



**UNIVERSITY  
OF OULU**

FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

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**SYSTEM-SUPPORTED INSTRUCTOR  
FEEDBACK ON THE STUDENTS' DESIGN AND  
PROTOTYPING PROCESSES IN FAB LAB  
EDUCATION CONTEXT**

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## **ABSTRACT**

**Fab Lab represents a unique concept in educational platforms where both teachers and students can get access to work on digital fabrication. Digital fabrication allows students to do creative tasks using different categorized software tools and technologies in the Fab Lab. Most of the time, students and instructors face challenges to compile a successful job through prototype designing and documentation in the proper way. Instructors have no opportunity to give feedback to the students' prototyping and documentation through any dedicated application in the present Fab Lab. For evaluating digital fabrication, it isn't easy to provide timely feedback in the traditional approaches. For this reason, the present thesis proposes a solution to the difficulty of giving timely feedback to the students based on their documentation and prototyping design which considers a reflection as an activity in Fab Lab. The solution based on several iterations of Fab Lab Oulu digital fabrication courses. This thesis presents means of Interaction and communication for both teachers and students using comment which helps students create a new and unique concept of prototype design through an application in Fab Lab. Based on the submission of students' weekly prototypes, this application implements the questionnaires for evaluation. It focuses on the easy way to give proper feedback to the students in the Fab Lab education context. This task performed various functions for developing new techniques for giving feedback, such as an evaluation of students. In this thesis, we developed a new application named "Protoboost Oulu" for providing feedback to the students. This thesis represents a real demonstration that assigns different scaling such as, rating, Semantic Differential, and Likert scales for grading the projects and giving feedback to students by instructors, which is also helpful to make decisions. This scaling can compare the current and previous works and quantify the development of individual students' works. This study also focuses on the various stages of prototyping and different satisfaction levels of the students. As a result, meaningful feedback comes from the educators, which is visible to both the instructors and the students. We also hope to develop new functions for education which are visual and fetch the data based on specific scaling in future. Adding more scaling helps educators give feedback very specifically on the students' prototyping design, and excellent results will be accurate and can be predicted.**

**Keywords: Digital Fabrication, Fab Lab education, prototyping, Scale rating, questionnaires, comment, script tool**

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ABSTRACT

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## **FOREWORD**

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## **LIST OF ABBREVIATIONS AND SYMBOLS**

Fab Lab	Digital Fabrication Laboratory
GUI	Graphical user interface
API	Application Program Interface
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
UML	unified modeling language
CSV	Comma-Separated Values
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol

## 1. INTRODUCTION

The concept of documentation while making a prototype is a very complex and challenging one. Users often need to redesign the entire prototype if the documentation fails due to the difficulty of the design process [1]. Fab Lab Oulu is a fabrication laboratory at the University of Oulu, and its main task is to simplify the digital fabrication process (Figure 1).



Figure 1. Digital Fabrication at Fab Lab Oulu, University of Oulu

Fab Lab is a working station where 1600 nodes work for digital fabrication across the world. Each node can create its equipment from scratch based on a specific collection of equipment and processes. For communication purposes, the node requires some material such as 3D printers, CNC machines, and laser-cut engine in Fab lab. These equipment used for converting the scratch into digital artefacts where digital artefacts present their creation of idea and skill [2]. Prototypes are an observable object that has many benefits and the main benefits include gathering knowledge and representation of experience through documentation in Fab Lab. The present thesis focuses on how to create prototype artefacts process, implementation of concepts and generation of an idea. Digital fabrication allows replication of their artefacts and making design through software. For making design, Fab Lab can use Computer-Aided Design and Computer-Aided Manufacturing software tools. These tools help create design files which are interpreted by machines to build the desired object and finally that can be shared globally. Moreover, digital fabrication is a potential digitization process where users can modify other creations through machines and local instruments. The present paper tries to investigate the prototyping design based on various objects that should record successfully following a process. This application provides an interactional path between teachers and students based on prototype research design documentation. However, different digital technologies can connect the digital project to other projects which can make or promote via online. Some of the main advantages of digital fabrication are that it can share with other devices, artefacts and it can overcome different obstacles. For the representation of prototype design, documentation is an extremely well-organized process [2]. It supports analyses of the creation of prototype design and explores the concepts of prototype [3]. Documentation also explains the reflective capability of the prototype design process [3].

This thesis aims to develop processes of designing the prototype, documentation of information in different stages and share information through online communication in Fab Lab. This system could help teachers evaluate student prototypes and provide feedback through separate comments and various types of scales of the prototypes. The main reason to develop this system is that both students and teachers get facilities for prototyping in a specific Fab Lab where students can work in a group and submit their work using the application. This virtual system can help collaborate between teachers and students. Besides, both students and teachers can share quality time and get qualitative feedback from each other through this system [4].

The challenge is to know how much time the students spend on documentation during a course and how teachers can evaluate this very rapidly. It is challenging for students to submit their documentation hand in hand, and get feedback from teachers. This system may reduce the time for documentation, and it is easy to explain each stage of performance based on their assumption and problem, capture photos from different angles and handle various issues. Moreover, from this system, teachers can view all of the prototypes.

Throughout this research, we have built a framework that helps encourage documentation, enabling the instructor to provide input and review on the documentation of the students' prototype—this framework based on an app where all content is dynamically maintained on a back-end server. Our system enables prototype capturing, design export, and input from teachers. This research aims to build an automated application system that explores the complexities of the documentation of prototype design. This application system expects to contribute to the area of digital manufacturing and create a more healthy climate for innovative skills development.

The main aim of this thesis is to design and develop a tool for Fab Lab Oulu for teachers which name as 'Protobooth Oulu'. This system generates for mobile application for operating via the android platform. Though we were inspired to do the work from "Protobooth Oulu Captured System" research, we found some limitations of this work for Fab Lab Oulu. Therefore, we focused on how to include the teacher feedback option and evaluation of documentation in the Fab Lab in our thesis. Since our application system exploits the android platform, individual educators need to have access to the specific mobile application to make the right decision(s) for evaluating the students' documentation of the prototype in Fab Lab. Students will get feedback on their different stages of literature on several ratings such as Likert scale, SD scale and grading. Instructors can view all the projects, such as weekly projects and individual projects assigned by the teachers. Additionally, teachers' assignments and assignment deadline can be viewed and notified in the students' dashboard. In this paper, we aimed to know how teachers can benefit from the application system and find secure solutions to give proper feedback to the students' documentation in Fab Lab Oulu. For these reasons, we developed several functions and features for the feedback system to get a solution as well as evaluation for Fab Lab Oulu. This android application also provides the quality of the prototype, which is designed by students. Teachers get a lot of tools to give feedback to the students' documentation, and prototype design and the input shows in the students' homepage in the system. Every student and group of students will get to know about the status such as uniqueness, innovation, related to actual work of their prototype through the feedback system. Moreover, students will get their weekly assignments and the due date(s) for submission through this



system. The goal of this paper is to illustrate a unique concept for providing teachers' evaluation in Fab Lab Oulu, where students and teachers can interact with each other. Additionally, students' documentation of the prototype design can evaluate through this system. Students can view their grade(s) and assignment submission stages from their dashboard. This work also provides a scripting tool which is generated with python and fetches data that comes from Firebase database.

## 2. LITERATURE REVIEW

### 2.1. Related Works

As per we know that Maker and DIY groups regularly exchange videos, documentation of projects, the concept of sketches and model [5]. Producing proper quality documents involves some problems, and one of such issues is the amount of time taken to build it. This journal provides an application tool where software is supported to create concurrent documentation. The software allows taking images, group annotation with text and audio. The creator improved the application having more options, i.e. adding text, reordering pictures and added more multimedia features as per the file design. The whole system developed for Fab Lab where documentation needed for individual design. This paper represents that a methodical tool developed for specific purposes such as designing documentation processes of a project and the artefact activities promoted as part of creating the research.

The researchers observed the exact tool for nine to thirteen months, and they identified some of the advantages and disadvantages of [6]. They investigated the sharing support based on reflection, projects discussion, reflection on research, creation, empirical data and cross-project scaffolding. Besides, the advantages of incorporating design materials and other types of objects into a device can only be provisioned later, for example, when writing for journal publications.

This journal [7] discussed difference universities were offered the course through a similar topic in Fab Academic. All academic works can be done by maintaining university standard and yet we need to investigate whether Fab Academy's evaluation methods are adequate for academic recognition. The workload of Fab Lab related courses was calculated based on the European Credit Transfer and Accumulation System (ECTs). The researcher analyzed the curriculum, and it was measured based on the range of subjects where the submission was needed to pass the course. We consider that the Fab Academy is consistent with the university curriculum. Therefore, we opine that it is possible to include materials approved by various universities in the Fab Academy of Oulu. Moreover, the quantity and quality of education and distributed education is growing up. It offers academics the opportunity to explore unique sources of expertise outside the institution's physical parameters as well as outside the formal and traditional education methods of learning.

This paper focused [8] on transforming the prototypes to 3D digital model representation and converting sketches into visual content. The spread of information occurs technically. There are dedicated tools to capture prototypes and data from early product development in the field where a digital archive uses to collect, store and exchange design output as a prototype and a physical method for capturing the input data. We provide a research framework in this paper that helps make a more comprehensive educational context and accelerate the emerging role of Fab Lab.

This research identified [9] movements of theoretical and practical communication based on informal and formal education. We tried to strike a balance of innovative and traditional education activities and focused on reflecting on the effect of learning and teaching in the new system. This research analyzed the design processes of the physical prototype and recorded it.

The author analyzed the design of prototype and testing of software tool of Oulu's Protobooth [10] We aimed to record the prototyping phase by taking process output ' snapshots' through a system from the early stages of product development. Our main objective was to promote documentation from an academic point of view which reflects in the documentation process. For this reason, we set a program as a tester during the course sessions, and the completion of the course work requires teams and a few weeks. We also took prototypes through capturing where the captured data can evaluate, and significant changes can make to the prototypes. Such changing of prototypes helped enhance the understanding of the accuracy and improvement of prototype performance.

There are lots of research studies that focus on the documentation quality for prototype designing among the documentation maker community. Here the author describes that documentation provides the best results for the academic sector. One of the most related software kits was "Build in progress" which was developed by Tiffany Tseng in MIT[11] Moreover, this application was developed based on as a software tool to improve the efficiency in the documentation. This method was fully process-oriented, which made the system more effective. This software kit supports three main principles: (1) Process of design should be clear(2) Encourage improvement of reviews (3) For representing the documents, it is necessary to create opportunities. The software kit facilitates visualization of the different paths taken during the digital fabrication process. Some researchers state that cognitive states are essential for building engagement with a system and their identification [12]. From a cognitive point of view, the artistic development of the Fab Lab includes art, science and technology, as well as combining real and virtual technology to discover, understand and generate new goods.

We emphasize [12] from a cognitive point of view; Fab Lab artistic development includes art, science and technology, combining real and virtual technology to discover, understand and generate new goods. The author focused on this paper [13] on the fact that interactions in the prototyping and producing processes are essential facts of the modern manufacturing trend. This system data can be gathered and organized, and using a microcontroller, the interactions prototypes among a digital manufacturing engineering team and design can capture. Moreover, we created a new framework for maintaining disciplines such as, how to think, generate ideas and implement prototypes. This study also developed various tasks options, such as contact between thinking and emotional to mental. To capture creativity in the Fab Lab, we suggested a system for capturing user-to-user interaction spontaneously and omnipresent where group-wise work was flexible, the interacting users can know about the tool, the machine and network. Users can quickly adapt to the machine-oriented interaction and can make capture designs in Fab Lab [14].

In this article, the researchers found some of the difficulties based on difference artefacts such as i) Physical functionalities of the 3D printer were not changeable or modified ii) the development and distribution of objects is much slower, more complicated [15]. The users face some problems in running the 3D printers [15]. Finally, we found an exciting thing named "3D printing elite" where users can understand what is happening. While using a 3D printer, they can gain knowledge of the primary process of handling this printing. Then after developing and managing the whole system, the users were engaged this machine for making design in digital

fabrication where some technical knowledge was a gap and observed by the "early adopter".

Both the design face and interaction design of practice created twisted problems during the research. In this paper, the author developed a useful tool for the documentation where project design described specifically [6]. Employing the machine, the researchers analyzed it for five months for, and they identified the advantages and disadvantages of this tool. They finally found some challenges such as, what kind of documentation should make, how the routine organized and other lacking, how to formulate the rules and regulations and monitor these as well. Moreover, they also got some advantages such as the system support based ongoing tasks, focusing on research questionnaires, processing, exchange project support and reflection. These advantages applied to the tools, but, these tools could not achieve the benefits fully in the whole system later.

## **2.2. Background**

Previous research and current approaches explored in this section intending to promote prototyping and documentation analysis. This study focuses on the coherence of various automated technologies which are used in the Fab Lab to enable teacher input and teacher feedback options to students prototyping documentation study. This research focuses on prototype documentation design where a smartphone can support the application technology. This research paper consults some previous works and explores the new possibility of improving the existing system.

### ***2.2.1. History of Fab Lab***

Fab Lab is an academic workstation known as Digital Fabrication Laboratory and this workstation used for making digital prototypes involving design, 3D printers and other technology tools such as laser cut machine [2]. Moreover, this workplace also has some software tools for creating designs which converted as a physical prototype [16]. Fab lab supports developing a creative plan where the innovative design requires testing, design, fixing errors and explaining the documentation process. Moreover, Fab lab provides opportunities to improve and revolutionize digital fabrication based on the human to machine or machine to personal user information and communication technology [2].

The idea of Fab Lab started with an expansion of education at the Massachusetts Institute of Technology Center for Bits and Atoms (CBA) to expand digital manufacturing and computing research. Using this framework helps both students and teachers for contributing to digital science, and by using the technology, both can be encouraged to develop creative courses in a Fab lab. Different accomplishments may come from Fab Lab's entire philosophy. From the Fab Lab, students learn lessons and improve themselves [17]. Fab lab plays an essential role for students to create new ideas, innovative thinking, invent and make decisions for a specific prototype [2]. The main thing is that students can work in a team, and the whole task runs on an internet network as a workshop. This workshop involves motivated, and interested

instructor, a research scientist and engineer so that the ideas can execute smoothly and information can share through research work [17]. Additionally, Fab Lab uses similar instruments and tools, same prototype, identical method, team working approaches for research across the world [2].

