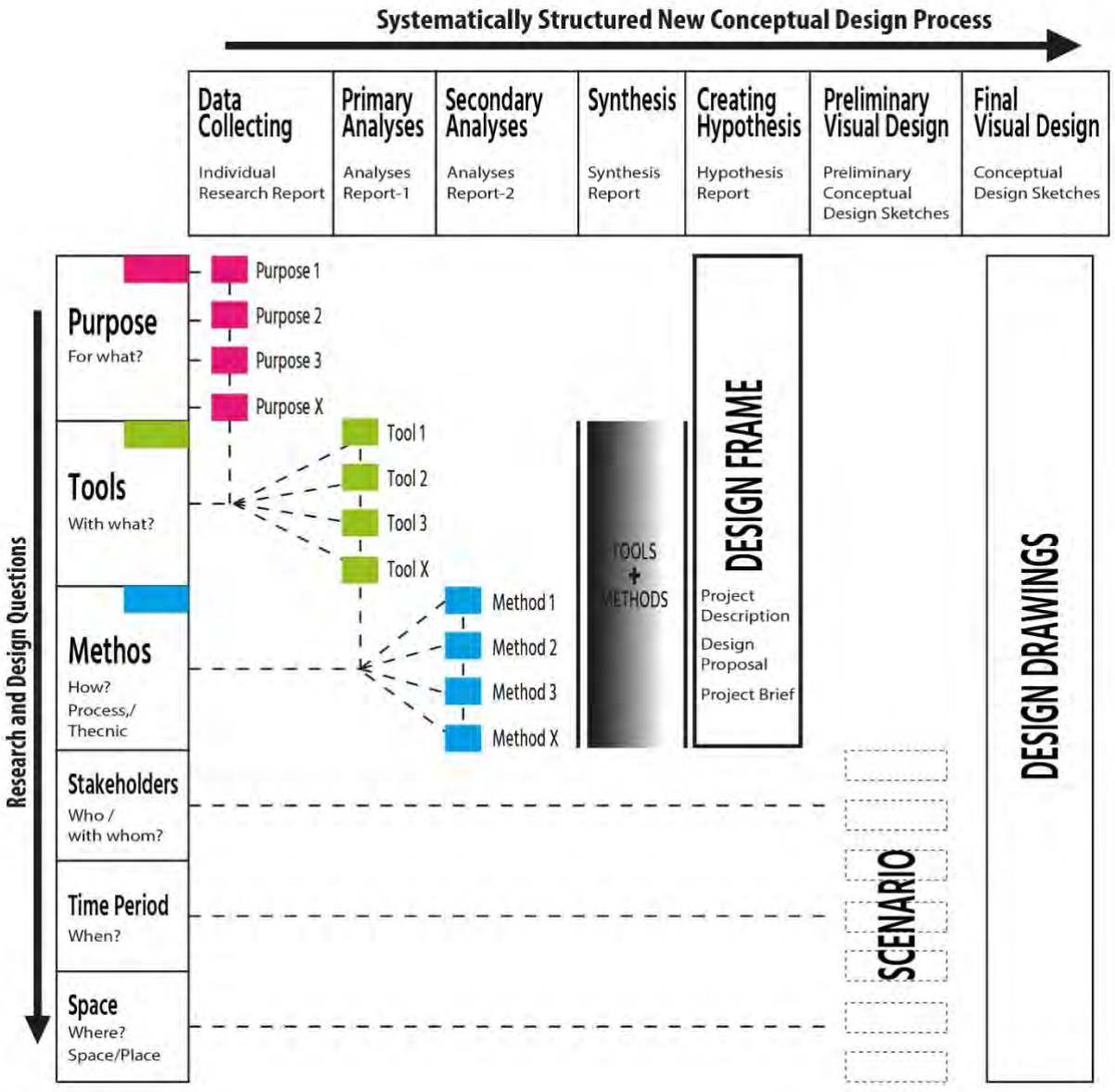


***Figure 6. The New Inquiry Based Teaching Matrix for Conceptual DP***

## Project Topic: Conceptual Design Project for Individuals with Disabilities

Individuals with disabilities are grouped as physically, mentally, hearing and visually impaired. 12 weeks of the 14-week course process were conducted through online platforms during the Covid-19 Pandemic. During the project, critical lessons were carried out synchronized online, while a project management online curriculum application was used for the recording of students' activities. The students uploaded the report of each project stage they developed for the disability group they chose, on the application.

A design brief was presented to the students as a guide that conveys the form and content of the reports they need to upload at each stage in detail. The reports submitted by the students at each stage, were criticized by the lecturers. After the student's report was found sufficient, the students added their decisions on to the process matrix. If the student's report was not sufficient the student was asked to repeat stage.

Using an online application, students were able to follow and examine each other's projects and processes.

**Analytical Phase**

It is the phase in which the students are asked to define the problem their designs will address. This step is important as it drives the rest of the DP and determines how project success will be measured.

*Programming*

At this stage, a business plan related to the education and training process was created and a guide was presented to the students. The contents of programming are specified in the following 2 titles.

*Guidelines for the Design for the Disabled*

At this stage, a design brief was prepared by the lecturers to guide the students, the presentations of the expected studies and the duration of the stages were shown.

*Design for Disabled: Disability Group Selection*

Before choosing the groups, for guidance, students be given the 9th and 30th articles of the United Nations Convention on the Rights of Persons with Disabilities (2020), an international human rights convention to protect the rights of the disabled. Students were asked to obtain information about contents of these titles (Table 2).

***Table 2. Articles of the Contract (UN Human Rights, 2020)***

| |
|---|
| Article-9 - Accessibility |
| Article-10 - Right to lifeArticle-11 - Situations of risk and humanitarian emergencies |
| Article-12 - Equal recognition before the law |
| Article-13 - Access to justice |
| Article-14 - Liberty and security of the person |
| Article-16 - Freedom from exploitation, violence and abuse |
| Article-17 - Protection of the integrity of the person |
| Article-18 - Freedom of movement and nationality |
| Article-19 - Living independently and being included in the community |
| Article-20 - Personal mobility |
| Article-21 - Freedom of expression and opinion and access to information |
| Article-22 - Respect for privacy |
| Article-23 - Respect for home and the family |
| Article-24 - Education |
| Article-25 - Health |
| Article-26 - Habilitation and rehabilitation |
| Article-27 - Work and employment |
| Article-28 - Adequate standard of living and social protection |
| Article-29 - Participation in political and public life |
| Article-30 - Participation in cultural life, recreation, leisure and sports |

After choosing the disability group the students examined the population distribution and demographic structures according to the groups.

*Data collecting*

*Format*: Be asked to present the data obtained in line with their literature reviews as an individual research report, to have a list of sources in the last part of the reports, and to refer to the relevant sources in the text in accordance with the APA format. The reports were uploaded to the board by the students.

*Content*: Universal design, accessibility in public spaces, ergonomics, design criteria, social services, spaces, events organized for the disabled, the problems and difficulties experienced by the disabled are the research topics. During the data collection, students who could not meet with users due to Covid-19 Pandemic were asked to benefit from previous written and visual scientific research to get their opinions on the problems and experiences of the users. They were able to use all kinds of written, visual, and video resources reflecting user opinions and experiences. They were asked to present written and visual research summaries of the literature on systems and technologies, communication, and social relations for people with disabilities, examples of space and product design, standards, and regulations for disabled, and surveys and analyses related to their research. Students were asked to collect data on the studies and products, services and systems carried out according to the United Nations Convention on the Rights of Persons with Disabilities (2020). The reports were asked to reflect the summaries of the literature and to analyze the technical data obtained. Finally, they were asked to present their answers to the research questions.

*Research Questions*: At the end of the data collection phase, the reports were completed by defining the design problem, objective/objectives, and goal/goals. What are you designing for? What is your design goal/purpose? Attention has been paid to ensure that the design goal and purpose, which directly shows the design emphasis is clear, measurable, realistic, and accessible during the project period.

*Matrix Processing*: The answers to the research questions are converted into keywords and entered in the matrix.

Students who could not fully define their goals and objectives repeated the stage.

**Creative Phase**

In this phase the student develops tools, methods, design solution and design idea for the design problem.

After the problem is determined, students continue to do research with written and visual tools. Then, students work on possible design solutions.

They are expected to draw their design ideas with diagrams or maps and communicate why they developed that design idea. The design idea is expected to be consistent with the design problem.

*Primary Analysis*

*Format*: For the continuity, the research was presented in a report with both written and visual content.

*Content*: During the data collection phase, the data provide possible solutions to the design goal. The students were asked to deductively analyze the tool(s) that will enable them to achieve their design goals and analyze the structures and relationships.

At this stage, they have investigated the tools with which they could achieve their design goals. This tool could be an object, a social or a physical activity. Students do not have to do research focusing on people with disabilities. User demand analyses were requested. The students were asked to do their research in line with the experiences and social or physical activities that could be a solution to the design problem, considering the competencies of the disability group within the framework of the design goal they determined. Finally, they were asked to present their answers to the research questions.

*Questions*: Which tools can you use to reach your design goal? What are the tool(s) required to achieve your design goal?

*Matrix Processing*: Entering into the matrix as primary analysis question-answer key definitions. Students can write more than 1 tool.

The students who could not fully define the necessary tools to achieve their goals and objectives were asked to repeat the stage.

*Secondary Analysis*

*Format*: For the continuity, the research was presented in a report with both written and visual content.

*Content*: At this stage, the students were asked to research the methods, processes and techniques they will apply while using the design tools they have determined. They were asked to analyze structures and relationships with deduction.

At this stage, they researched design methods in line with design goals and design tools. This method can be an action or a known technique or process. Students do not have to do research focusing on people with disabilities. In the primary analysis phase, the students were asked to conduct research, within the framework of the design goals and tools they determined. Finally, they were asked to present their answers to the research questions.

*Questions*: Which method/technique/process do you plan to implement to achieve your design goal? What are the methods required to reach your design goal?

*Matrix Processing*: Entering into the matrix as secondary analysis question-answer key definitions. Students can write more than 1 method.

In the Secondary Analysis stage, the students who could not fully define the necessary tools to achieve their goals and objectives were asked to repeat the stage.

*Synthesis*

Form: Students prepared a report with original written and visual content in the continuation.

*Content*: This stage is the summary stage where the primary and secondary analysis data are defined. One of the tools and methods that are in a cause-effect relationship towards the goal was asked to be selected and declared. It was asked to define which user needs it could meet by combining the decided tool and method. In the conclusion part of the report, they were asked to present their answers to the research questions.

*Questions*: How do you plan to reach your design goal (method) and what will you use (tool)?

*Matrix Processing*: The selected tool and method were entered into the matrix.

If the tool and method was not consistent within the framework of cause-effect relationship, students were asked to repeat the stage.

*Creating Hypothesis (Development)*

*Form*: In the continuation, the original reports were asked to define the project in writing and to transfer their definitions using drawings, graphics, storyboard, animation, scenario map, user map, system map.

*Content*: It is the stage where new and original assumptions are put forward, it is the design framework. Design is the first stage in which solutions turn into an idea and the design idea is developed. The students were asked to develop a design idea of a product or a space within the scope of a tool and a method that was combined for a purpose and a target. Finally, they were asked to present their answers to the research questions.

*Questions*: What's your design idea?

*Matrix Processing*: Entering design ideas into the matrix.

A step repetition was requested for design ideas that did not include previously determined tools and methods.

**Visualization Phase**

The design idea is visualized, and design sketches are made. Finally, it is requested to work on determining the dimensions, the choice of material, color, and texture.

*Preliminary Visual Design*

*Form*: In the continuation, sketches were requested.

*Content*: It was requested to transfer the fiction and scenario including the stakeholder, place and time period of the created hypothesis. It was requested to design the user relationship and preliminary form.

*Matrix Processing*: Visually entering projects into the matrix.

*Final Visual Design*

*Form*: In the continuation, sketches were requested.

*Content*: It was requested that the preliminary designs be detailed in terms of product-space, product-user, space-user relationship. It was requested to determine the dimensions for the product or space, and to review the preliminary designs of the form according to the measurements.

*Matrix Processing*: Visually entering projects into the matrix.

### Stage Evaluation

Students who successfully completed each stage with clear answers were asked to enter their decisions into the matrix and they were asked to be prepared for the next stage. The students who were not consistency and clear were asked to repeat the stage aligned with the given criticism.

### Project management

Stage contents and timing of the students were important to manage the project. The stages and timelines are shown in Table 3.

***Table 2. Reports and Timelines***

| *Project Phases* | *Week* | *Reports* |
|---|---|---|
| *Analytical Phase* | *1* | *Business plan* |
| | *1-2* | *Data collection* (Determining Goals and Targets, Defining the Design Problem) |
| *Creative Phase* | *2-3* | *Primary Analysis (Identifying Tools Towards the Design Problem)* |
| | *3-4* | *Secondary Analysis* (Determining the Methods Regarding the Design Problem) |
| | *4-5-6* | *Synthesis* (Determining the Design Solution for the Design Problem via Tools and Methods) |
| | *6-7-8* | *Hypothesis* (Conversion of Determined Design Solutions into Design Ideas) |
| *Conceptual Visualization Phase* | *8-9-10* | *Preliminary Design* (Fiction of Design Idea, User Relationship and Visualization Studies) |
| | *9-10-11* | *Final Design* (Determination of the Dimensions of the Visualized Design Idea, Applicability) |
| | *12* | *Jury Evaluation* (Presentation of the Matrix and Project) |

### Evaluation of Projects

Finally, each project was evaluated by 3 lecturers according to the criteria the level of qualification in the Likert scale. The qualitative evaluations used instead of points in this study are shared in the results section.

## Analysis of Projects and Process Observations

Lecturers used a rubric consisting of criteria determined according to the learning outcomes to evaluate projects. Evaluation criteria were in 2 parts as process and project. Process evaluation criteria are project management, critical thinking skills, report presentation quality. Project evaluation criteria are consistent cause-effect relationship, presentation quality, effective communication skills, holistic design approach, originality, and innovation. The common observation findings of the lecturers for each project were conveyed as analytical phase, creative phase, and visualization phase.

The expected learning outcomes at the end of the newly developed Conceptual DP methodology stages are stated as follows:

- Being able to read written and visual data,
- Developing critical thinking skills (analysis, synthesis, evaluation),
- To conduct evidence-based research, to develop a meaningful product concept,
- To be able to create consistent cause-effect relationships between the design problem and idea,
- To grasp the conceptual DP,
- Developing project management skills,
- Developing effective thinking, speaking, and writing skills,
- To create awareness on Design for Disabled.

**Post-project questionnaire**

Questionnaire completed by instructors: A rubric was asked to 3 lecturers to calculate the mean values of the subjective evaluations (project evaluations).

Questionnaire completed by students: It was developed using the Likert scale to get feedback from students about the effectiveness of the new teaching model developed to better learn the conceptual DP defined as the fuzzy front-end. The questionnaire was applied to all the class and answered by all of them.

## Results

Fourteen students attended Gazi University 2019-2020 Distance Education Academic Year Fall Semester Design for Disabled course. It can be said that the new teaching tool developed with the students developing projects according to different disability groups is applied for different projects. In this study, projects that constantly participate in the course and fulfil the tasks determined at each stage are presented. Then, the results of the questionnaire were administered by the fourteen students and finally the evaluations were made by the lecturers according to the criteria.

The lecturers made the examinations in 3 stages. These stages are listed as analytical (programming and data collection) (1), creative (primary and secondary analysis, synthesis, hypothesis) (2), conceptual visualization stage (preliminary CD and final design) (3). The findings below are made in the order given.

**Project-1- Judo Education and Play Material for Visually Impaired Children**

Student who chose the subject of design for visually impaired individuals were grouped under 3 headings as ‘facilitative designs for reading-learning, psychological/social themed research and physical barriers encountered in the environment’ and it was concluded that the least number of studies were on Psychological and Social themes. The student has chosen to work on 'Article-30 - Participation in cultural life, recreation, leisure and sports’. The student categorized the visually impaired individuals according to their demographic characteristics and conducted research on their needs and problems. It was found that one of the problems faced by visually impaired individuals is balance and it is mostly encountered in children between the ages of 5 and 10. So he decided on the concept of balance as a design purpose. The student defined the design problem to solve the balance problems of visually impaired children in the 5-10 age group.

The student continued to research and analyze the design goal of the balance problem. He avoided doing his research only on visually impaired individuals. He utilized scientific research on the balance problem that can be encountered in every individual. At this stage, the student asked 'what' and 'which vehicle' questions to achieve the design goal. He found that some sports, especially judo, have important and positive effects on balancing. In the secondary analysis phase of the research, he sought answers to the questions of 'how', 'which method/technique/process' to achieve the design goal. He reached the data that children in this age group learn best with games, toys or in social settings. He found that the best way of learning for visually impaired individuals is from piece to whole.

When the student reaches the synthesis stage, the basic concepts that he obtained are balance, judo, game/toy, social learning, and puzzle. He developed a new judo training solution through a game/toy aimed at the student design goal.