### ***2.2.2. Digital Fabrication Equipment in Fab Lab***

Lots of equipment and instruments are available for designing prototypes in a Fab Lab. The Fab Lab in Oulu has a large machine to network. There is a gallery of electronics and students can research circuit works, i.e. brain analysis, prototype implementation, microprocessor programming. There is also cutter machine of Vinyl in Oulu Fab Lab. This machine used to make versatile circuits and structures. The laser-cut tool is the most critical machine in Fab lab for making 3D design format. There is also a 3D printing machine for printing prototype in Oulu Fab Lab. There are many other tools in the Fab lab, and these tools help the learning process and show how to properly use for designing, making a prototype in their way or for getting help from instructor [17]. Fab Lab is an academic environment in which students avail of learning opportunities through their restricted outcome and instructors' feedback[17, 2]. Furthermore, we can say that fab Lab learning process can be more flexible, enhanced understanding, and create group work, and context-based documentation. Students can think independently and generate creativity for designing their prototype and share it with other [18].

### **2.3. Making Prototype Using Protobooth**

Prototype design plays a vital role in the Fab Lab. Students can think for brainstorming and create their new things using their ideas in Fab Lab. Fab lab has lots of tools and instruments where students can innovate their ideas through prototype [3, 10]. Moreover, prototypes can present at an initial step, design or any samples where students can think based on the artefact. A prototype has lots of categories such as conceptual prototype, work-based prototype, visual, client- experience, practical and paper prototype. Such categorization provides a general target where both program analysts and focused users can test a new design for enhancing and boosting accuracy [19, 20]—this system to generate the prototype based on theoretical concepts and prototyping instead of summery. Additionally, "Protobooth" performs as a system that users can work through the passing data based on prototype project[21]. This "Protobooth" system is useful for students, and this system helps capture any visible sample or prototype based on the design from the current experimental stage, where students can produce the physical prototype to provide instructors with the information and knowledge at the early stage. The system consists of a digital archive for ensuring data collection, storage and share the results of prototype and physical design for input data collection of the project via social media, e.g. Instagram. In this paper [21], the digital repository where there are two cameras used for capturing photos of different views of prototypes and the cameras used to capture metadata for linking the

captured photos through users who use the radio frequency identification card (RFID). The "Protobooth" mainly supports the captured prototype through the design activity.

## **2.4. Product Prototyping Documents**

The primary method of creating an idea or concept of the prototype is complicated. From the paper[22], we focused on the development process of different activities such as observation, review, evaluation, testing, assessment and replication. These activities are very crucial to enhance the task performance of the prototype. While carrying out a prototype, documentation for the prototype is essential as it serves multipurpose based on the drawing of the prototype, description of product data, brainstorming for the prototype. This research developed a website for documentation based on the design of the prototype, and this can connect imagination and contact facility through various ways including perspective, quality and responsibility for documentation. Moreover, prototype physical design must draw within various categories through interface design. Most of the researchers already expressed disapproval and suspicion of the inadequate adoption of formal documentation for design processes [3, 19]. Most importantly, the lack of proper organization of documentation has some limitations which do not yield the appropriate result[19, 22]. For finding a solution to this problem, some researchers analyze and describe the (PRT) that means "Project Reflection Tool" system and this system is entirely web-based online system where everyone can quickly join in this system [6]. Besides, this web-based program allows the audio capture mode and fundamental design method inactive tasks, making this accessible to record it simultaneously. This research also provided some sub-events and summary notice for fast accessibility and structures that rely on the cost involved, which was efficient for filing each phase of the prototype model or task interfaces. It is essential to mention that the definition accomplished through the use of statements, explanations and behaviour to the related case[18]. This PRT web-based system proved that users could design in various ways using various tools; they can conduct experiments and share the results via media. On the other hand, another study [18] provided PRT supports the definition of reflection-in-action and reflection-on-action, which can add to the design at any stage.

## **2.5. Background of Technology**

The design approach and got several challenges; the most appropriate technical methods investigate that uses for the realization of this thesis.

### ***2.5.1. Mobile Based Application***

Nowadays developing mobile applications is an open platform for rising software technologies [23, 24]. Mobile application development, especially for mobile devices which existed for the last few years and day by day it is growing since its creation. Nowadays various mobile phones allow an open-source application such as android,

ios, windows etc. [24]. This application used in the android programming language, fire-base database, which is the best platform for android devices. For android programming language, we used visual studio that we compiled using the android application where java language built. Moreover, the exciting part of the mobile app is that we can use an android programming language with studio framework which provides the best result for making a software [23]. Nowadays, mobile applications facilitate significant support in various sectors such as the business sector, education sector and personal issues of the users. It is essential to recognize the form of the software engineering process to develop high-quality application [23]. In this sense, software engineering is the current method used by an individual or a group of people to manage the development of an application-intensive system. Furthermore, it is crucial to be concerned about mobile devices and tackle management simultaneously for software processes for striking a proper balance.

## 2.6. Scope of the Thesis

We state that the primary purpose of using the documentation for performing prototypes can share via social media and collaborate with other researchers. Our research study mainly focused on solving the problem of documentation based on prototype design in Fab Lab [10, 5]. For this purpose, we have designed some tools for representing the documentation of prototype. This study aims to communicate between analysis of prototypes and documentation using different tools of the system. Some researchers reported in their works that the main problem for designers and instructors is having documentation of their development process, which needs to be analyzed. We faced some difficulties while developing this application such as, connecting fire-base databases and organizing all features and functionality in the dashboard—moreover, this system specially designed for students and teachers where they are interconnected and can communicate virtually. We focused on the teachers' feedback through this system and how students benefit using this system. We also believe that this system offers a complete educational environment for both teachers and students in the Fab Lab. Fabrication Library focuses not only on the project documentation skill but also on sharing based on the network. Fab Lab is a platform where students can communicate with others for developing the project and brief the progress via online communication and distribute it among all of the Fab Lab users. This paper focused only on three concepts of the Fab Lab. This are: 1. Using Drupal tools for photo space and WordPress for writing project documentation 2. For documentation using open source platform 3. All knowledge should open discussion, documentation.

In this thesis, we have developed a unique and new technology tool for documenting and evaluation of prototype, which helps educators to give feedback on the students' design of the prototype in the Fab Lab Oulu. Basing on Sánchez Milara's and Georgiev's works, our application performs several tasks for students and educators ensures better performance than other practices. We have implemented the testing section for evaluation and measuring performance in our system.

### 3. SYSTEM IMPLEMENTATION

We have developed a system named "Protobooth Oulu" for an android application, and this application follows some specific architecture, e.g., cloud server architecture from the previous works "Protobooth Oulu capture system" of Onur Ozoduru and Joshua Adeegbe. Our practices extend to add some new features along with the system earlier. From the earlier works "Protobooth Oulu capture system", we developed a system tool for documenting while doing prototypes design and capturing an image, recording audio and text. All these tasks are stored in a web server and can view from the web application. The previous system had some limitations, such as educators could not give feedback, had no evaluation options using several rating scales from the teachers' panel, no options for multiple interactions between students and teachers. Additionally, "Protobooth Oulu capture system" developed only the students' related functions such as, capturing prototype design, and documenting prototype and stored in web application. Though these are not pertinent to our work, we incorporated these features into our system, where we implemented the students' module. In our new application system, teachers can give feedback instantly to the students' projects; both teachers and students can view the ongoing project, teachers can modify the weekly assigned plan and other functions. we added some features, i.e. semantic differential, Likert scale and several kinds of scaling in our system in Fab Lab Oulu. "Protobooth Oulu" mobile application mainly supports system tools that we can use for prototype design for students' and teachers' feedback functions simultaneously. In this section, we implemented the design process following the 'documenting while doing' design and other different artefacts. This application involves two specific clients and server-side, where server-side stores all data and logic which comes from users, and the client-side provides a design layout where users can put data for specific tasks. Moreover, our system design for Fab Lab where provides the real-time prototype processing with different functions. Students can process their documentation using the features of the prototype. We used the following features for our application:

- Android Mobile Application.
- Application Server Architecture
- Students and Teachers interaction process.

#### 3.1. Flow Chart Model of the Protobooth System

For the "Protobooth Oulu" system, we have designed a model where we presented the whole system and showed how the system works smoothly based on teachers' feedback in Fab Lab. Fab Lab provides a unique idea and implements individual creativity in different artefacts and instructors such as professors help students think and design their own digital fabrication. Moreover, this research work analyzes the processes of documenting through teachers' feedback system to students' creativity at Fab Lab Oulu University. We developed this ideal model for the network called "Protobooth Oulu" application, and we compared it with the previous works. Furthermore, this "Protobooth Oulu" application includes a distributed system where users and teachers



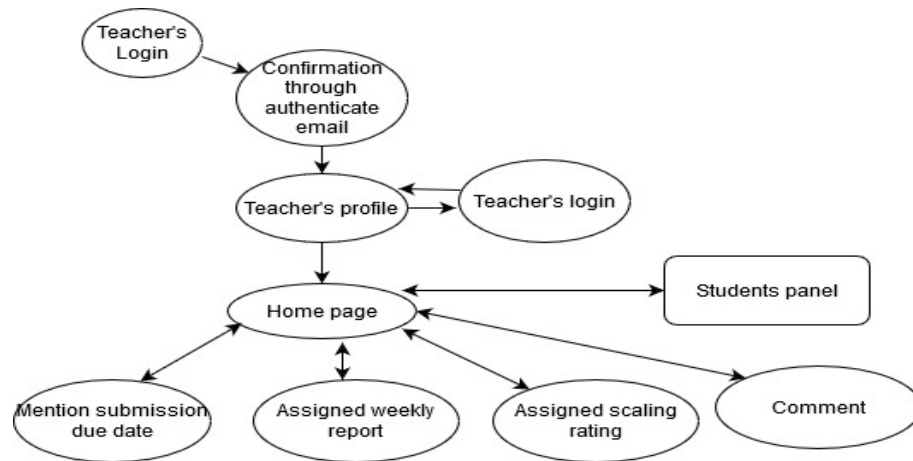


Figure 2. Flow chart design of teacher's side of Protobooth Oulu app

are capable of working together. Figure 2. shows a physical diagram which is responsible for creating an environment for providing teachers' feedback on students' prototype. In this application system, students can capture photos of different ways of the prototype, which are editable. We have customized the previous model and reorganized the model as per the requirement of Fab Lab Oulu. One of the noteworthy things our "Protobooth Oulu" Mobile application is that the system runs in/with Android visual studio and android operating system. Our app also runs in Android version 6 and upper. Figure 2. provides the complete overview and the architecture of the system.

### 3.2. Description of the System Design

In this section, we will present tools using which we have designed the system. For this system, we used API which includes Android application based on interface. Lots of features are incorporated to enable teachers' feedback on student's prototype documenting in Fab Lab Oulu. Some functions allow communication between teacher and students through public and private comments. Most of the features also showed the students' prototyping documentation with background. We will show the full features of design in our Fab Lab system.

### 3.3. System Authentication Design

In this section, we have designed the teacher's interface design and email authentication system. This section also explains the domain email, which is authenticated and provided from the Oulu University. This function provides all information on the registration process of the application for teachers at Oulu university. We have provided the interface of the system bellow shows in figure 3. This authentication system helps to create accounts to the users.



Figure 3. Home page view of the system authentication

### 3.3.1. Teachers' Login Activity

Teachers can register and view the login screen of the system, and teachers have to use the specific domain email such as xxx@oulu.fi in the University of Oulu. We have used this email authentication for the registration process in our system. This system accepts only the authenticated and valid email domain for the registration purposes, which show in below figure 4.

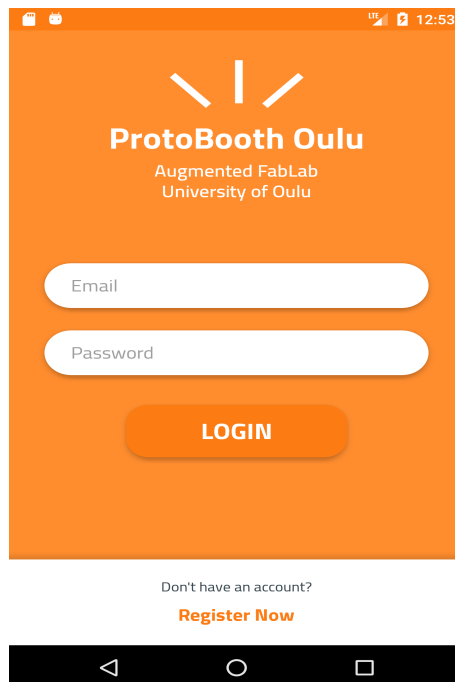


Figure 4. Login page view for teachers.

Our system will also identify the teachers and the students email address through university email domain.

### 3.3.2. Teachers' Registration Activity

The program must provide the authentication email of the instructor for the confirmation of the identity.

Firstly, we have created sketches using pencil and this system authentication design as a demo which gave us a clear concept of how our mobile application looks like showing in figure 5. This work provides the usability of the application based on the registration process using the Firebase database. All data coming from the registration process will be processed by Firebase database.

Figure 5. Registration page view

In this registration section, teachers can quickly access the page through the registration procedure using the valid email address and password, as is shown in figure 5.

### 3.3.3. Profile Update

After logging into the teacher panel, teachers can access the Dashboard. Educators will be updating their profile information using this feature which shows in figure 6.

Educators can modify and change their password using this function. They also can add their photo at their profile.

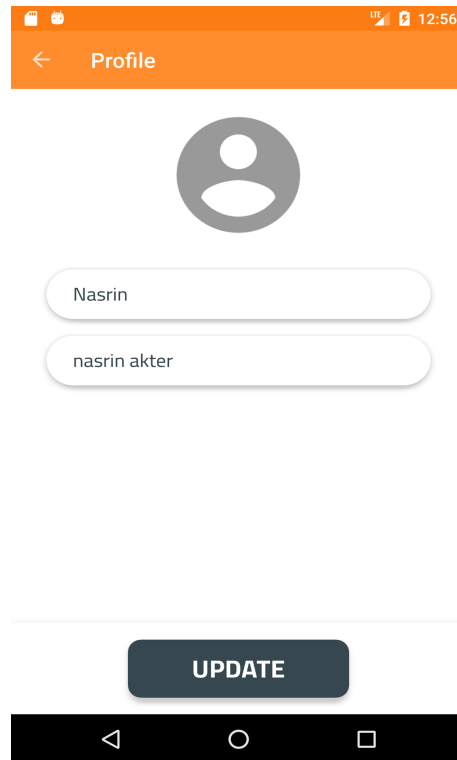


Figure 6. Profile update page view

### 3.4. Teacher's Home Panel

We describe the teachers' home screen panel. Here teachers can access to view the prototype design, which was uploaded by students. All registered teachers can see the the Students' uploaded pictures in the Home panel. Teachers can also view the time as early, middle and final stages based on students' prototype design and documentation shows in figure 7.

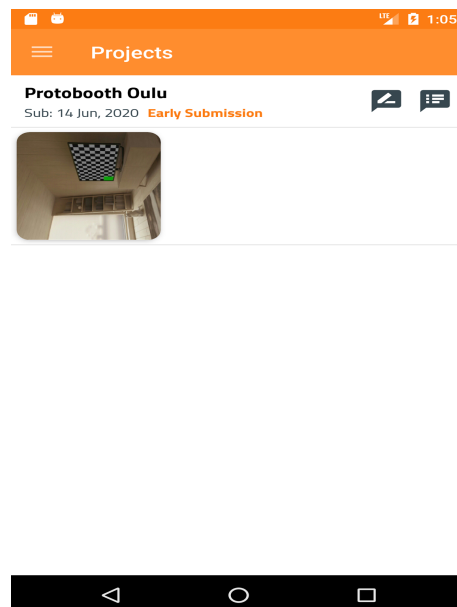


Figure 7. Teachers' home panel

Teachers can view the time of the post of the prototype and functions that students submit on their students' board. Moreover, teachers have the authority to assign any date for submitting the project. The most important feature of the application system is the satisfaction level accrued from the feedback on the weekly report project. Here we have categorized three satisfaction levels such as, 'yes', 'maybe' and 'no' for the teachers' panel that may give to the students. Each view of the home screen for the teachers' group provide below.

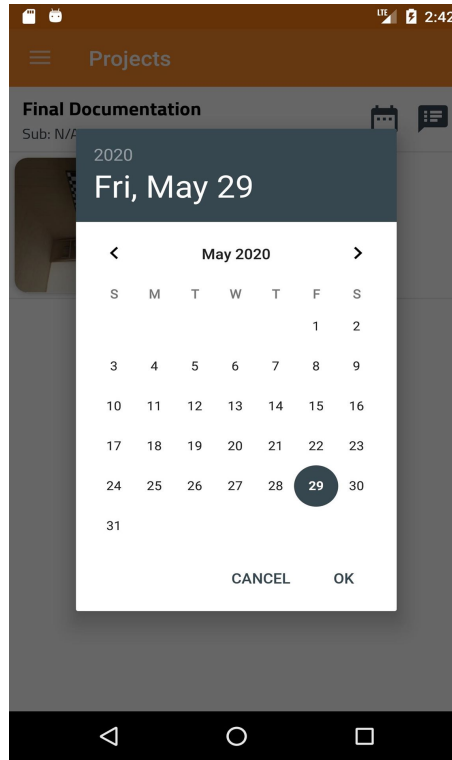


Figure 8. Assigning date for students' project

In this section, teachers can determine the submission date of the student project. Students also can view the due submission date of their project and documentation in figure 8. Students can submit their prototype before or in the middle or on the last day of the due date. If students submit their prototype before the due date, teachers can observe the postmarked with the submission date. This feature often plays a significant role for both students and educators—the calendar view of the application shown in the figure below.

### 3.5. Ongoing Individual Project

Our system has a function for an ongoing project. Students will create the project title based on the prototype, and teachers will assign the project from the teachers' Dashboard. Students can view the assigned project and the duration for completion of the assignment from their home panel. At this situation, the teacher will follow up the plan with guideline and help the students through the comment section by maintaining privacy. Students can enquire about the process and how to implement the prototype

for ensuring the quality and uniqueness with the teacher's help. The ongoing project has some questions for the weekly plan. Students get to know about the issues for the weekly report project through the navigation application. Students can post their documentation with the prototype design as per the teacher's question. The project is also changeable.

### 3.6. Weekly-Task View of the Students' Prototype

In this section, teachers will assign the weekly project for the students. Teachers can also view the submission of the project, which comes from the students' Dashboard.

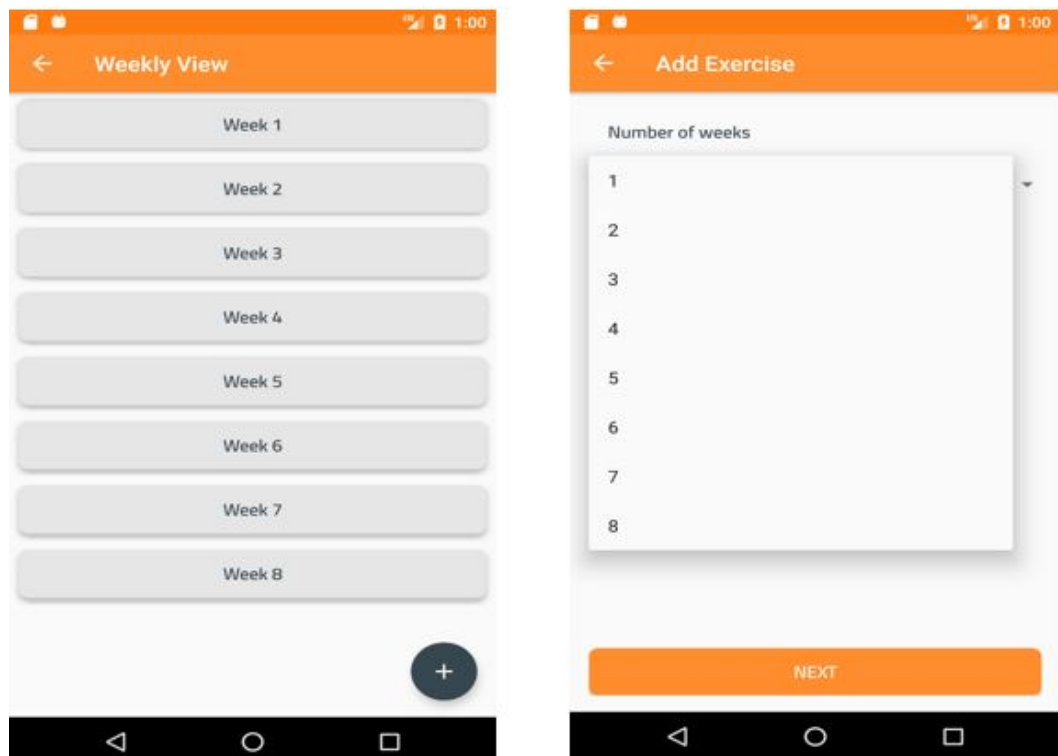


Figure 9. Weekly project view

The figure 9 shows that from the navigation function, instructors can view the project with submission deadline. Additionally, teachers will assign a total of eight weekly projects during the entire course. Each weekly project posts each question which is visible to all teachers and students. The teacher can modify the items using adding and deleting functions. From the figure, we can see that total of eight weekly projects has eight questions. Each weekly project has one subject and students can view the question and answer it. Our mobile application has to drop down option for selecting a weekly project and getting the specific item for each weekly project. The particular number of the weekly project has a particular question which depends on the design of the prototype.

Students get notification of the weekly question and deadline for submitting the report, which is visible to all registered users. Students have to answer the weekly Questions and upload the weekly task for each weekly project. From the weekly report,

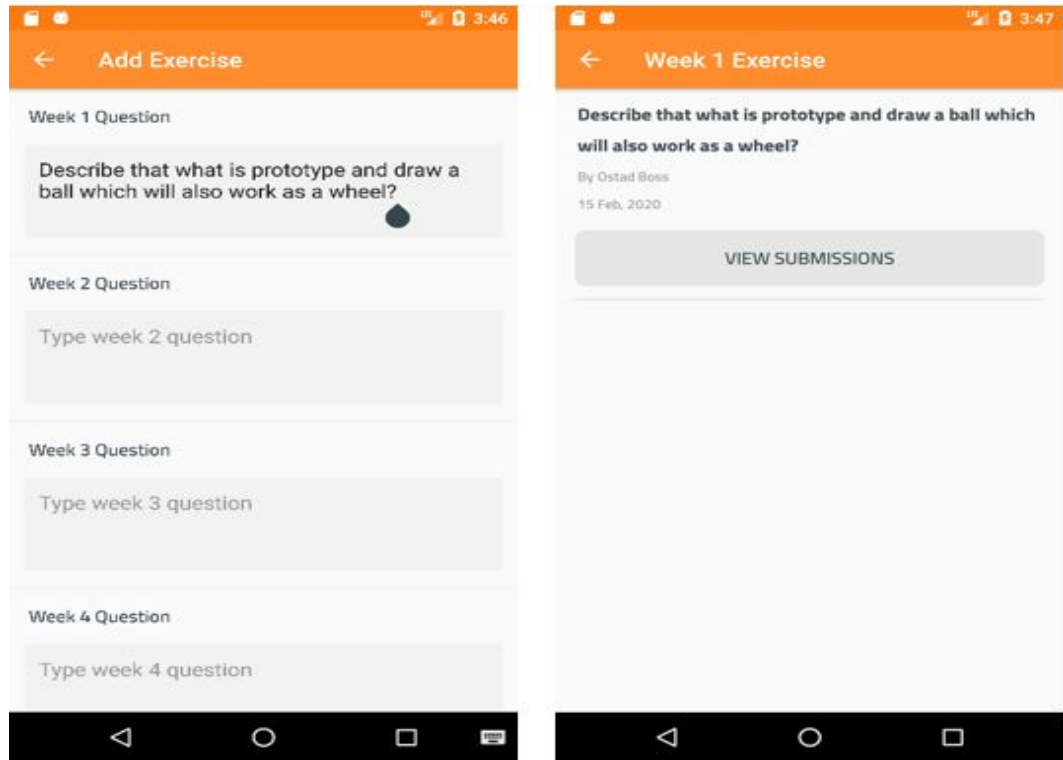


Figure 10. The weekly questions assigned by teachers

teachers will evaluate each report and prototype design as per the issue. Students will submit their prototype design and documentation through their homepage. After submission, teachers will view the projects and evaluate those using different scales.

In figure 9, we have shown the design of the weekly reports and the assigned questions. The above Figure 10 shows that this practice enables a student to access the project creation and individual achievement. Students will get notification of each weekly project and question for their specific prototype design and documentation. The navigation bar of the model provides a List of views for an individual weekly project. Every report has a view icon which allows students to view the question and create new projects for another weekly report.

### 3.7. Feedback through Comments

In this task, we focus on the comments function of our application for both teachers and students. This system allows two types of comments for interaction and communication between teachers and students. This function shows in the teachers' Dashboard. This function is most famous for making evaluation decision on the prototype design. We have shown the public and private comments as feedback to the students' prototype.

### 3.7.1. *Public Comment from Teachers' Module*

In this section, the public comment section creates for the educators' module. This public comment helps make decisions on students' prototype design and documentation.

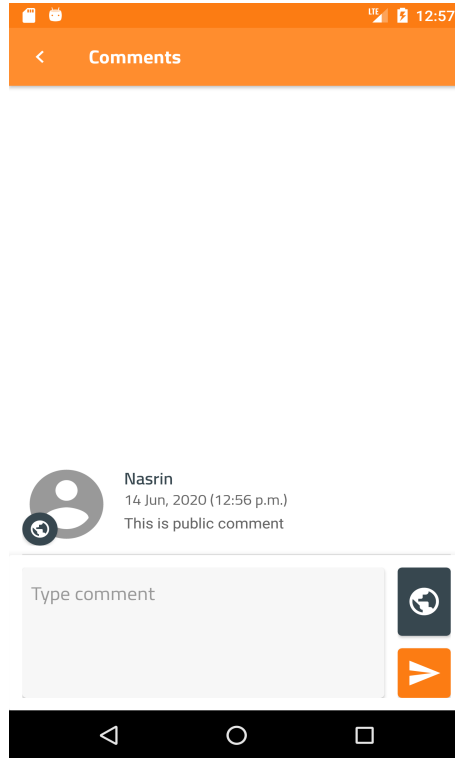


Figure 11. Public Comment from Teacher's Module

Figure 11, represents the public comment section from the teachers' panel where all teachers have access to comment (s) for evaluating and making a decision on the students' prototype. This decision considers feedback from the students' module, where students can view all teachers' comments. Every teacher can post their comment(s) and view comment(s) given by other teachers. All teachers have the right to provide feedback for deciding on the students' prototype. They can discuss students' projects and prototypes that students implement and rate the prototypes based on quality and uniqueness.

### 3.7.2. *Private Comment from Teacher's Module*

Figure 12, shows the private comment function, which provides information to the students about the comment on their prototypes. Accurately, the teacher can communicate with the students for making a prototype. The teacher can guide and interact with the students to make their prototype via this function. They can provide information privately as to how to make their prototype maintaining excellent quality. Each teacher can communicate and interact personally with each student through this function.