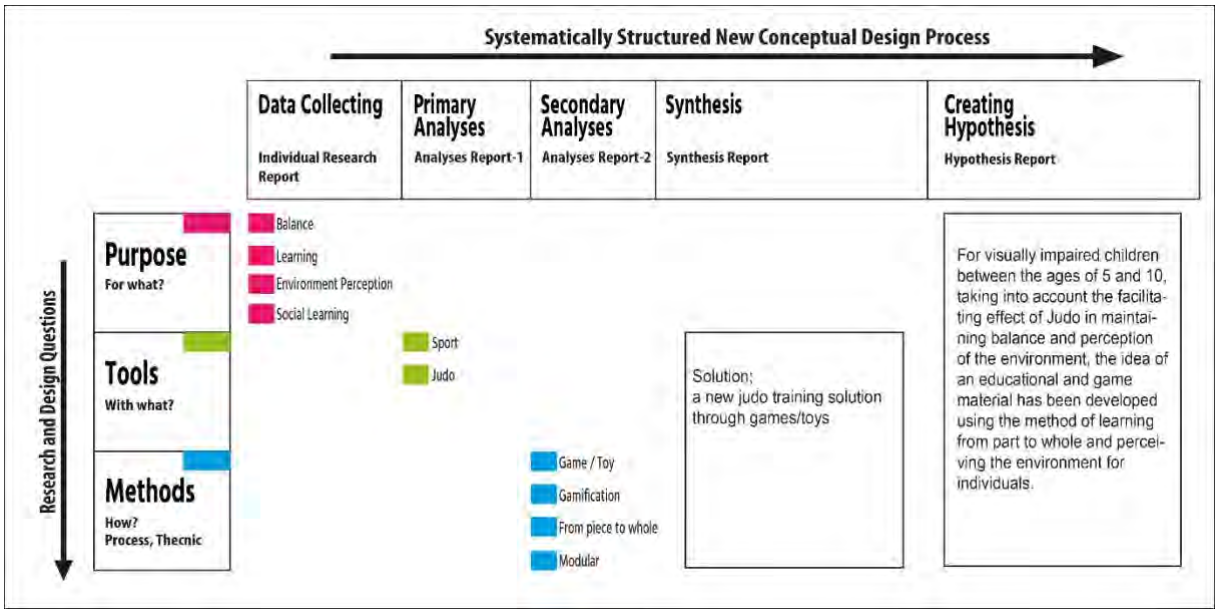


***Figure 7. Project 1 Matrix***

In the development phase, considering the facilitating effect of Judo in maintaining balance and perception of the environment, the idea of an educational and game material has been developed using the method of learning from part to whole and perceiving the environment for individuals. He drew and studied the basic movements of judo and worked on wearable parts that were compatible with the movements. A new judo learning model has been developed by combining games, education, and judo in this designed product group. In the first stage of the training, individuals use training and game materials to practice perception and matching by touching. While the mathematical skills of individuals are improved with the modular units where the Braille alphabet numbers are imprinted, the perception of touch is improved by matching the modular units where different textures are embedded. Individuals who complete this stage move to judo training. At the end of the second phase, the student developed a new idea of judo training and educational material design to help balancing issue of the visually impaired children.

In the last phase, the student visualized the design idea and assembly. The product group designed for a judo learning model that can be used for one person or two people consist of a judo mat, arm baguette and wearable units. The judo mat consists of textured and smooth modular units that assist in placing the feet in correct positions while learning steps. The judo baguette, which is designed for short and long-distance arm movements, allows users to perceive the limits by units placed on it. Wearable units for shoulders, elbows and knees allow the user's perception of the right move towards the opposite player by the triangular units on them.

The matrix of the project is shown in Figure 7.


***Figure 8. Project 1 Preliminary Design Phase***

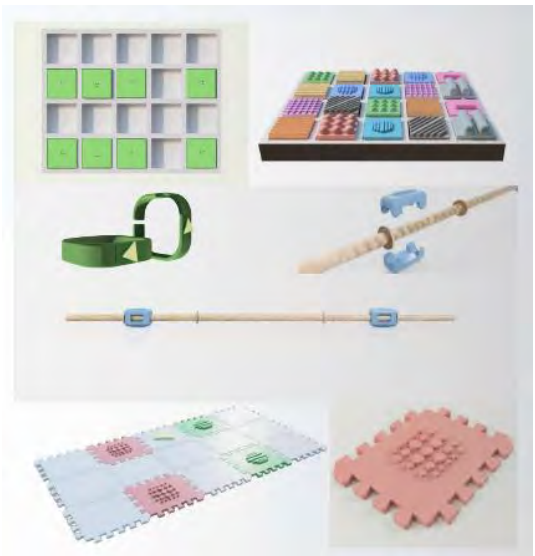

***Figure 9. Project 1 Final Design Phase***

**Project-2- Acoustic Exhibition Area Design for Visually Impaired**

The student has decided to work on 'Article-30- Cultural life, recreation, leisure and participation in sports' to design for visually impaired individuals. The student categorized the visually impaired individuals according to their demographic characteristics and conducted research on their needs and problems. He reached the data that one of the biggest obstacles for visually impaired individuals is to socialize and participate in various cultural activities due to navigating problem. The student defined the difficulties visually impaired individuals experience in navigating to socialize as a design problem.

The student reached the examples indoor and outdoor spaces. It has been determined that the samples developed only help them find direction and do not contain any social experience. Within the scope of Article-30, the student defined exhibition areas as a means for disabled to socialize. Thus, the student worked on interior spaces where they can have social and cultural experience by using space and product together. The exhibition area designed for the visually impaired has been functionalized with acoustics and building elements. There is a space design with a U-shaped circulation structure dominated by concrete and glass. Users enter the venue, take their headset from the box office at the entrance, and then proceed in the direction of circulation and perceive the work of art placed with a 60-degree slope by touching.

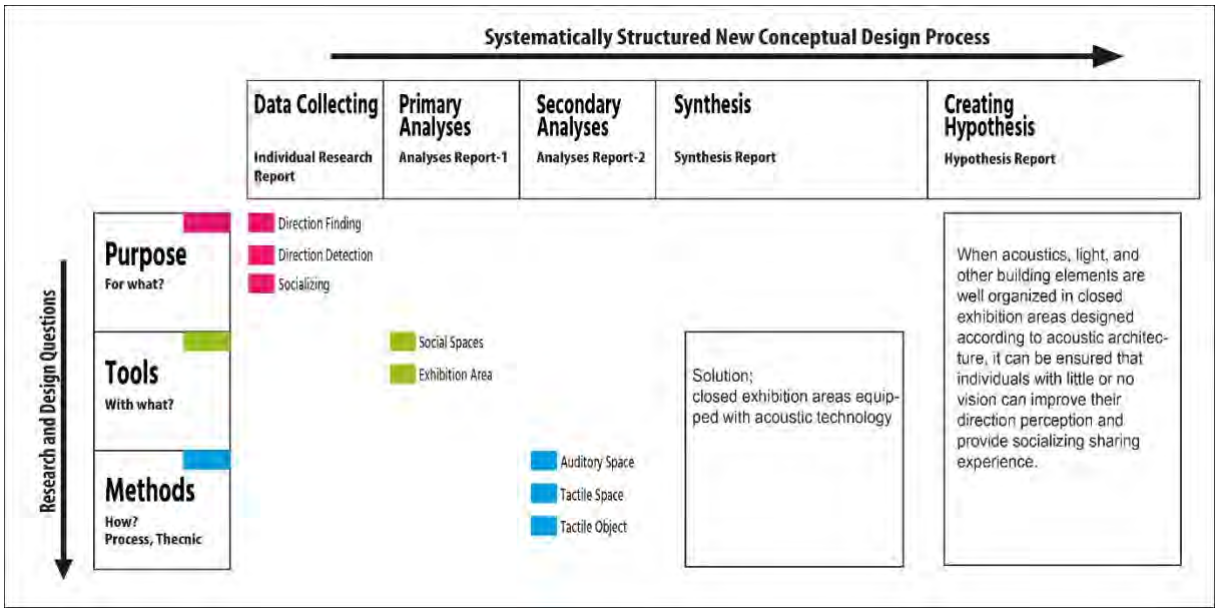


***Figure 10. Project 2 Matrix***

In the third phase, the student visualized the fiction between space and product, designed product-space physical relationship, materials, and measures. Visually impaired and healthy individuals are guided in the space by headphones that are integrated with the central sound system. The glass, which is used as a reflective surface on the exterior, also provides contrast lighting for individuals with low vision. There are tactile surfaces on the floor to guide users in the direction of circulation. He tried to analyze architectural elements, light, sound, and building.

The matrix of the project is shown in Figure 10.

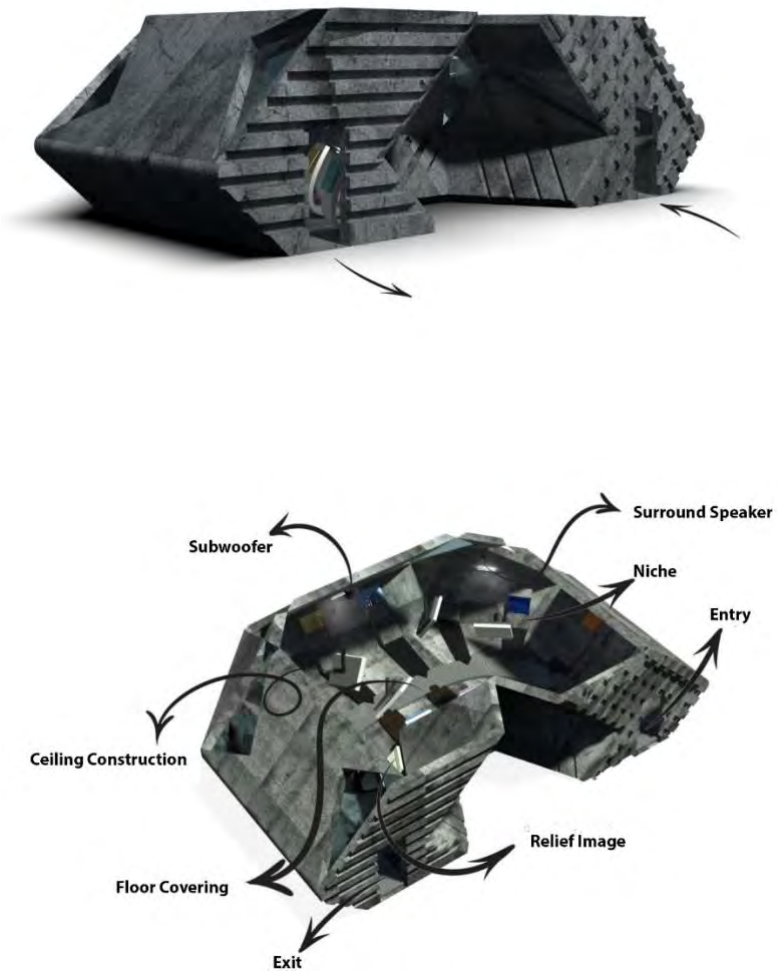


***Figure 11. Preliminary Design Phase of Project 2***

**Project-3- Learning with Social Story for the Mentally Disabled**

The student who chose the design subject for mentally handicapped individuals decided to work on 'Article-24 - Education', one of the contract articles in the first phase. In the researchers conducted for the mentally disabled, the student found that the parents of disabled children had difficulty in their behavioral training. These behavioral disorders are listed as follows:

1. Solving problems experienced while traveling on foot (leaving the mother's hand while crossing the street and running),
2. To explain not every desired object can be taken,
3. It aims to reduce the overreaction to change.

The student developed a project for these problems.

The student researched the tools and methods that could be used to increase the learning levels of individuals. The student has reached the data showing social stories used to help children with intellectual disability to help them gain daily life skills. However, these social stories were presented as written sources supported by visuals. The student formed the

knowledge by thinking critically that the social stories presented in books could not be up to date. The student reached the data that these individuals learn best by mirroring and taking someone as an example (model-based learning). He tried to establish a relationship between the social story he wanted to use in his project and to find a design solution to bring learning and mirroring. However, the student aimed to use digital technologies to keep social stories up-to-date and use them easily in every environment. Within the scope of the project, a digital product with an animated didactic social story and a physical product used to remind the information learned through stories were designed for individuals with mild mental disabilities such as autism. Basically, the digital product aims to convey the correct theoretical information to individuals through animation, to show the results of the elections again with animation; the physical product aims to remind the theoretical knowledge learned in real life. The physical product can be used both in mobile and stationary places.

The student conducted research on the characters and colors that should be used for these special individuals. He designed an animation by developing all the characters and interfaces according to the story he fictionalized. The student designed 3 stories containing successful characters and fiction due to his special interest in the field of illustration. The matrix of the project is shown in Figure 12. The editing and contents of the stories are shown in Figures 13 and 14.

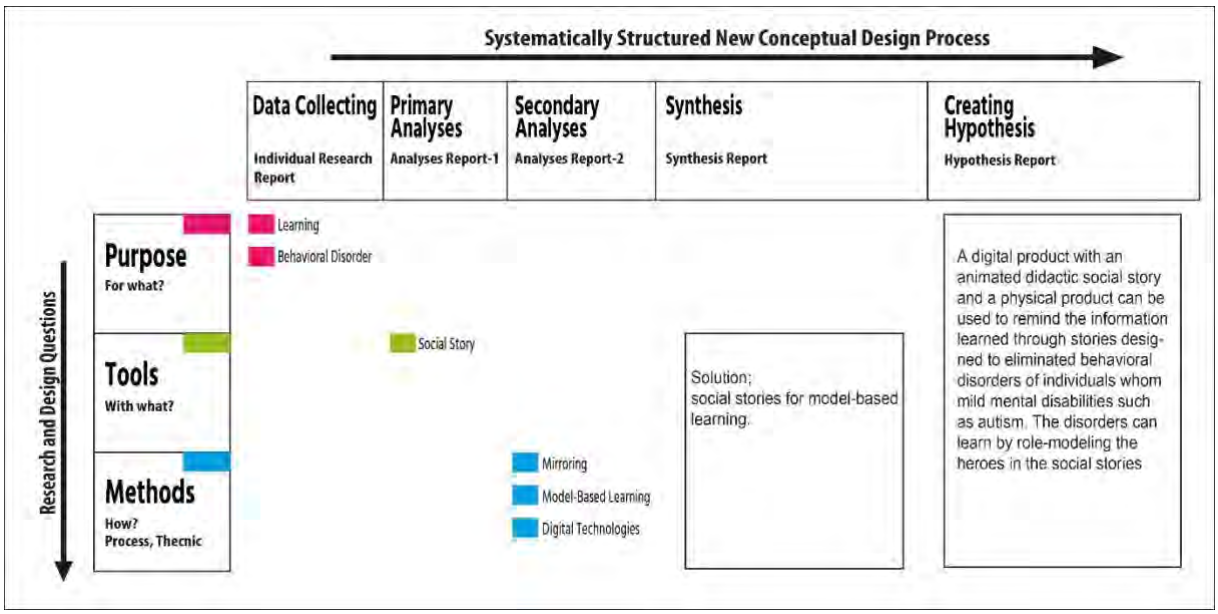


***Figure 12. Project 3 Matrix***

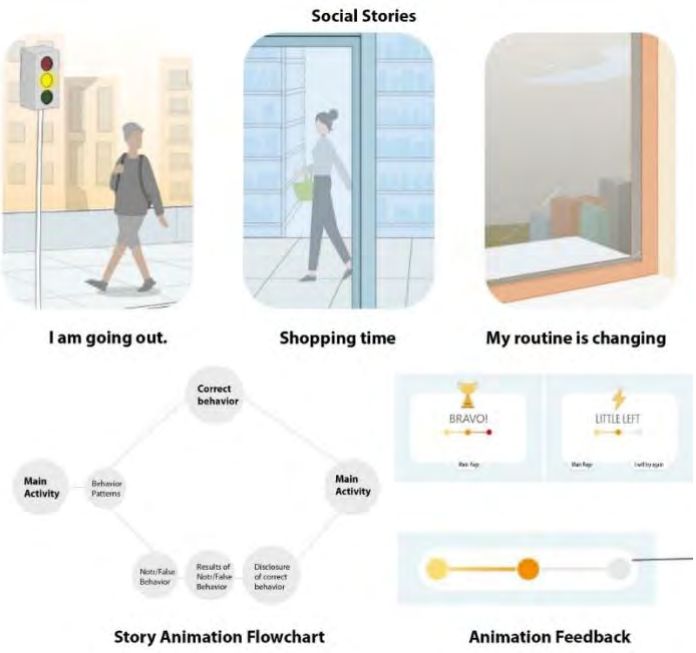


***Figure 13. Project 3 Preliminary Design Phase***


***Figure 14. Project 3 Final Design Phase***

**Project-4- Gardening Area and Equipment Design for Physically Disabled**

The student decided to work on one of the contract clauses 'Article 26- Habilitation and rehabilitation' in the first phase and design subject for physically disabled individuals. The student searches on the rehabilitation needs of physically disabled individuals and determined socialization and rehabilitation as the design goal.

Through the studies on the rehabilitative effect of soil, one of the rehabilitation tools, the student researched the hobby gardens. Hobby gardens are areas where people can relate to nature, relax, and spend time in their surroundings. In line with the literature, the horticultural therapy method used in the project includes the disabled individuals' activities with soil and nature in the garden. Therefore, the student presented the definition of an agricultural area, agricultural system and agricultural facility and the method he would use in his design idea. It is primarily aimed to plan the area where they can be active together on farm and to develop agricultural units and systems suitable for those individuals to get away from the stress of the city and spend time in gardens. A social facility including a parking lot for the disabled, a common social area and a business office is planned. The matrix of the project is shown in Figure 15.