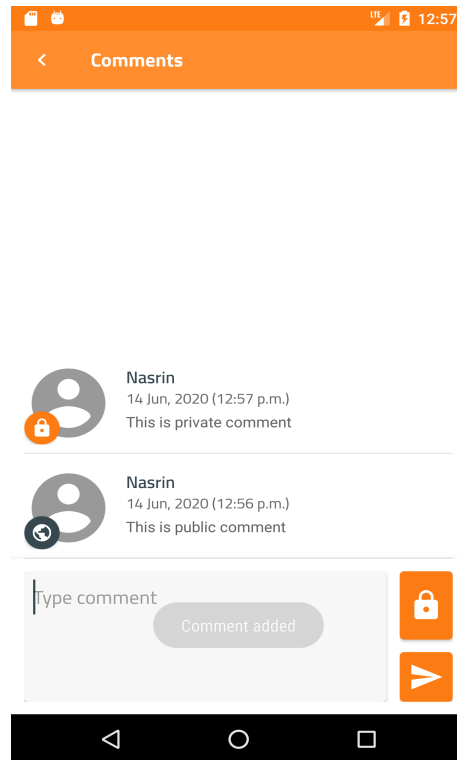


Figure 12. Commenting view unit

### 3.7.3. Final Stage of the Prototype Design

This feature provides the concluding stage of the students' prototype. From the creation of weekly and individual projects to the end of the prototype design, both teachers and students can interact with each other to develop their plan and submit it through the system. During the whole process, teachers can give instruction(s) to the students concerning their prototype design. After presenting the project through the system, the teacher will get notification of the submission of the project. Then teachers can give feedback using the scale, which is very important to decide on students' projects. Moreover, several scaling methods are included in our system to give precise feedback. These scaling methods provide accurate and specific feedback such as a new concept or existing idea, about the quality of the prototype design. Different mounting methods, i.e. the rating, semantic scaling, Likert scaling, having 1 to 5 points where one means strongly agree, and five ways strongly disagree, can be used. Moreover, teachers will give three individual, and specific questions with the Likert scale and students will view the items and answer them. After getting the feedback, the data will be stored and fetched from the python tool for analytical purposes. These feedback data are generated as a CSV file through scripting after analyses.

## 3.8. Teachers' Feedback on Ongoing Project

In this Unit, teachers can provide feedback to the students' project—on their design and documentation of prototype. Students can view the results and evaluation of their plans from the teachers' feedback system. For evaluation, this system provides different

levels of scales such as SD scale, Likert scale, rating, for giving feedback at the various stages of the project. Moreover, teachers can provide feedback on the weekly work project from the home panel. We present the different stages of scales and project stages as feedback from teachers.

### 3.8.1. Rating Scale

The rating scale uses for evaluating the different stages of students' development in the educational section. This scale provides a measurement scale by providing information from both the qualitative and quantitative point of views. Usually, there are three types of a rating scale such as, numeric scale, graphic rating scale and descriptive, realistic rating scale, which shows figure 13:

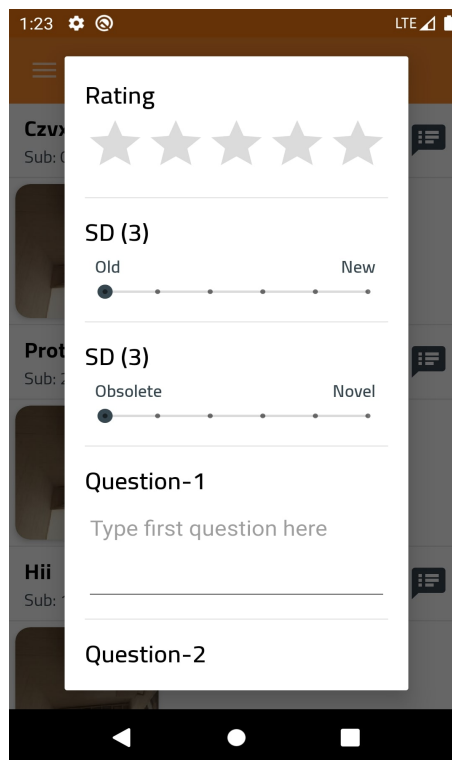


Figure 13. Variety of Rating scales possible

From the perspective(s) of our system, we have used a numeric rating scale where teachers can choose any level of the range to give the mark on the students' prototype as feedback. Moreover, this rating scale is used in our system to evaluate the students' prototype design. Teachers can give any range from 1-5 ratings for the students.

### 3.8.2. Semantic Differential Scales

We have mentioned four types of SD rating in scale. These are 'old', 'new', 'obsolete' and 'novel'.

If the newly designed prototypes have some similarities with other existing system, then teachers can see the extent of similarities evaluate them as 'old', on the other hand,

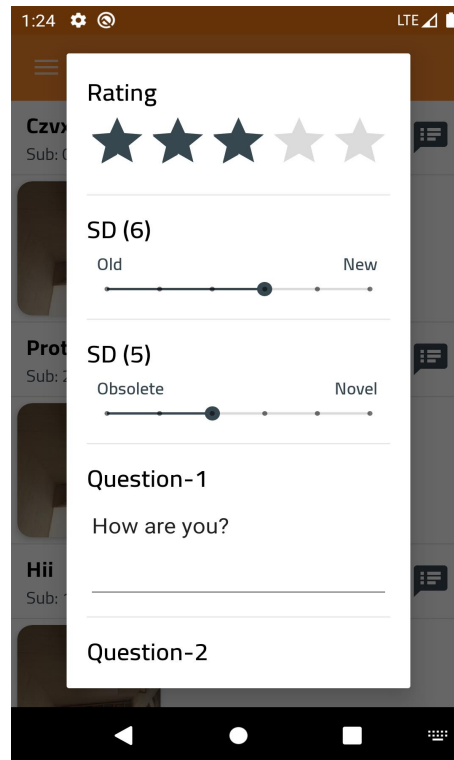


Figure 14. Feedback through Semantic Differential scale

if newly designed prototypes have no similarities are totally unique and creative then students the mark (novel) based on the newness and creativity of the project showing in figure 14.

On the other hand, the obsolete rating should be marked based on the previous achievement of the work and novel must measure the new, uniqueness and the further ideal of the prototype design. All SD rating scale markings reserve in the Firebase database.

### 3.8.3. Likert Scale

In our system, we also used the Likert scale for the evaluation purposes of the students' projects. The Likert range serves a series of questionnaires which helps to give feedback of students' prototype design and documentation. We provided three different questions with the Likert scale that students expect to answer mandatorily—these questions set from the students' designing of the prototype. Students must answer the questions as per the experience of doing their project. This scale has helped to make the average questionnaires respond to individual inquiries.

Likert scale allows correlated internal consistency question patterns based on the students' project. Teachers can select maximum three questions for answering that come from students. All results are stored in the system database below in figure 15.

The screenshot shows a mobile application interface with a feedback form. The form is titled "Question-1" and contains three questions: "How are you?", "How old are you?", and "Type third question here". Below the questions is a "Project Stage" section with a button labeled "Early". The background shows a list of items with titles like "Czvo", "Prot", and "Hii".

Figure 15. Feedback through Likert scale

#### 3.8.4. Project Stage Evaluation

Another decision making feature is the project stage evaluation, where teachers can give feedback on the students' project. This project stage has three different levels, such as Early, Middle and Final stages below in figure 16.

The screenshot shows a mobile application interface for project stage evaluation. It features a "Rating" section with five stars (the first four are filled), an "SD (3)" section with a slider, a "Question" section with a text input field, and a "Project Stage" section with three buttons labeled "Early", "Middle", and "Final". The background shows a list of items with titles like "Prototy" and "Sub: 15 F".

Figure 16. Figure of the project stages

This figure shows the students' final project stage after submission. At this stage, the teacher can give feedback on the different stages of the students' project through our application. This project stage evaluation shows the deadline of the project submission, and when students submit their plans, the teachers' assigning date etc. If the students present the project before the deadline, the teacher can give feedback at the initial stage. Similarly, the teacher can provide feedback at the middle and final stages based on the students' submission of the project. From this project stage, we collected data, and after the analyses, the data store in the admin panel. Finally, we fetch all the analytical data through the CSV file using the scripting tool.

### 3.9. Final Stage Evaluation

In this section, students can view their evaluation in the feedback system, which comes from the teacher's module. After submitting the design and documentation of the prototype from the students' module, the teacher can perform the evaluation task of Submitted projects from students. In this section, students can only view the results of the proposed projects in their Dashboard. Teachers can give feedback using several scaling such as rating, project stage and project satisfaction level. We have implemented the function the way as is shown in figure 17 below:

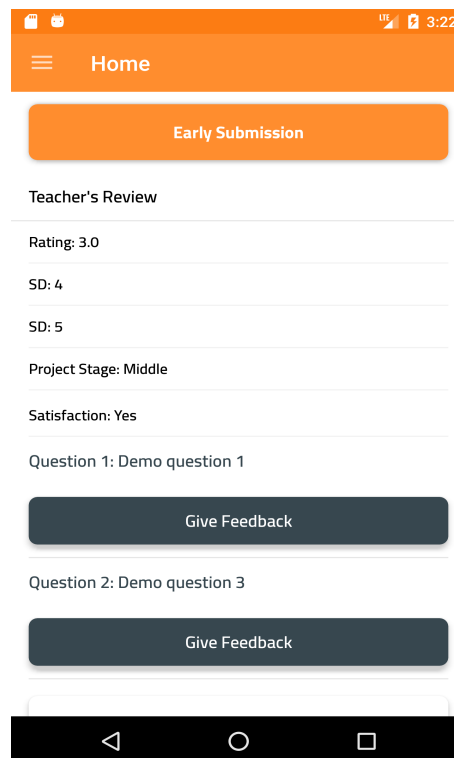


Figure 17. Evaluation viewing stage

Figure 17 shows, this feedback system is beneficial for making a decision.

- Teachers can share their feedback that takes much less time in a mobile application.

- Teachers can make the decision instantly, while students make the prototype design.
- Moreover, this feedback features will be viewed privately by teachers and students.

### 3.10. Back-End Design

The users' Dashboard can implement by android studio. Here we have used python and cloud server systems for storing data on the server. This technology reflects the API programming interface which can combine and control the data. Furthermore, we have included cloud google storage using a database, namely Firebase. Here all data come from the application which stores in Firebase database. This cloud server allows the data coming from the Firebase database. This system stored the authenticated data for maintaining security and privacy, and we have stored all data in a database. Some built-in function set up in the Firebase database where we can easily store the data.

### 3.11. System Design Architecture

Since both the students' and the teachers' modules integrate through one application system, for this purpose, we provided a system design architecture which present as a database design for the whole system. Teachers' module has a total of five tables. Firebase database follows the NoSQL database framework. For our system data allows JSON. Each table involves an object-based relationship with other tables through a form of the tree node. Moreover, we had designed a database architecture before implementation for more clarification and identified table relationships for our application. This figure 18 (below) shows a particular link, and this Firebase database relationship provides better understanding, performance, scalability, flexibility and more useful functionality. Here we present the full database system architecture of our system as an image.

Figure 18 (below) shows that there are in total of nine tables for our system. For the teachers' module, we have followed five tables from this database design, and the other tables follow the students' module. Here the authentication table is appropriate for both teachers and students, and this table provides a unique function for users. This authentication function carries the authenticated data which store in the cloud server—the authentication unit directly connected to the teachers and students. After the completion of the verification process, teachers can access the account as users. Here each database table contains a specific reference number which refers to another table and connects as a node.

The above figure shows each table connects to another table which provides a relationship as to how they establish the connection node to node. When teachers access the Login, then teachers can create weekly assignments through a reference id and in that case teacher can create many weekly questions and teachers have access to create comment keeping this either public and private to the students. Another node

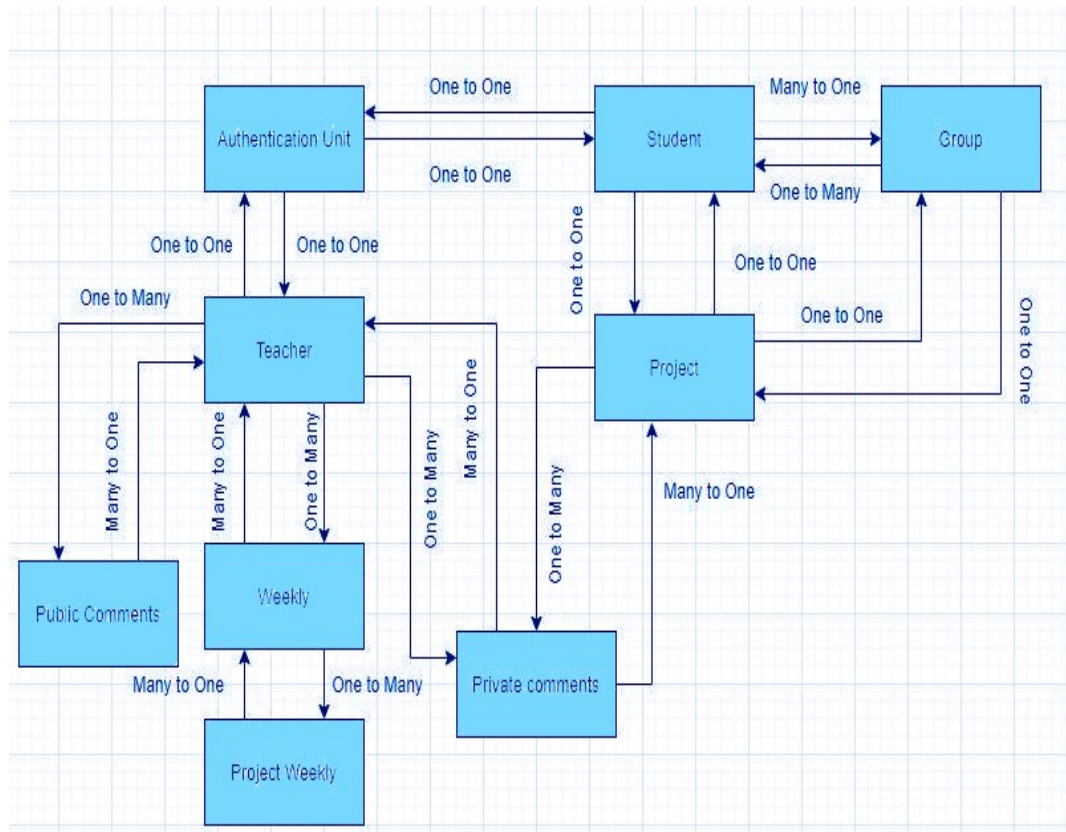


Figure 18. System database diagram

is a weekly project which connects to the weekly node through weekly reference id. Here one weekly project can be created in a week by a teacher.