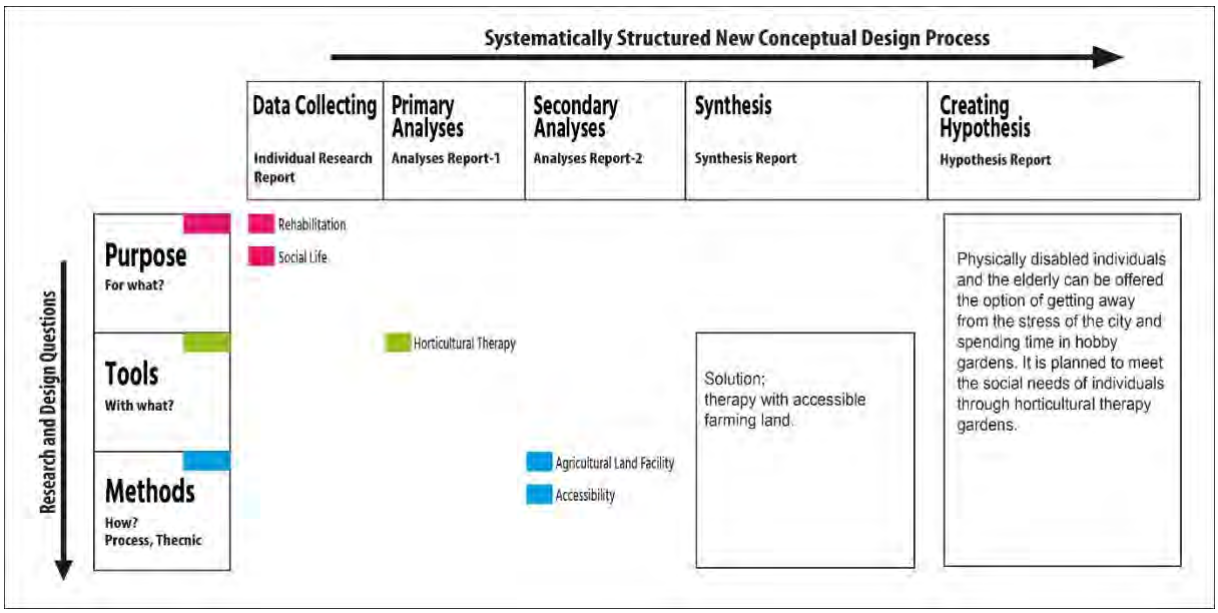


***Figure 15. Project 4 Matrix***

In the third phase, the student worked on ergonomic and agricultural system units. There is a user in each agricultural unit in the agricultural facility, units are protected by pergola which is also used for stacking garden tools. Ergonomic and functional solutions have been developed to provide easy access to root crops and other plants in agricultural units. Vertical opening lids in the units are used for soil, fertilizer, etc. horizontally opening lids are designed for the cultivation of underground plants (potatoes, onions, carrots, etc.). Rainwater flowing into the PVC pipes attached to the roof passes through the drainage pipe and reaches the storage under the agricultural units. In common areas, it was envisioned that individuals socially interact during rest and breaks and engage in cooking activities using fresh produce from their gardens. The preliminary and final design phases are shown in Figure 16 and Figure 17, respectively.

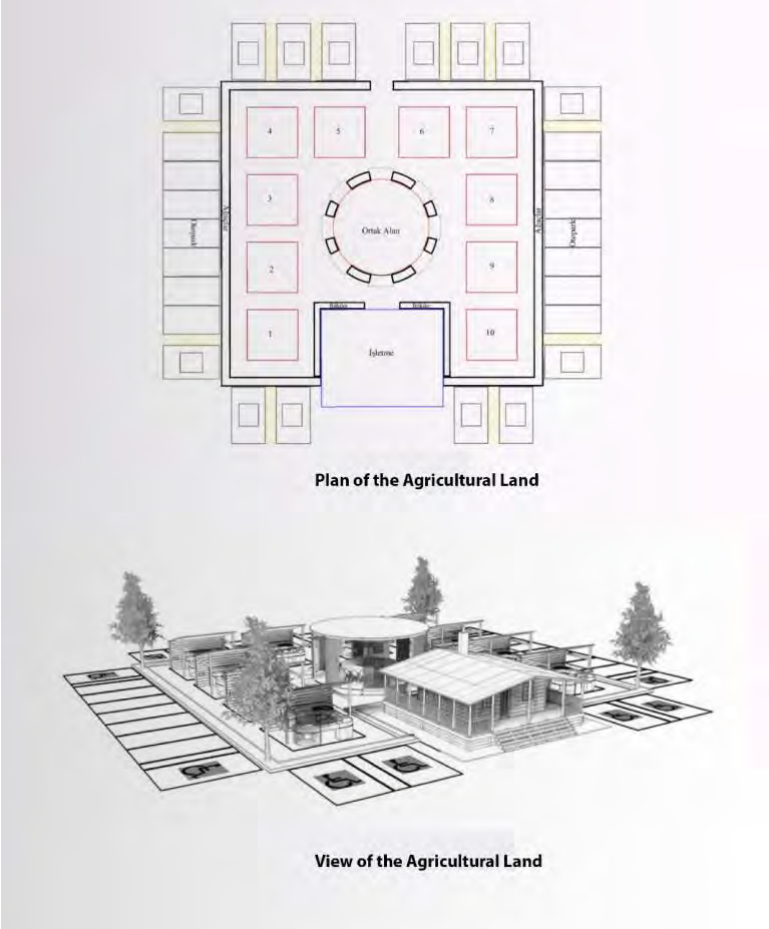


*Figure 16. Project 4 Preliminary Design Phase*

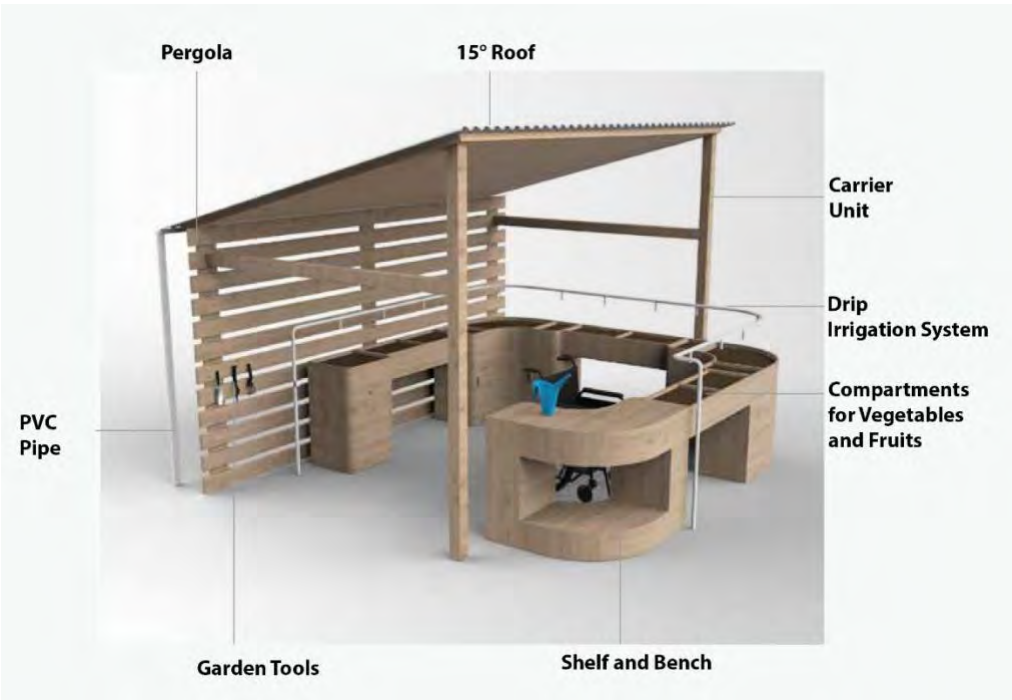


*Figure 17. Project 4 Final Design Phase*

**Post-project student questionnaire**

Students were asked to evaluate the new developed model and asked to score their learning outcomes. The questionnaire of 14 students is shown below.

*1-Critical Thinking Skill*: Skill, was examined under the titles of design problem definition, data analysis, data synthesis, and idea development. More than half of the students stated that they developed critical thinking skills. 84.5% stated that they improved their design problem definition skills, at least two-thirds stated that they improved their synthesis and idea development skills. In Figure 18, it can be said that synthesis and idea development skills are less developed than the ability to define data analysis and design problems. However, less than one-third rated their idea development and data synthesis development skills as 2 or 3 out of 5.

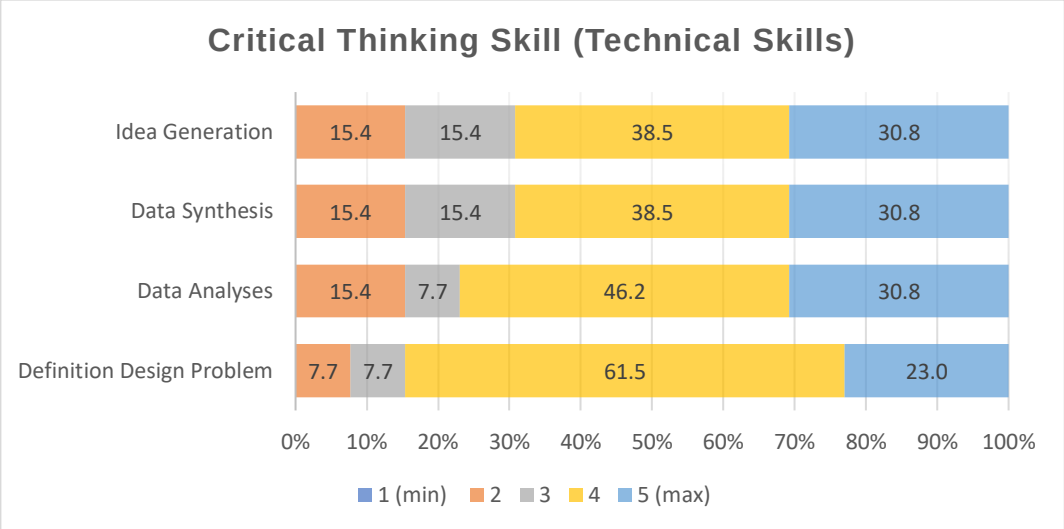


***Figure 18. Student Questionnaire -1***

*2-Professional Skills*: Skills was examined under the titles of conceptual DP and project management. As shown in Figure 19, 92.3% stated that they learned the conceptual DP through the newly developed model. More than two-thirds stated that they improved their project management skills. Some students had difficulty in keeping up with the schedule of stage contents and timelines (Table 3). It can be said that the project management score is underestimated.