### 3.11.1. Database System for Login Authentication

Our application contains several functions in the database for storing. This application consists of the login panel for teachers where admin can view that teacher can access the Dashboard, and teachers also can view the students' update, such as prototype design through Login. This system allows authenticated information for registration and login page. This system acts as the control panel of application in the home dashboard, and admin can directly access to the admin panel and view the stored data. In this section, we have shown various tables of information, i.e. the teacher's identity, email and username. In the Firebase database, admin can remove or modify any data which can be changeable in the database. Moreover, if admin modifies the information, then users can view the changes in the application in figure 19.

From this figure, admin can view the teachers' authenticated information based on teacher's email. Every user has their own unique identity. Users can get their user id in their email for verification, and after confirmation, they can log in the system for viewing and evaluating the students' prototype design. Firebase also provides data based on the date of signing in and account creation. In this table, there are four attributes that admin can view, modify and delete. Firebase provides storing of data based on teachers authenticating information, and we have provided a database table

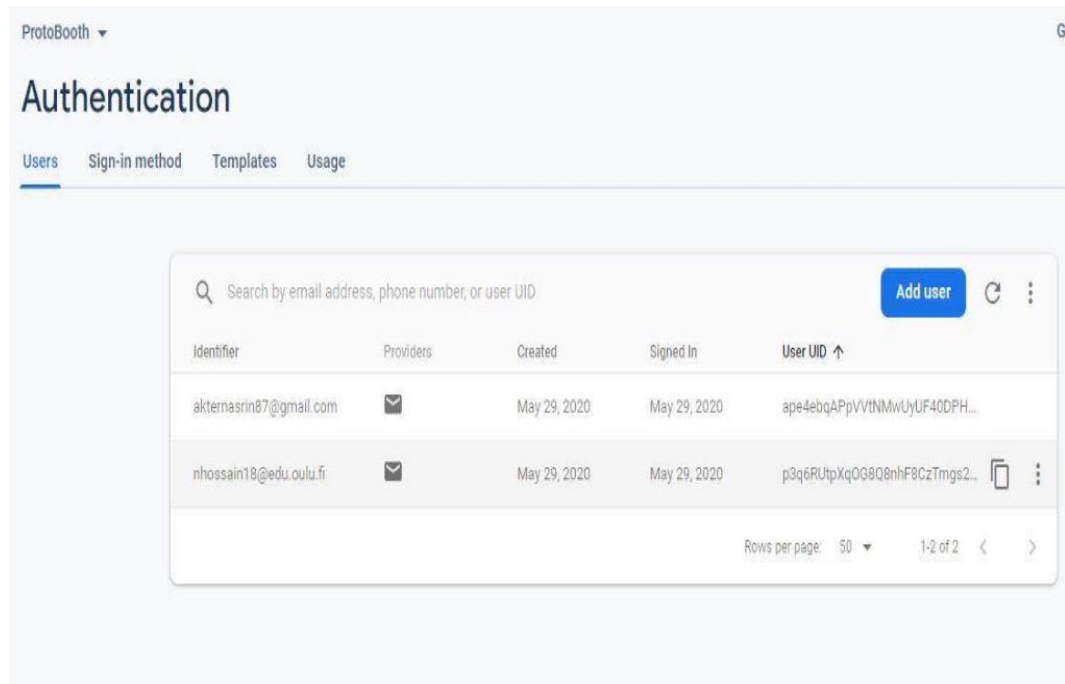


Figure 19. Login page authentication

of the teacher's Dashboard where Firebase stores the data sequentially. Whenever the application picks up the data from the system, the Firebase engine recognizes the information and saves it. We have presented the teacher's Table 1.

Table 1. Teacher Login table

Field Name	Data Type	Characteristics
Email	String	Identifies unique user id
Password	String	Confirms registration
Date	Integer	Shows login time
User Id	String	Verifies the valid email

### 3.11.2. Admin's View of Teacher Authorization in Database

In this database section, Firebase database stores teachers' information where teachers use their name, email, keyword and specific reference for individual persons. Admin can view all data stored on the teacher dashboard in this section.

Here admin can search the teachers' information from the database using their keywords and the specific reference number. We have shown the figure of the Firebase database where all data is visible. Every teacher has a reference number which randomly generates from the Firebase database and sent to the teachers' domain email,



Table 2. Teacher authenticate information stored in database

Field Name	Data Type	Characterize
Email	String	Email verified from teachers domain email
Full Name	String	Stored full name of user
Keyword	String	searching keyword of user
Reference	String	Generated reference number for user
Username	String	Viewing user name

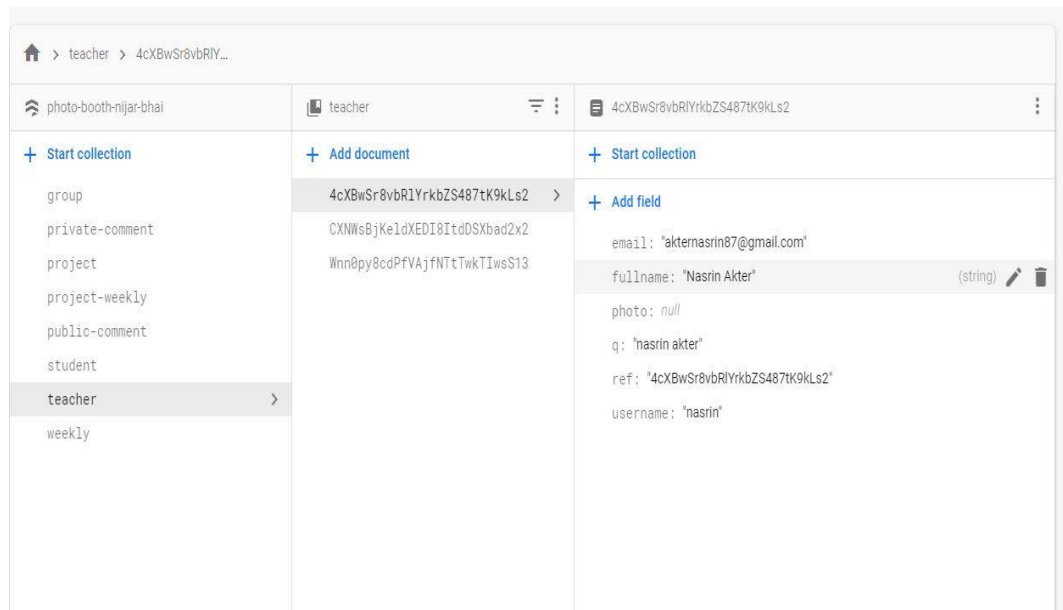


Figure 20. Teacher's authenticated information stored in database

which verifies for confirmation in the figure shows 20. Moreover, we have created the table for this database, and we have generated some columns based on the database.

### 3.11.3. Feature Overview of Weekly Assignment in Database

Our application database uses a Firebase to store teachers' posts as feedback. Teachers posts can view from admin such as creation date, number of weeks, questions, reference number, teachers' name and teachers' reference information in below figure 21.

The admin panel can view the teacher's assigned activities for the students' weekly project.

This table shows 3 the six attributes that can view in Firebase database. Teachers create the date of submission of the project. Every week allows posting one question with a question number. The database establishes a default reference number for the weekly report.

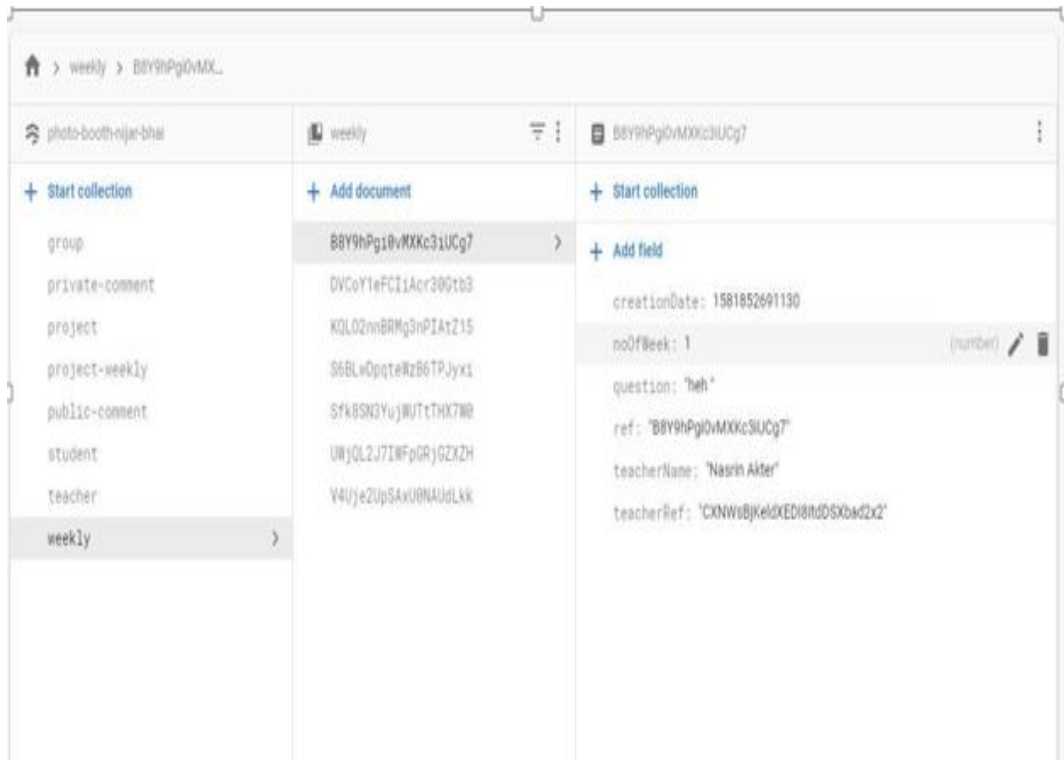


Figure 21. Weekly view from database

Table 3. Features stored in the database

Field Name	Data Type	Characterize
Creation Date	String	Creates date from teacher side
No of Week	Integer	Generates weeks' number for students
Question	String	Assigns question based on weekly project
Reference	String	Generates default reference for weekly project
Teacher name	String	Mentions instructor's name
Teacher Reference	String	Unique number against teacher identity

#### 3.11.4. Comment Feature in Database

Firestore database provides a comment storage section where students and teachers can interact. For maintaining security and privacy, teachers can communicate with students both privately and publicly. They are considering the private comment, database stores body of the content, date, project reference, and other references, e.g., teachers' name, reference and type of feedback which randomly generates from the database. The same data are stored in the public comment section from where admin can view all information. The main difference is the type of comment for storing in the database. We have generated the public and private comment sections in the database to store the comments.

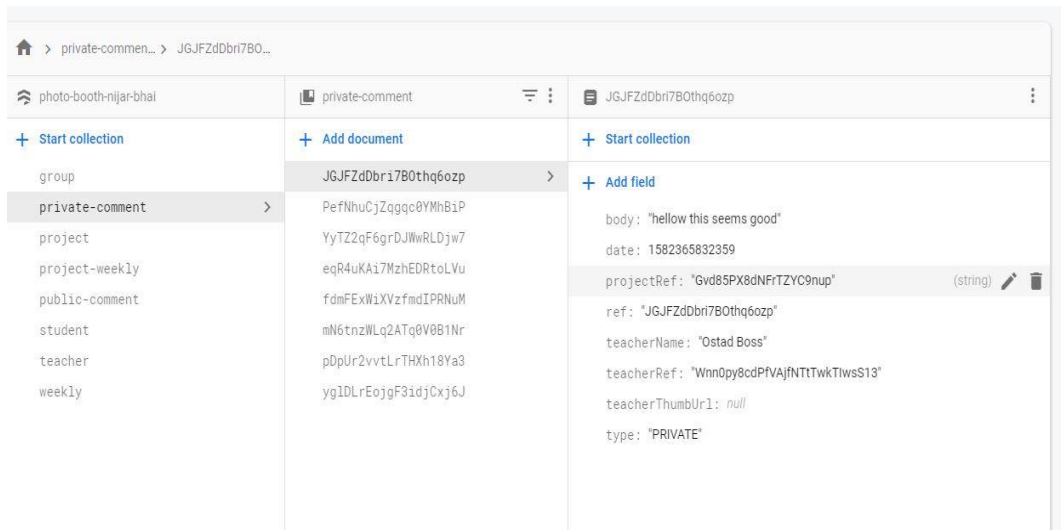


Figure 22. Private comment view in the database

Table 4. Private comment in the database

Field Name	Data Type	Characterize
Comment body	String	Post comment for students
Date	Integer	Generated weeks' number for students
Project Ref	String	Carried a reference number for project
Reference	String	Generated default reference as a foreign key
Teacher name	String	Mentioned instructor name
Teacher Reference	String	Unique number against teacher identity
Type	String	Private

Firebase database creates a table for private comment and allows viewing the specific data by teachers. Firebase database stores the commenting section from where admin can view both public and private comment with the same attributes. Database also stores data for public comment which is shown in table 4. Database also stored data for public comment which is shown in figure 22.