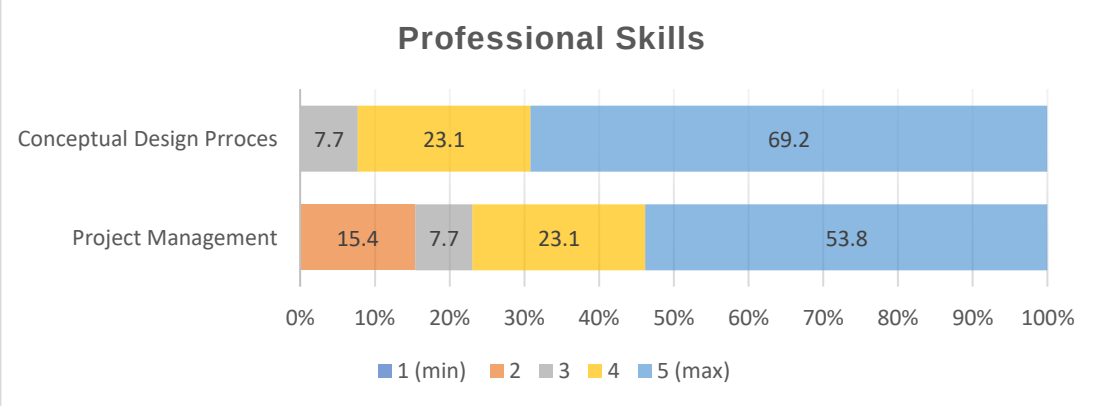


***Figure 19. Student Questionnaire-2***

*3- The Effect of Systematic Research on Learning*: It was investigated with 8 questions presented below. The acceptability of the sentences presented by the students was evaluated with the Likert scale. Results are presented in Figure 20.

- Q1: I learned to do research that will benefit my project.
- Q2: I have learned to analyze research data.
- Q3: I learned to obtain data from my research.
- Q4: I developed my project idea based on the data I obtained from research.
- Q5: I learned to synthesize the data I obtained.
- Q6: I understood the relationship between ideation and research.
- Q7: I understood the relationship between design process stages.

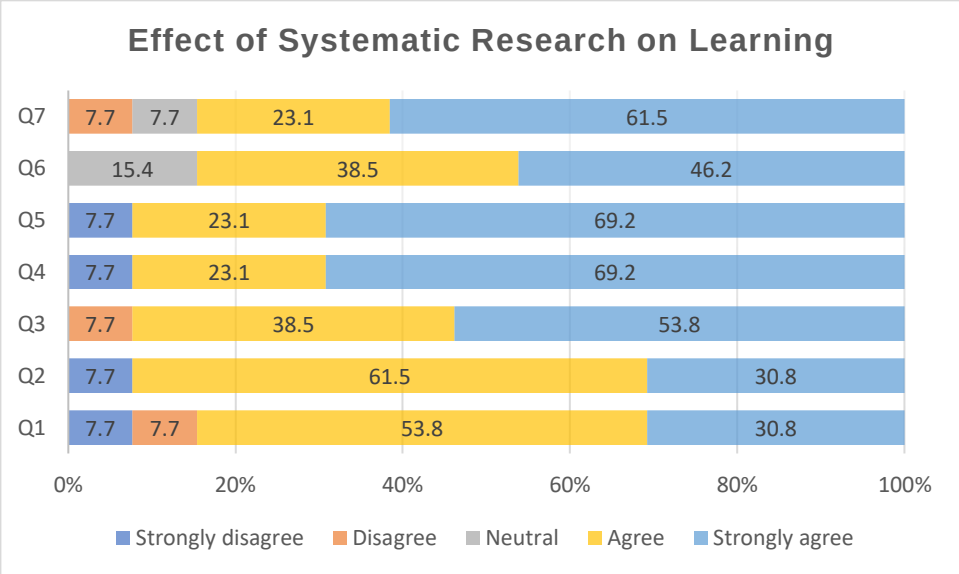


***Figure 20. Student Questionnaire-3***

Two-thirds using the new model comprehended the data they obtained through research. They stated that they understood the effect and importance of the data obtained as a result of the research on the development of the project. The students stated that they learned the relationships between the stages of the DP and have experienced the DP that had to progress cumulatively. 15.4% stated that they were undecided in the effect of the research on idea development.

4- Contribution of the Project to Personal Development: It has been researched with the next 2 questions (Figure 21). While 92.3% stated that their individual awareness of designing for disabled individuals has increased, they also have realized their professional responsibilities. 92.3% said that they obtained scientific data about disabled individuals through a research-based project as 4 and 5 out of 5.

- Q8: I have obtained scientific data on disabled individuals.
- Q9: I have increased awareness of design for disabled.

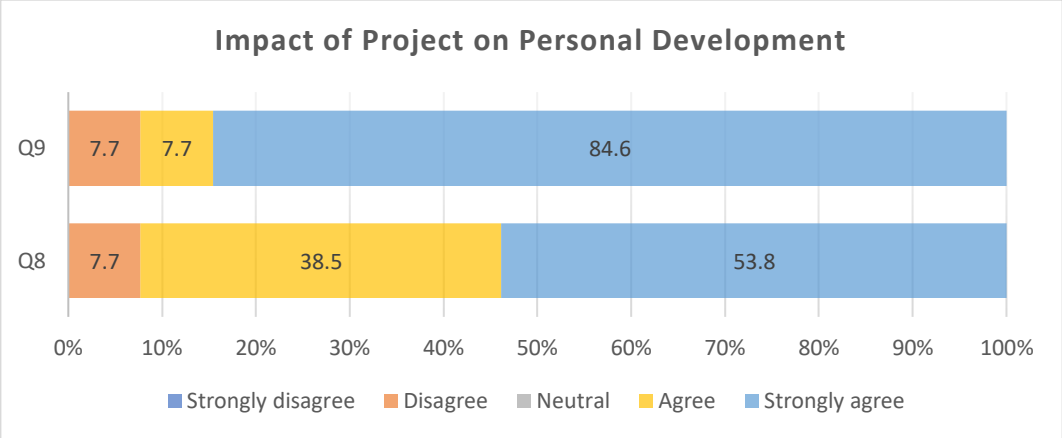


***Figure 21. Student Questionnaire-4***

*5- The Comparison of the New Model with the Traditional Models:* It was aimed with the following questions (Figure 22). It was evaluated as 4 and 5 out of 5 that the students benefit more from the research results through the new model. The relationship between the newly developed model and the stages of the conceptual DP that needs to progress cumulatively was comprehended by the students 76.9% more. Students made lower evaluations of the effect of the new model on creative idea development.

- Q10: I benefited more from my research while developing my project.
- Q11: I understood the relationship better between the stages in the process.
- Q12: I developed a more creative idea.

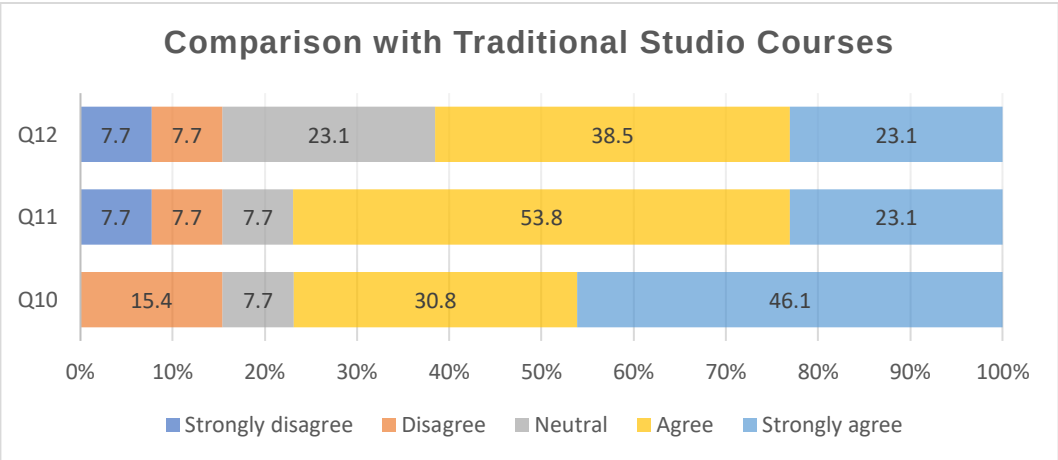


***Figure 22. Student Questionnaire-5***

**Lecturer reviews of projects**

The lecturers evaluated the process and project using the Likert scale. Project management, critical thinking and reporting quality are determined as process criteria, while project evaluation criteria are consistent cause-effect relationship, presentation quality, communication skills, innovation. After taking the average of the lecturers' evaluation results, the final results are shown in Figure 23.

As shown below, project management, critical thinking process criteria and consistent cause-effect relationship, presentation and communication skills were mostly rated as accomplished and exemplary.

However, creativity and report quality criteria were evaluated lower than other criteria. It is known that design students are generally insufficient in preparing written reports. More than half of the class was evaluated at developing and beginning levels in the report quality criteria. Innovation criteria evaluations are of equal weight in beginning, developing and accomplished degrees.