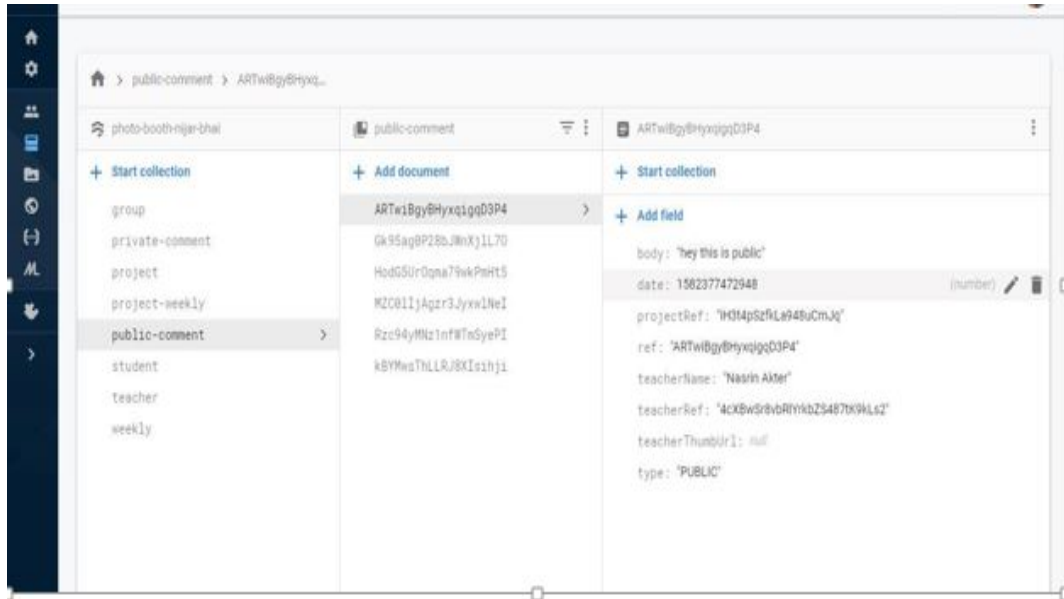


Figure 23. Public comment view in the database

Table 5. Public comment in the database

Field Name	Data Type	Characteristics
Comment body	String	Posts comment for students
Date	Integer	Generates weeks' number for students
Project Ref	String	Carries a reference number for project
Reference	String	Generates default reference as a foreign key
Teacher name	String	Mentions instructor's name
Teacher Reference	String	Unique number against teacher identity
Type	String	Public

### 3.12. The Interface and Architecture of Android Application

The mobile application called "Protobooth Oulu" application compile within an android studio and android operating system. The Model View Controller supports the operating system in which the model undertakes the primary liability to organize and maintain the data and control the model and user interface panel from where teachers can view the students' concept and logic. Figure 23 shows that the user interface architecture of the application. The controller connects the Model and view parts in this case. Here we proposed some functionalities and classes for the system.

Table 6. Organization of architecture and interface of the application

	File name	Explanation
Model view	Login.java Registration.java Comment.java Photo.java Teacher.java weekly question.java Dashboard.java Profile.java activity.java	All functions execute teachers documentation
Controller	Photo.java	Control the photos

### 3.13. Package Description

In our system, we have used different packages to develop our application. Each package has its task, and every package performs a specific task. Lots of activities had to run in this system, such as the model view where packages show in the comment section, teachers section, weekly questions section. Packages also control the opinions of photos from the students' Dashboard, which should be maintained from the Firebase database and storing system in cloud storage. In this section, we have described the packages of the system and the back-end architecture of this system showing table 7.

Table 7. The organization of the model view

Package name	Purpose
Comment package	Functionalities for commenting both public and private
Teacher package	Home page view, scaling as a feedback, viewing students' prototype
Weekly Question	Functionalities for assigning weekly question

#### 3.13.1. Authentication Functionality Package

Our application provides the packages where the class has control authentication procedure included in the database.



Figure 24. Authentication package view

Authentication verifies the domain of email address, and this class of model maintains the functionality. Here the auth.java package controls the view of the authentication process. Both Login and registration processes are controlled by this package as show in figure 24.

### 3.13.2. Dashboard Package

Teachers' Dashboard consists of a Dashboard home panel to activate all features such as teachers assigned questions, feedback system for evaluation using rating, SD scale and Likert scale for students. Moreover, this package provides a viewing section from the students' section, where teachers can mark and evaluate students' prototype.

### 3.13.3. Package Function for Teacher's View

In this package function, teachers can view the students' updates such as, students' grouping, students' post, viewing photos and answering that are provided from the teachers' side showing in table 8.

Table 8. Function package for teacher's function

Package name	Purpose
Students group	Teachers can assign group for students
View prototype	Students' prototype designs were viewed by teachers
Students activity	Teachers can select deadline submitting prototype and post activity from students
Evaluation	Teachers can give feedback to the students' work

### 3.13.4. Function Package for Weekly Report

Teachers are allowed to create the project for students through this package function. Teachers can add questions based on the project exercise shows in table 9.

Table 9. Package of weekly report

Package name	Purpose
Exercise adding	Teachers can assign exercise based on the project
Viewing project	Teachers can view the project from the students' home panel
Activate of weekly exercise	Teacher can give weekly exercises based on report
Activate of weekly view	Teachers can view the answered assigned question

Moreover, this package function also allows the generated view of the answer to the question of the project. Additionally, teachers can assign weekly exercise views and activities. This function shows the submission of the prototype from the students' side.

### 3.13.5. User Interface Layout Package

This package provides the layout design of the system. We have created the layout using xml. Here we show the design of the layout for teachers.

Table 10. User interface layout package

Package layout	Purpose
Login.xml	Teachers' Login page view
Register.xml	Teachers can view their registration page
Project_submission_xml	Teachers can view the students' project submission
Teacher.xml	Teachers' home page view
Weekly_view.xml	Students' weekly report view

## 3.14. System Implementation Module

We provided a model diagram where the system classes and methods are presented. Moreover, here we also mentioned some example classes for our system. We implemented our system through this model architecture. This system model provides a User class for both teachers and students, which contains inherited operation in the classes.

This model such figure is called Class diagram provides full operation of this system implementation. Users connect teachers, and every teacher has access to the comment section depending on public and private attributes. Furthermore, the system model represents several methods which have specific attributes and tasks. This system model

represents the class method and its attributes in this diagram. We mentioned several classes, some of which are connected to other classes based on inheritance and other classes are connected through a trigger where all data models explicitly performed.

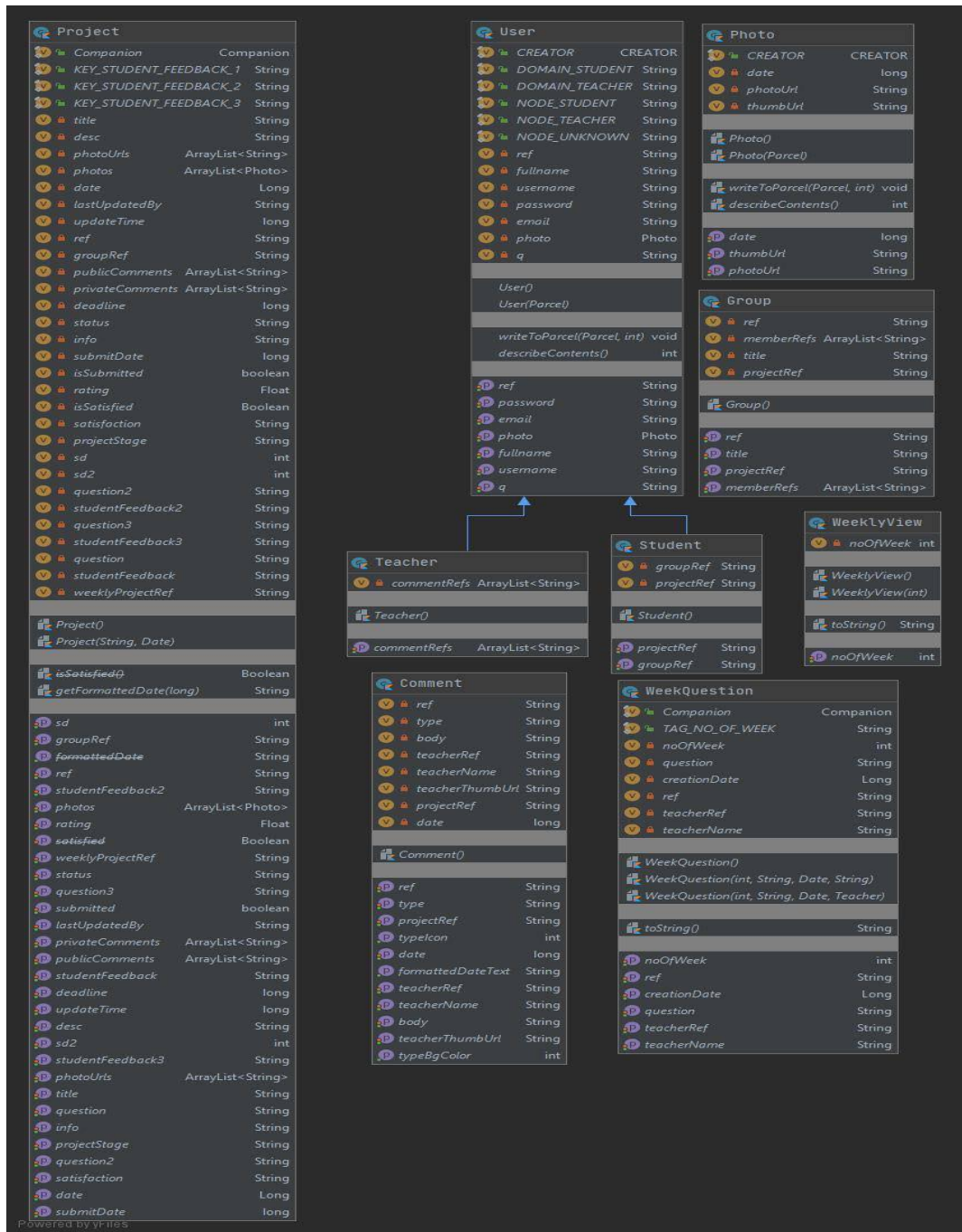
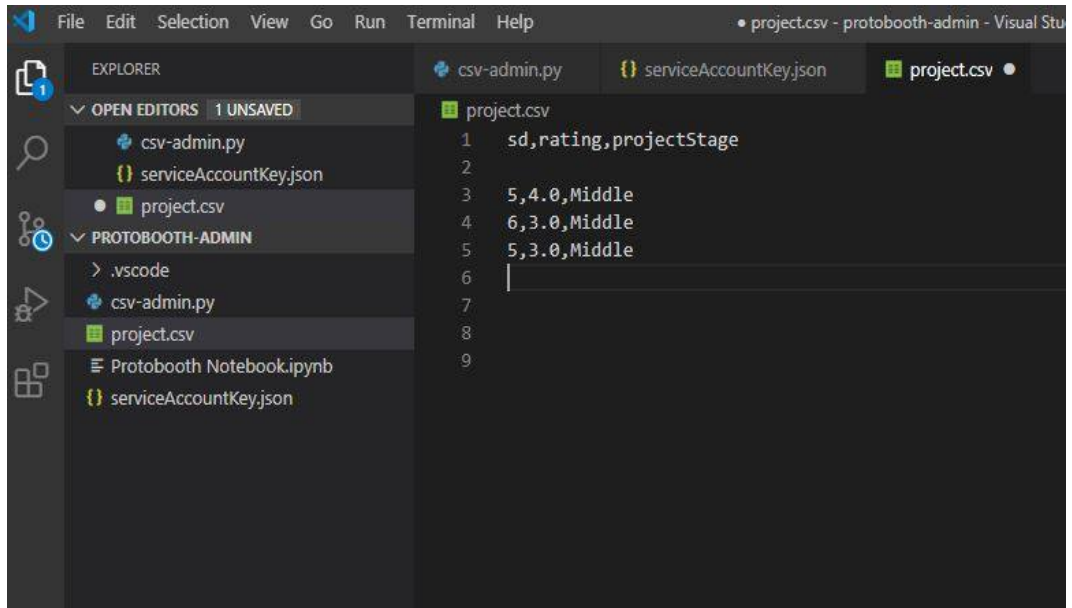


Figure 25. System Implementation Module

Model figure 25. shows the structure of our application with all classes where classes provide the specific concept and operation process of the system.



### 3.15. Generating Scripting File



```

File Edit Selection View Go Run Terminal Help
project.csv - protobooth-admin - Visual Stu

EXPLORER
OPEN EDITORS 1 UNSAVED
  csv-admin.py
  serviceAccountKey.json
  project.csv
PROTOBOOTH-ADMIN
  .vscode
  csv-admin.py
  project.csv
  Protobooth Notebook.ipynb
  serviceAccountKey.json

csv-admin.py
serviceAccountKey.json
project.csv

1 sd,rating,projectStage
2
3 5,4.0,Middle
4 6,3.0,Middle
5 5,3.0,Middle
6
7
8
9

```

Figure 26. Generating scripting file using python

We generated the scripting file for our system. We have used a python tool for making the CSV file which comes from the Firebase database. We already mentioned that our system database based on the cloud; this is why all values come from the cloud database.

Moreover, for counting and for connecting, we have used Jason file in scripting file. We have generated Jason file using Firebase database and scripting tool for CSV file. In the CSV file, we have created three types of parameters such as rating, SD scale and project stage. We have shown this in figure 26.

From the figure, we have seen that the three parameters belong to different values which come from the cloud database. All these values are variable and can be modified if the database is updated. For creating these parameters, we have used the scripting for CSV files which are created by python programming.

## 4. EVALUATION AND RESULTS

In this section, we provided the results that we obtained through usability testing of this mobile application. This testing allows us to understand both the teachers' and students' feedback and users can find the right way to use the system. From users' feedback, we have modified the system as per the required functionalities for this system. Moreover, we provided some questions and opinion options for evaluating the system. Some participants from the University of Oulu performed and valued the order, and we accrued some results from this feedback. We formulated some specific questionnaires for individual users and collected the feedback on the application. For this research, 9 participants aged between 22-36 took part. Participants took part in this testing part willingly, and before the survey started, every participant was informed of/about the concept of the application. Here we provided a consent form to the participants that show the proof and right of legal statement for conducting the survey. This consent form also represents the actual efficiency and functional activities of the Fab lab in Oulu, and we will get the evaluated result from it. We have tested usability testing of this application based on two categories, such as teachers' feedback operations and the admin. Participants acted as teachers to complete the testing part of the form. There were some individual and specific questions for completing the usability test. After completing the test, we took some captures of the test case scenarios for analysis and evaluation of the results. We conducted another test for admin because from the admin page; we need to get information from the generated data using the database especially, CSV and Firebase database. We present some test cases for students below:

- Firstly, participant teachers have to create an account through an authenticate email address domain for using our application "Protobooth Oulu".
- Verify email and login into the system using their own account.
- Viewing their own profile and dashboard in the application.
- Assigning a deadline for submitting students' projects and weekly projects.
- Assigning questions for weekly report.
- Viewing students' prototype design of project and weekly report.
- Establishing direct interaction and communication through public and private comment.
- Assigning feedback using scales such as, rating scale, Semantic Differential scale and Likert scale.
- Assigning any rating between 1 to 5 on the rating scale. SD represents the scale as an 'old', 'new', 'obsolete' and 'novel' category. Moreover, Likert allows up to three questions for students..
- Assigning project stages through early, middle, final and satisfaction levels allows such as yes, middle and no.

For testing the admin, we showed some CSV generated files of the project. This CSV file of the project was developed using a python programming tool for admin. This project file uses the data that comes from the Firebase database, and these data are variable. All data are stored in a cloud database. We provided some test cases for the admin, where we used the script tool.

- We used mainly a visual studio for generating scripting code.
- Run the scripting file which was created by python and developed a project csv file for the application.
- Finally showing the final output of the project csv file.

We organized these questions based on usability testing, and we scheduled for interviews with the persons operating for answering the questions. Moreover, we have concentrated on the stability level of users where users perform the task. Participants got a form such as a script for evaluating the system so that we can get the proper result as feedback from the participants. We present the questions that we gave to the participants for getting feedback below:

- I think that I would like to use this system application frequently.
- I found this system application unnecessarily complex.
- I thought this system application was easy to use.
- I think that I would need assistance to be able to use this system application.
- I found the various functions in this system application were well integrated.
- I thought there was too many inconsistencies in this system application.
- I would imagine that most people would learn to use this system application very quickly.
- I found this system application very cumbersome to use
- I felt very confident after using this system application.
- I needed to learn a lot of things before I could get going with this system application.

We compared each question based on the data collected from participants, and we categorized all questions in the Likert scale options, i.e. strongly agree, agree, neutral, disagree and strongly disagree formula. Participants provided with the answer of the questions on a specific form, and we collected the way from individuals using a usability testing method based on their own experience. Participants chose any point of the scale at their flexibility and willingness, and we got the results as per their own experience. Finally, we conducted an interview session at the final stage of data collection to know about the ways to better our mobile application. All participants responded spontaneously and answered all the questions very carefully during the interview. Here we applied a semi-structured method interview for the participants.

However, we wanted to know the results of the following queries from the participants:

1. How much do you focus on Fab Lab ventures?
2. Would you think the feedback and evaluation from teachers is a good idea whilst students are doing prototyping design and documentation ?
3. How much time do you provide instructions to students when they worked on designing prototypes and documentation in Fab Lab Oulu?
4. How do teachers take the prototype design and documentation from students? Do they have faced any difficulties for submitting prototypes?
5. Which approach and technique would you like to follow for taking the documentation from students in Fab Lab Oulu?
6. Do you want to have contracts and interaction with students while using an application and performing multiple tasks through the system?
7. Do you want to have the commenting option public and private between teachers and students?
8. Did you find any unnecessary functionalities?
9. Did you find any better functions and operations which are necessary for application in Fab Lab?
10. Do you agree that this application will help both teachers and students in Fab Lab Oulu?
11. Have you had any experience of any such existing system where teachers can provide feedback to the students' prototype through mobile application?
12. Do you agree that teachers can evaluate through scaling such as, rating, Likert scale and Semantic Differential. Is it helpful for students?
13. Did you give any evaluation and feedback before to the students' prototype stage and satisfactory level in any application?
14. Name of participant in the study?
15. Gender
16. Age
17. Occupancy
18. Mobile number

## 4.1. Analyses of the Results

In the analysis unit, we have presented the collected data and information as feedback using the questionnaire form from participants. We represent the results in graphs based on the analytical process. Seven participants participated in the test of our mobile application, and they provided answers from their perspective, and it was 72.14 based on SUS score. Here the average result showed that our mobile app is worth use in real life. Moreover, the figures are generated based on the SUS questions which are provided in the list. We analyze these questions and create a bar graph as per the results.

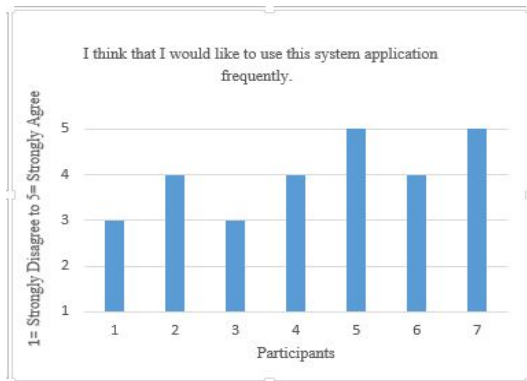


Figure 27. Question1 response

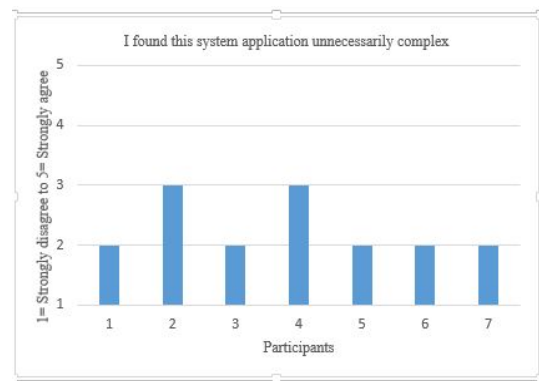


Figure 28. Question2 response

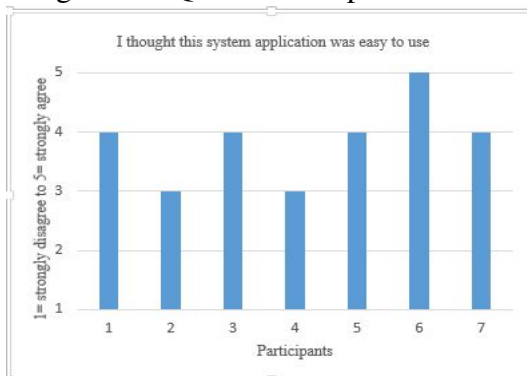


Figure 29. Question3 response

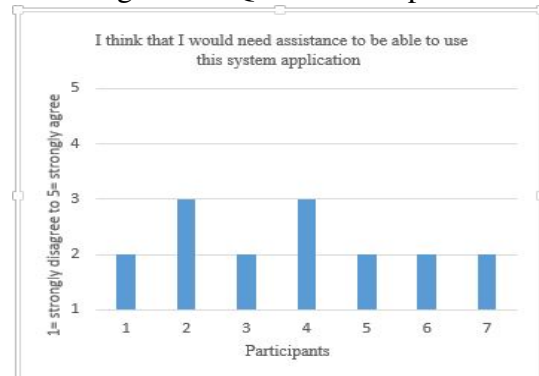


Figure 30. Question4 response

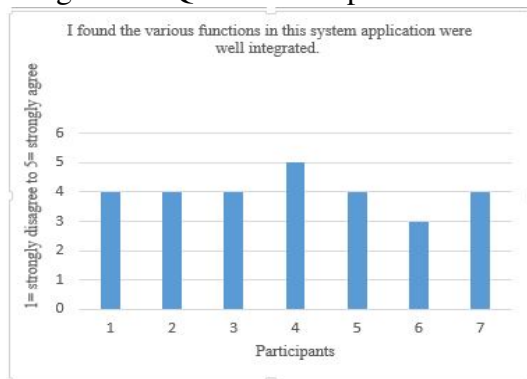


Figure 31. Question5 response

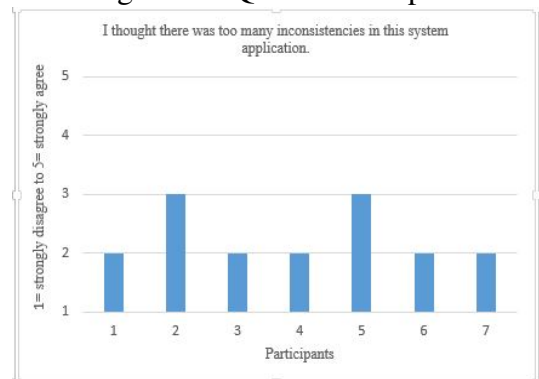


Figure 32. Question6 response

Figure shows the users feedback, which we measured by the scale. Here we provided questions to the users for evaluation, and every question belongs up to 5 ranges where

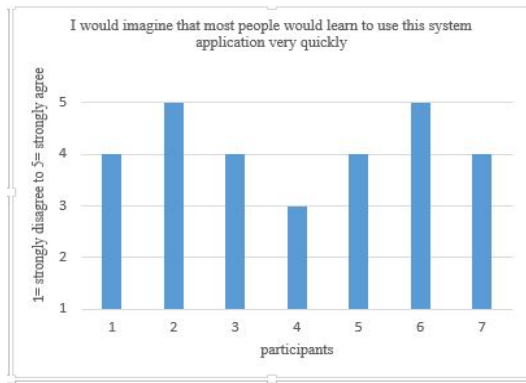


Figure 33. Question7 response

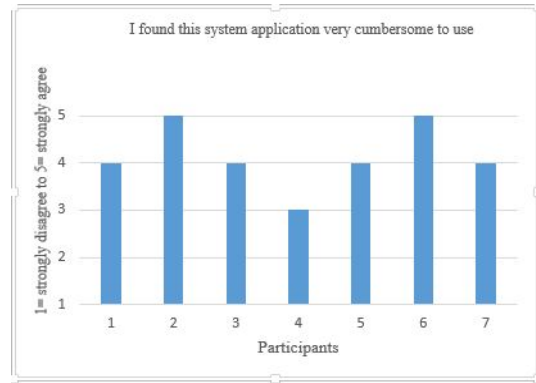


Figure 34. Question8 response

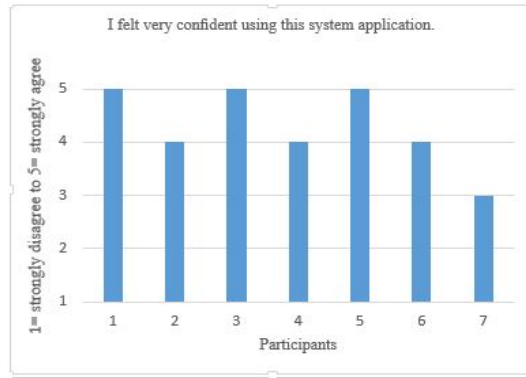


Figure 35. Question9 response

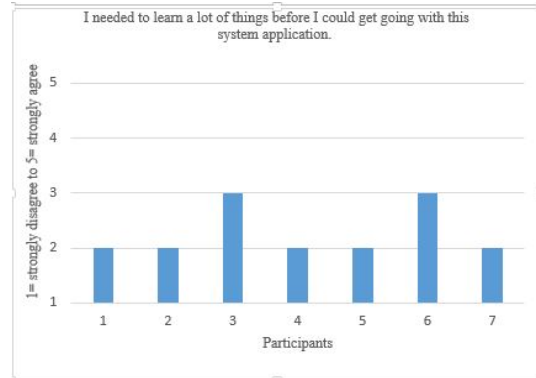


Figure 36. Question10 response

every range carries a unique value. Of the options, 5 means Strongly Agree, 4 means Agree, 3 indicates neutral, 2 represents Disagree, and 1 indicates Strongly Disagree. Participants could easily understand the questions and the range of answer options. They selected the answer option as they preferred which function they felt comfortable to use in the application. Every graph has a total of 7 bars representing the test users' responses to the questions. From this graph, we can notice that the first questions' answer is 3 range out of 5, and this indicates neutral to the participants. We counted and analyzed other graphs in the same process. After this, we analyzed all graphs and SUS score findings from the responses obtained by using the questionnaires. We calculated the SUS score coming from the test participants, and we got the final average SUS score of 72.14. This score proves to us that this system is perfect for use in Fab Lab. This system is usable, and it also needs some functional improvement for the further process from SUS average score. Each participant took 25 to 30 minutes to give feedback on our system through the questions. We found the results from the participants and got the SUS to score based on the SUS evaluation. From the participants, we received various feedback such as positive, negative and neutral, which is very specific and helped find out the particular SUS score.

## 4.2. Comparing between Educators' and Students' Modules

ANijar Hossain conducted another similar study focusing on the students' module, and he tested the module with SUS scaling, which got 71.071. This score also provided a

practical application where users have proved of the ability to use the system. The app will update the policy with each stage in future. The students' module represents good results for using the order through the SUS score. The educators' evaluation of the prototype designing provided a 72.14 rating, and the students' assessment provided a 71.071 score. Both counts of the evaluation are near to each other, which proves that the system is usable for users. Nijar Hossain and I expect to update the policy in future. We worked together on these two modules, where teachers and students perform in one platform through our system. Finally, we got the results that confirm that the two modules are capable of performing under the scheme. These methods are ready to use the systems in one frame, but different SUS scores will also be provided for improving further in our system where user can get better performance through this system.

## 5. DISCUSSION

### 5.1. System Evaluation and Results

In this section we addressed the problems of our program that we faced during the developmental stages — from beginning to end and trying to find the solution from the results obtained. Our thesis aims to develop a creative documentation tool for giving feedback through evaluation in Fab Lab Oulu. This tool supports assigning specific feedback to the students' prototype design and documentation. Both teachers and students can communicate with each other through public and private commenting. We developed a new module for teachers where teachers can evaluate the students' prototype on different scaling in our system. In Fab Lab, teachers can view all prototype designs and documentation and give feedback to the students. In the previous thesis work of Adeegbe, there was/is no facility to provide feedback by the educators. For that reason, we have focused on solving the problem and started to implement the task because this work is very new to achieve in the system in Fab Lab. However, we have faced some difficulties in the designing sections, which is complex to use. We redesigned the teachers' login account, which requires an email domain from the University of Oulu, and we followed this User Interface from the previous thesis work, which was developed for students. We had to concentrate on the teacher's flexibility for using the application.