The evaluation of students' critical thinking skills including problem definition, analysis, and synthesis activities as accomplished and exemplary shows that students use research data effectively in their projects. Therefore, the criterion of cause-effect relationship was evaluated at an approximate level with the criterion of critical thinking skills.

In the visualization phase, the students presented ideas effectively. While 77% were rated developing and accomplished in visualizing the design idea, 7.7% were rated as exemplary.

69.3% were rated as developing and accomplished in their communication skills. This criterion evaluation can be explained by the fact that students mostly have to use verbal communication during the distance learning-teaching period.

According to the lecturers' observations, the projects are generally at an accomplished level. It can be said that the goal of developing critical thinking skills and learning the conceptual DP are mostly achieved with the new model. However, a small part of the class met the expected level in the innovation criteria.

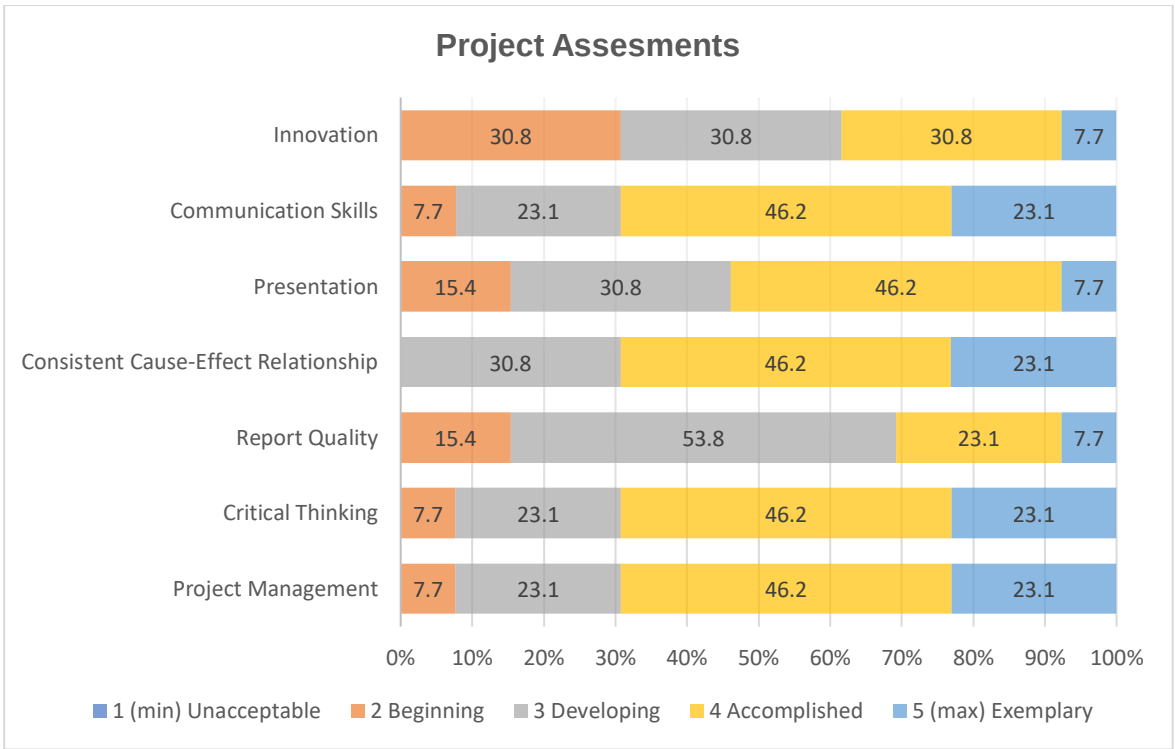


***Figure 23. Evaluation of CD Projects***

## Discussion and Conclusion

In this study, a toolkit focused on IBL was developed to ensure that the conceptual DP defined as fuzzy front-end can be comprehended by students. This toolkit consists of 8 stages of conceptual DP tool and matrix as presented. The tool set has been developed with the approach that the DP can only be comprehended when it is structured systematically (Archer, 1965) and Wildt's (2009) inquiry-based active learning approach. The main purpose of the toolkit is to guide students to develop design solutions consistent with the design problem and develop critical thinking skills. The new tool developed encourages critical thinking about the aspects of the problem that need to be addressed to develop a good design idea, with guided questions in the process stages. The new teaching model was applied in the Design for Disabled Class at Gazi University during the Covid-19 pandemic in the 2019-2020 Distance Learning School year. The methodology of the project is designed to achieve the determined learning outcomes. Students have developed different innovative solutions for individuals in different disability groups. The new teaching model was evaluated by the students through a questionnaire. Student projects were evaluated by lecturers using a rubric.

Through the systematic and task-oriented new model, students are guided to create a consistent cause-effect relationship between the design problem and the design idea they developed. It has been ensured that the relationships that they need to establish between all stages of the conceptual DP, which must progress cumulatively, are comprehended. A significant portion of the students found that the new model improved their critical thinking skills. The students stated that the ambiguity of their research purpose in the previous project is a waste of motivation and time. The students experienced the effect of a conscious and systematic research, starting with a question, on creating knowledge, developing the design problem, its solution and idea through analysis and synthesis throughout the DP. The students acquired this experience through iterative stages.

When research is mentioned, students who focus on non-scientific written and visual data through internet resources have realized the effect of scientific research on developing design ideas with this project. Students stated that with the design project for the disabled, they used written and visual resources more consciously and effectively than ever before, and their data literacy skills improved.

In the new learning model developed, they stated that the phase in which the students had the least difficulty was the visualization phase. It was stated that the most challenging phase was the creative phase and the analytical phase, respectively. Students have not carried out a research-oriented project in their past education process, and they mostly conducted research on the superficial and late design phase such as sample analysis, user comments, user needs, product technical analysis, material selection.

Students have stated that their professional responsibility and awareness in the field of social design increased. While the projects developed by students for children and adults with disabilities are in the fields of music, sports, professional life, games, social areas and education, the students addressed games, social areas and education more than others. However, the lecturers stated that the courses with social design content are in the lesser number of university curricula.

According to the results of the evaluation made by the lecturers, the success of the students in the process was found satisfactory. While the projects are mostly found successful in the cause-effect relationship criteria, it is not the case in the innovation criteria.

It was stated that in this project, the design students were less successful in the fields of research or presentation report creation, written text creation, written communication when compared to visual communication areas. This can be explained by the fact that design departments include more visual presentation techniques in their curriculum. However, written text literacy of students also needs to be improved.

Combining the Kolb learning model in which design students are positioned in active learning and the IBL model, Width (2009) states that active learning takes place with research.

The evaluation criteria made by the lecturers were determined according to their learning outcomes. According to the results, project management, critical thinking and consistent cause-effect relationship, presentation and communication skills were mostly rated as good and extraordinary. However, a small part of the class met the expected level in the innovation criteria. It can be said that the goal of developing critical thinking skills and learning the conceptual DP are mostly achieved with the new model.

The similarity rates of the data obtained through the scientific literature research conducted by the students are quite low. Most students focus on similar problems and develop similar solutions, as they do similar research in their projects where they do not apply any model. Even if similar problems are handled in the above projects where the new conceptual design model is used, there is no similarity between the solutions developed. Although the students with Project 1 and Project 2 both developed projects for the visually impaired, they were able to develop quite different, impressive, and innovative processes and techniques in their projects by using the new model. The student who has Project 3 has successfully synthesized the existing scientific knowledge with the matrix he has completed based on scientific research and presented a new approach that keeps up with the digital age. Although the owner of Project 4 did not develop an innovative solution, he developed a quality solution in terms of ergonomics and organization by successfully synthesizing the scientific data he obtained in the field of ergonomics and establishing cause-effect relationships well.

More comprehensive results can be obtained by repeating the study with a larger sample group as this researched was done with a limited number of students. The overall results of the project showed that the new model has improved the design students' competencies and learning outcomes. Although the research focused on design for the disabled, the developed process model can be adapted to different design problems.

Students could not develop their projects as prototypes and discuss their results with users because the research focus was conceptual DP defined as fuzzy front-end, in other words, early design process. By completing the entire design process (early and late design process), different findings and results can be obtained with a repeated study.

## References

Açıcı, F. K. (2015). A Studio Study on Re-Interpret the Comments of a Brand in the Design Training. Procedia-Social and Behavioral Sciences, 182, 295-300.

Akin, Ö. (2001). Variants in design cognition. In Design knowing and learning: Cognition in design education (pp. 105-124). Elsevier Science.

Aktaş, B., & Çolakoğlu, M. B. (2018). Systematic approach to design builds for freeform façade: AFA Cultural Center. In XXII Congreso Internacional da Sociedade Iberoamericana de Grafica Digital, Novembro 2018, 5 (1) 2.

Alexander, C. (1964). Notes on the Synthesis of Form (Vol. 5). Harvard University Press.

Archer, L. B. (1965). Systematic method for designers. Council of Industrial Design, London.

Asimov, M. (1962). A philosophy of engineering design. In Contributions to a philosophy of technology (pp. 150-157). Springer,.

Bayazit, N. (2004). Investigating design: A review of forty years of design research. Design issues, 20(1), 16-29.