User Interface design should be reliable and comfortable for teachers because it is necessary to give feedback on students' documentation and prototype design. We compared our thesis work with the previous work, but our concept is unique from other research. Here we have implemented the system for teachers' feedback, and we focused on the feedback system for evaluation of the student's projects. For evaluation, we created several scales such as Semantic Differential, Likert and Rating scale. Those scales have scored from 1 to 5 where 1 indicates 'strongly agree' and 5 means 'strongly disagree'. Educators will give feedback through this scaling very precisely and accurately, which makes a useful decision for students. The rating provides some specific functions such as old, new, novel and obsolete. Additionally, Likert scaling also provides feedback through three unique questions for all students based on their projects.

Moreover, our system focused only on educators' feedback, where they communicate with the students and assign the task for giving feedback through this system. We experimented this thesis for making feedback providing flexible for teachers where teachers can view students' work with less time and provide the feedback quickly. We have performed the system evaluation through on/with test participants. From the test evaluation, we found the real-time interaction with the system, and we provided questions for evaluating the system usability. Finally, we calculated and analyzed the data obtained from the participants' SUS score and calculated the average SUS score. Our application "Protobooth Oulu" is now developed and usable for teachers' module in Fab Lab. Moreover, system usability testing needs to find error and problems. We developed our application as user friendly so that teacher can use it at any time through their mobile. Our app will be used only for teachers who have valid domain email address and any other persons without a valid email domain address cannot use the system. Additionally, an internet connection is



needed for using the application and this application is based android operating system, and analytical data is stored in the cloud server.

## **5.2. Limitations and Challenges**

We have encountered several issues while developing this system and for making it usable in Fab Lab. We solved the specific problems at different phases. We applied different scaling for getting feedback from the students through our app so that it could make the right decision for evaluating students' design prototype. There are various types of scaling. We mentioned about the scaling so that prototype design will be meaningful and unique from other works. Using the scaling, teachers can decide on students' prototype. Additionally, this system has other stages such as, satisfactory level and project level of students' project, which serve essential functions for making the decision. For the relationship, we had to make a database relationship which is connected to another table. We designed the system architecture based on logical activity, and we faced some challenges in implementing the feedback of this application. Moreover, the teacher can create the projects questions and provide students with the description box, but this function can be modified from the teacher's panel. Teachers can help the students when they make design and documenting through commenting. All educators have access to provide feedback through comments to the students. This phase was challenging to develop accurately. We have implemented the system based on user's requirement for Fab Lab. We have faced challenges in back-end development specially, Firebase database creation and maintained to store analytical data. We collected the analytical data from scaling rating and fetch the data through csv file. To enhance performance, we need to add more feature for more accurate decision.

## **5.3. Performance and Reviews**

From the usability testing, we found that our system is ready for use for Fab Lab users. Also, the SUS score calculation provided an accurate result which came from the test participants. Additionally, from the result, we got suggestions concerning the improvement of our system for better performance and making it more usable in Fab Lab. The SUS results indicated that this application is more satisfying to the users. Achieving users' satisfaction was our main goal for undertaking the research. "Prothobooth Oulu" application provided specific work for teachers, and it mainly focused on documenting feedback on students' projects. In this work, we presented the teacher feedback module with a different rating scale, project stage and evaluation of other parts. We developed our system with the flexibility to use for users, and the reviews come from the test users. The performance of our system is overall good from SUS score, which is usable for teachers in Fab Lab. Still, we need more correction and add more functionalities for achieving more usability of the system.

#### 5.4. Summary and Reflections on the Thesis Work

My thesis work targets designing and implementation of the prototypes in FabLab. Students can share their ideas, knowledge and information through the design and development of the prototype. The main goal of this system is to provide a repository to store information in the cloud and share the prototype is social media. Moreover, this system focused the teacher's evaluation system via mobile application name "Protobooth Oulu" app. For the ideas in my work, I have investigated various previous research for my analysis of the thesis work. Most of the work provides lots of information based on the design of prototype which students generated in Fab Lab using different kinds of tools such as Laser cut machine, 3D printers, Highly precision milling machine, electronics workbench and so on. My ideas come out about the evaluation part where I cant found anywhere from the teacher's side. Teachers can evaluate the whole project which prototype made by students. This research work provides a piece of great information for students via a mobile application from the teachers' side. Teachers can see while doing prototype with documentation which is quite challenging to provides this simultaneously—the whole system based on android mobile application. Here, teachers have first to authenticate email and then he/she can log in the page. Then teachers can see the home page such as weekly project, profile and students information. Here the main goal is to multiple interactions with teachers and students. Teachers can select the due date where students have to submit their projects like the weekly project and final project, which is visible to the student's side.

Moreover, the teacher can comment to teachers as a public comment, and the teacher can say to the students as a private comment via mobile app. Teachers can also select the questions based on the weekly project for students where students can get the questions and answer it. The most critical part is a weekly report where students can do the project and write their document at a time, and they have not spent much time. In a weekly report, teachers can see the project status level such as early, middle or late submission. The purpose of the system is documenting of the prototype which implemented the students and teachers can view the prototype and feedback to the students through the app. Several users tested the system based on the of time duration such as how long it takes time to go one function to another function.

My research work is most efficient for students and teachers. Students design and implement their prototype using different artefacts where teachers can communicate directly through the app. Specifically, the features, functions and interactions parts are described bellow: 1. Multitask perform through application for both teachers and students. 2. Teachers view students to prototype, which they implemented and uploaded in the app. 3. Teachers selected the submission date of the prototype with documenting. 4. Teachers and students can use the same app with their own authenticate email. 5. Teachers write specific questions for a particular weekly report where students can view and answer the question regarding the weekly bulletin. 6. Teachers can comment based on public and private. 7. Teachers interact with the students' project and rating the project such as teachers can estimating up to 1-5. 8. Teachers can evaluate those project through SD scale where SD scale provides old, new, obsolete and novel. Teachers can choose from those based on the project situation. 9. The Likert scale also can be selected based on the student's prototype, and this scale provided up to three questions for answering. 10. Multiple function-based

application and here, students and teachers communicate directly through this app. 11. Group viewing from the application. 12. Viewing/capturing photos. 13. This system provided where students and teachers both can use simultaneously and communicate virtually. They don't need to spend time evaluating each other in a real way. Those functionalities are efficient for both. Multiple functions are most effective for both in Fab Lab. I will analysis how could it be more useful for teachers and students in Fab Lab.

### **5.5. Future Work**

Our mobile application provides a friendly and smooth system where users use it frequently based on the prototype in Fab Lab Oulu. The SUS scaling provides a very good scale for using our system, and we have tried to incorporate all functions that users want. Moreover, all users have enough information about the prototype design and while doing documentation for using the system. Our system is run only on android devices where users use the android application. In this case, we hope to implement a different platform as a cross-platform. We have a plan to develop this application where we can run it in IOS, web application etc.

Additionally, We will also be using machine learning and deep learning methods to / with our app. Regarding these techniques, we will have the ability to simulate large amounts of data and guide the project for better development in Fab Lab and evaluate each task based on their project and compare it to others. One of the limitations is that we need a good network for storing the data from the system on the cloud, and we need a live server for storing data on the server. More mechanism and techniques for feedback can be added, which is very specific from the teacher's panel. Also, we should carry out our mobile application with a perfect approach in future work. We can give more time for testing and running our application to the test participants throughout the entire duration of a course. It will help get more usability and stability for using this application and will get better analysis support.

## 6. CONCLUSION

This research provided a lead and generated feedback on prototype design and documentation in Fab Lab Oulu. This study focused on the feedback system from teachers that they give on the students' prototype design and while documenting digital fabrication in Fab Lab. The majority of challenges are to achieve better results, such as evaluation through this system. We mainly focused on how teachers perform to give feedback to the students' task and how they analyze and understand the whole thing based on the students' documentations. In Fab Lab, students usually use several tools for developing and completing their prototype, and teachers evaluate it manually. From this system, teachers can easily trace the development of students' work and give feedback on it in various ways and stages. Both teachers and students can interact and communicate using this platform. This system allows communication with privacy, and other users cannot see the conversation. In this way, the frameworks established in the study include mobile applications where teachers can give a better solution and feedback to the students. It is observed that these systems, particularly for educators, have the ability to be beneficial for Fab Lab users. By using this application, teachers get a notification to give the evaluation to the project through several scaling, and students get to know about their project stage from this feedback. Questions and answers are also provided from this system which is helpful to the students. Interview sessions of the participants were included, which helped make it sustainable and suitable to utilize the system where students have an excellent opportunity to submit their work and teachers can modify, evaluate using the same method. This system is also included in social media such as Instagram, WhatsApp and others. More other features such as students can get their grading through different functions, and they can view the project quality and how long it relates to others' works etc. are included in this system for students' feedback. The main concern of this research is that teachers can measure the project stages and satisfactory level of the documentation.

Moreover, this system requires an android application and users can easily access it any moment through their mobile. Finally, we would like to say that this research represents the complete outline of the process of the application for teachers in Fab Lab Oulu. From the SUS testing and evaluation section, we got some results. In the discussion section, we talked about some improvements by adding some more functions to upgrade the application of our system. Additionally, we can analyze the system evaluation from more participants and add more functionalities depending on the demands of the participants and users. Both teacher and students can get better results in the academic section.

## 7. APPENDICES

Appendix 1	SUS usability Testing
Appendix 2	Questions for interviewing the participants

## Appendix 1

System-supported instructor feedback  
on the students' design and prototyping  
processes in Fab Lab education context

*participant ID* : \_\_\_\_\_

*Name* : \_\_\_\_\_

*Date* : \_\_\_\_\_

# **1. PERFORMANCE TEST OF THE SYSTEM**

## **1.1. SUS Usability Testing**

Our system helps students prototype feedback based on their works. Firstly, test participants joined to test our mobile application to be used in Fab Lab. We analyzed the evaluation which comes from the test participants. The main concern is to observe the best solution for our application based on the SUS scaling and users can use the system very smoothly. Moreover, our application incorporates more functionalities for evaluating the students' prototype and giving the best feedback to them in Fab Lab. Our application also provided an evaluation for admin where participants can test that part as an admin. Both testing parts were evaluated from the participants where we got useful feedback from the participants and it helped us improve our system for more usability. Teachers have great opportunities to give feedback to the students through this system in much less time via mobile phone. For this reason, the participants used this system as a tester and provided feedback on it through a form. They evaluated the system and suggested for more improvement and modification of some functions for better understanding.

## **1.2. Methods**

Our system was evaluated by seven participants who took 20 to 25 minutes for testing the system and giving worth feedback. The participants were given verbal presentation of the procedures and tasks. We selected all the participants from Oulu university and they are familiar with Fab Lab Oulu.

## **1.3. Contractions**

In Oulu university all teachers conducted the course in two languages. Of the two languages, we preferred English because everyone could understand and we could interact with the participants in English. Participants were of different nationalities and for this reason we

communicated with them in English. Moreover, we set ten SUS questions where participants can ignore any question if they don't prefer to answer that.

#### **1.4. Users' Confidentiality and Rewards**

We maintained privacy and confidentiality when we collected data from participants. This is why individual users performed the testing of the system privately. From this testing, this research can improve for better performance for users. We applied two methods such as, Questionnaire survey for SUS testing and interviews for data collection and getting feedback from participants. We provided different types of questions that the participants needed to answer for SUS scaling and conducted an interview on how to improve the system based on Fab Lab users.

I comply with the Assessment Privacy policy.

*Signature* : \_\_\_\_\_

*Date* : \_\_\_\_\_



### 1.5. SUS Usability Testing

**Instructions:** Follow the questions and mark the box that expresses best your opinion and performance during the testing period.

Q1.I think that I would like to use this system application frequently

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Q2.I found this system application unnecessarily complex.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Q3.I thought this system application was easy to use.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Q4.I think that I would need assistance to be able to use this system application.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Q5.I found the various functions in this system application were well integrated.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Q6.I thought there were too many inconsistencies in this application system.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Q7.I would imagine that most people would learn to use this application system very quickly.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Q8.I found this application system very cumbersome to use.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Q9.I felt very confident after using this application system.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Q10.I needed to learn a lot of things before I could get going with this application system.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

## 2. INTERVIEW QUESTIONS FOR PARTICIPANTS

### Appendix 2

#### 2.1. Interviews with Participants

Q1.How much do you focus on Fab Lab ventures?

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Q2.Do you think that getting feedback and evaluation, whilst students are doing prototyping design and documentation, from teachers is a good idea?

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Q3.How much time did you give instructions to students when they worked on designing prototypes and documentation in Fab Lab Oulu?

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Q4.How do teachers take the prototype design and documentation from students? Do they have faced any difficulties in submitting prototypes?

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Q5.Which approach and technique will you follow for taking the documentation from students in Fab Lab Oulu?

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Q6.Do you agree on the contracts and interaction with students using an application and performing multiple tasks through the system?

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Q7.Do you agree on the public and private commenting between teachers and students ?

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Q8.Did you find any unnecessary functionalities ?

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Q9.Did you find any better functions and operations which are necessary for application in Fab Lab ?

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Q10.Do you agree that this application will help develop skills and efficiency for both teachers and students in Fab Lab Oulu?

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Q11. Have you had any experience of an existing system where teachers could give feedback on the students' prototype through mobile application?

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Q12.Do you agree that teachers can evaluate through scaling such as, rating, Likert and SD. Is it helpful for students?

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Q13. Did you evaluate the students prototype stage and satisfactory level in any application before?

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Q13. Name of Participants in the study ?

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Q11. Gender

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Q12. Age

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Q13. Occupancy

---

Q14. Phone number

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