Björklund, T. A. (2013). Initial mental representations of design problems: Differences between experts and novices. Design Studies , 34 (2), 135-160.

Börklü, H. R., Bozbuğa, F., Sezer, H., & Özdemir, V. (2018). A Novel Conceptual Design of a Stairlift for Elderly and Disabled People. Gazi University Journal of Science Part A: Engineering and Innovation, 5 (1), 17-29.

Cagan, J., Cagan, J. M., & Vogel, C. M. (2002). Creating breakthrough products: Innovation from product planning to program approval. Ft Press.

Carmel-Gilfilen, C. (2012). Uncovering pathways of design thinking and learning: Inquiry on intellectual development and learning style preferences. Journal of interior design, 37(3), 47-66.

Cross N. (1986) The Development of Design Methodology in Architecture, Urban Planning and Industrial Design. In: Trappl R. (eds) Cybernetics and Systems ’86 (pp 173-180). Springer, Dordrecht.

Cross, N. (1997). Descriptive models of creative design: application to an example. Design Studies, 18 (4), 427-440.

Cross, N. (2004). Expertise in design: an overview. Design studies, 25(5), 427-441.

Cross, N. (2008). Engineering design methods: strategies for product design. Chichester: John Wiley and Sons.

Davis, S. B., & Gristwood, S. (2016). The Structure of Design Processes: Ideal and Reality in Bruce Archer’s 1968 doctoral thesis.

Demirkan, H., & Demirbaş, Ö. O. (2008). Focus on the learning styles of freshman design students. Design Studies, 29 (3), 254-266.

Deschamps, J. P., & Nayak, P. R. (1995). Product Juggernauts: How Companies Mobilize to Generate a Stream of Market Winners. Harvard Business School Press.

Dewey, J. (1986). Experience and education. In The educational forum (Vol. 50, No. 3, pp. 241-252). Taylor and Francis Group.

Gedenryd, H. (1998). How designers work: Making sense of authentic cognitive activities (Vol. 75, pp. 1-123). Lund University.

Gharib, E. I. (2016) Exploring Idea Generation Techniques in Conceptual Design Stage. In The 4th International Conference of the Faculty of Applied Arts - Hewlan University

Grierson, D. E., & Khajehpour, S. (2002). Method for conceptual design applied to office buildings. Journal of computing in civil engineering, 16 (2), 83-103.

Herr, C. (2008). From form generators to automated diagrams: using cellular automata to support architectural design. (PhD Thesis). Department of Architecture: The University of Hong Kong.

Herstatt, C., & Verworn, B. (2004). The 'fuzzy front end of innovation. In Bringing technology and innovation into the boardroom (pp. 347-372). Palgrave Macmillan.

Herzog, M. A., Katzlinger, E., & Stabauer, M. (2016, October). Embedding Interuniversity Peer Review in Virtual Learning Groups. Of International Symposium on Emerging Technologies for Education (pp. 614-623). Springer.

Ho, C. H. (2001). Some phenomena of problem decomposition strategy for design thinking: differences between novices and experts. Design Studies, 22(1), 27-45.

Jones, J. C. (1965). Systematic design methods and the building design process. Of Proceedings of the third CIB Congress, Copenhagen (pp. 81-3).

Kannengiesser, U., & Gero, J. S. (2017). Can Pahl and Beitz' systematic approach be a predictive model of designing? Design Science, 3.

Koca, C. (2010). Engelsiz şehir planlaması bilgilendirme raporu. Dünya Engelliler Vakfı, İstanbul, 4.

Kokotovich, V. (2007). Strategies for Creative Connections: Fomenting Technological Change. In ConnectED: International Conference on Design Education. University of New South Wales.

Kolb, D. A. (1984). Experiential Learning. Prentice Hall.

Kolko, J. (2007). Information architecture and design strategy: The importance of synthesis during the process of design. Of Industrial Designers Society of America Conference,2007

Kolko, J. (2010). Abductive thinking and sensemaking: The drivers of design synthesis. Design issues, 26(1), 15-28.

Lawson, B. (2005). Oracles, draughtsmen, and agents: the nature of knowledge and creativity in design and the role of IT. Automation in construction, 14(3), 383-391.

Leon, M., & Laing, R. (2014). Application of a conceptual stages design protocol for early collaborative design through computer-based mediation. Available from http://openair.rgu.ac.uk.

Linden, J. C., Lacerda, A. P., & Aguiar, J. P. (2011). The Evolution of Design Methods. 9th International Conference of the European Academy of Design at: Porto (Portugal)

Macmillan, S., Steele, J., Austin, S., Kirby, P., & Spence, R. (2001). Development and verification of a generic framework for conceptual design. Design Studies, 22 (2), 169-191.

Mathias, J. R. (1993). A Study of the Problem Solving Strategies used by Expert and Novice Designers. (PhD Thesis). University of Aston, Birmingham, UK.

Middleton, H. (2005). Creative thinking, values and design and technology education. International journal of technology and design education, 15(1), 61-71.

Mieg, H. A. (2019). Inquiry-Based Learning-Undergraduate Research: The German Multidisciplinary Experience (p. 406). Springer Nature.

Norman, D. (2009). The design of future things. Basic books.

Oygur, I. (2012). Configuring and reconfiguring the user: How designers process user information. Washington State University.

Pahl, G., & Beitz, W. (1974). Baureihenentwicklung. Konstruktion, 26(2), 71-79.

Papanek, V. J. (1995). The green imperative: Natural design for the real world. Thames and Hudson.
Payne, J. (2013). Design analysis and synthesis: A palette of approaches. In IDSA 2013 Education Symposium, Chicago, USA. retrieved May 12th, 2020, from http://www. idsa. org/sites/default/files/Payne-Paper_Design_Analysis_and_Synthesis. pdf.
Perkins, D. N., & Perkins, D. N. (2009). The mind's best work. Harvard University Press.
Radcliffe, D. F., & Lee, T. Y. (1989). Design methods used by undergraduate engineering students. Design Studies, 10(4), 199-207.
Restrepo, J., & Christiaans, H. (2003). Design requirements: Conditioners or conditioned? In DS 31: Proceedings of ICED 03, the 14th International Conference on Engineering Design, Stockholm (pp. 61-62).
Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. Policy sciences, 4(2), 155-169.
Rittel, H. W., & Webber, M. M. (1984). Planning problems are wicked. Developments in design methodology. John Wiley and Sons, 135-144.
Salkind, N. J. (Ed.). (2010). Encyclopedia of research design (Vol. 1). Sage.
Sanders, E. B. N. (2005). Information, inspiration and co-creation. In Proceedings of the 6th International Conference of the European Academy of Design. Bremen: University of the Arts.
Sanders, E. B. N., & Stappers, P. J. (2012). Convivial toolbox: Generative research for the front end of design. Bis.
Schon, D. A. (1983). The Reflective Practitioner: How Professionals Think in Action. Basic Books, 1983.
Selau, L. G., Linden, J. C. D. S. V. D., & Duarte, C. A. M. (2020). O ensino do método e a compreensão da oportunidade de projetos: por que é importante problematizar no design?. Nunez, Gustavo Javier Zani; Oliveira, Geísa Gaiger de (Orgs.). Design em pesquisa: vol 3. Porto Alegre: Marcavisual, 2020. p. 657-675.
Simon, H. A. (1973). The structure of ill structured problems. Artificial intelligence, 4(3-4), 181-201.
Snider, C. M., Dekoninck, E. A., & Culley, S. J. (2014). A study of creative behavior in the early and late stage design process. Of DS 77: Proceedings of the Design 2014 13th International Design Conference
Sturges Jr, R. H., O'Shaughnessy, K., & Reed, R. G. (1993). A systematic approach to conceptual design. Concurrent Engineering, 1(2), 93-105.
UN Human Rights. (2020). retrieved October 4th, 2020, from https://www.ohchr.org/EN/HRBodies/CRPD/Pages/ConventionRightsPersonsWithDisabilities.aspx#2
WDO. (2015). World Design Organisation, retrieved December 12th, 2020, from http://wdo.org/about/definition/
WHO. (2011) World Report on Disability, WHO Library Cataloging-in-Publication Data, retrieved December 10th 2020, from https://www.who.int/disabilities/world_report/2011/report.pdf
Wildt, J. (2009). Forschendes Lernen: Lernen im „Format “der Forschung. journal hochschuldidaktik, 20(2), 4-7.
Wormald, P. W. (2011). Positioning industrial design students to operate at the ‘fuzzy front end’: investigating a new arena of university design education. International Journal of Technology and Design Education, 21(4), 425-447.

Yavuzcan, H. G., Şahin, D., Gür, B., Sevgül, Ö., & Yavuz, C. (2019). An Instructional Model for Social Design Education: A Design Project for Stray Animals Including Production-Based Learning Approach. Design and Technology Education: An International Journal, 24 (1), 33-64.

Zimmerman, J., Tomasic, A., Garrod, C., Yoo, D., Hiruncharoenvate, C., Aziz, R., et al. (2011). Field Trial of Tiramisu: Crowd-sourcing Bus Arrival Times to Spur Co-design. In Proceedings of Conference on Human Factors in Computing Systems (pp. 1677–1686). ACM Press.