FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

Nijar Hossain

AN APPLICATION SUPPORTING PERSONAL AND TEAM DOCUMENTATION OF STUDENTS' DESIGN AND PROTOTYPING PROCESSES IN FABLAB EDUCATION CONTEXT

Master's Thesis
Degree Programme in Computer Science and Engineering
June 2020

Hossain N. (2020) An Application Supporting Personal and Team Documentation of Students' Design and Prototyping Processes in FabLab Education Context. University of Oulu, Degree Programme in Computer Science and Engineering, 64 p.

ABSTRACT

Documentation is common practice in an integral part of a modern digital fabrication process while designing a prototype in Fab Lab. DIY and Maker communities are trying to share their documentation through the Fab Lab global networks. Sometimes, the users follow different ways to make their documentation, which has no straightforward interpretation for other users or communities. For designing a complex and original prototype, the users of Fab Lab often eradicate the challenging phases and forget to document the essential parts of the solutions that occur during the design process. Documentation tools figure out the best possible writing technique(s) that can be shared with the global Fab Lab researchers. In designing the prototype, mobility becomes a factor for making the documentation tools more comfortable to the Fab Lab users as well as future researchers. Additionally, the time taken during the documentation process increases during the post-development phase of the prototype. In this work, we have introduced a new and upgraded version of the existing tool called "Protobooth Oulu app", and expanded different features for documenting while doing the prototype designing technique for consuming less time and ensuring better mobility. This tool also presents and performs the existing guidelines for the Fab Lab Oulu users for creating, managing, and updating personal or team works. Connectivity between an instructor and a team will add useful features for developing the digital fabrication process(s) regarding the documentation practices in Fab Lab Oulu. Different types of scaling and ongoing project feedback are considered the best approach for making the documentation unique and distinguished from other works. Additionally, we also discussed new admin tools for fetching the different scaling data for future data visualization. Post-development in prototype designing research will ensure the advantage of generating and visualizing the data for predicting the analytical result. In this thesis, we also discussed the admin tools and its features for making rational decisions as to the uniqueness of the prototype designs.

Keywords: Fab Lab, Digital Fabrication, Prototyping, Semantic differential, Likert scale, Feedback, Dashboard, Scripting tool.

TABLE OF CONTENTS

FOREWORD

At first, I would like to express my gratitude to the Almighty who gives me the strength and mercy to live my life.

Then I express my special gratitude to Associate Professor Georgi V. Georgiev from the Center for Ubiquitous Computing, ITEE. His continuous supports and offering of different guidelines for this thesis were really valuable for me to overcome new challenges. I am grateful to the Postdoctoral Researcher, Ekaterina Gilman from the Center for Ubiquitous Computing at the University of Oulu for valuable comments for my thesis. Research Assistant Yazan Barhoush, from the Center for Ubiquitous Computing at the University of Oulu, worked as a technical advisor for me for the entire thesis. I also extend my sincere appreciation to MS. Nasrin Akter for her valuable advice regarding the application designing process from the very commencement of this thesis. I am thankful to the Director, Professor Timo Ojala from the Ubiquitous Computing and all other teaching community for giving me an opportunity to pursue the Master's program in Applied Computing and also enrich my vision regarding the new technology. I would also like to thank my parents, Mr A.K.M Abul Hossain and Mrs Nasima Khatun, who have been loving me unconditionally throughout the course of my graduation years. I would love to thanks my wife Fatema Binte Sultan, who provided me with positive and constant motivation throughout my years of study. It would not be possible to accomplish this work without the substantial support of my family members. Thank you.

Oulu, June 16th, 2020

Nijar Hossain

LIST OF ABBREVIATIONS

Fab Lab	Fabrication Laboratory
API	Application Program Interface
GUI	Graphical User Interface
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CAE	Computer Aided Engineering
XML	Extensible Markup Language
RSS	Really Simple Syndication
PCB	Printed Circuit Board
PHP	Hypertext Preprocessor
HTML	Hypertext Markup Language
SUS	System Usability Scale
IANA	Internet Assigned Numbers Authority
MCU	Multipoint Control Unit
CSV	Comma-Separated Values
VSCODE	Visual Studio Code

1. INTRODUCTION

While designing a prototype, documentation is very difficult and challenging [1]. Sometimes users need to redesign the whole prototypes, which fails because of the complexity of the designing process. In many cases, iterative prototyping is an instrument in design thinking [2]. Prototyping and materialization are instrumental for higher creativity of the designed solutions [3]. In this regard, we urgently need a solution where the users can get the benefit and be able to design smoothly irrespective of the types of prototypes [4]. If we do the documentation while doing the project or build any prototypes, it will help the present Fab Lab users and future projects, developers. Various organizations such as Maker and other communities, e.g. DIY constantly express their interest in making artefacts and prototypes to their community [5, 6].

Sometimes the Fab Lab users sketch their designs and take notes for documentations. They might want to share some interesting key topics or points of their projects, or they might want to share the whole documentations. When any user of Fab Lab designs any complex prototypes, he/she might forget to mention the core challenges of designing the prototypes for the documentation [7]. For any modification of the existing prototypes, the process might sometimes lead to difficulties and time-consuming steps. Because of these reasons, documentation is highly recommended to eradicate this kind of problem. Sánchez Milara and Georgiev have introduced us to a documentation tool while designing the prototype to ease the complexity [7]. Additionally, they advised all users of the Fab Lab must do the documentation for presentation and also for future modification regarding building any of the prototypes. Gershenfeld states that digital fabrication is one of the best approaches for innovative digital revolutions, which empowers the individual users to design and fabricate physical objects [8]. Makers of the world depend on the CAD (Computer-Aided Design) and CAM (Computer-Aided Manufacturing) software tools for designing their artefacts [7]. These designing files are easily shared with the world digitally, and, day by day, the digitalization of this process is becoming mountainous. Any user who wants to build artefacts, he or she can follow the designing approaches from the digitalization of others' CAD and CAM designs. In this way, anyone can replicate anyone's works and create such a prototype that can benefit society as well as the whole world. However, sometimes, it takes a completely different scenario in the longer run. Members of the community usually share their common interests in the creation of new devices, artefacts, and objects [9, 7]. Sometimes, they tinker with the existing devices through digital fabrication, physical computing, electronics, and programming. These approaches and movements impact our daily activities, i.e. education, business, ecology, and international cooperation. Each of the contributions in the Fab Lab creates numerous opportunities, which can help massively by collaborating with the arts based on the engineering for developing any modern artefact [9].

Every new practice and regulation must adhere to the Fab Lab charter [4]. Every Fab Lab must have some tools by which a Fab Lab will differ from other ordinary University labs. A Fab Lab has several types of equipment for completing the operations, like- 3D printer which does 3D printing from CAD tools, a laser cutter machine that works for cutting any boards or CNC router that cuts hard materials [7]. A Fab Lab also needs some high tech software related to CAD and CAM. For

Figure 1. ProtoBooth Oulu

the networking purpose, Fab Labs maintain almost 1600 digital manufacturing areas around the world. According to Sánchez Milara and Georgiev, the principal object is to designing and developing a prototype while doing documentation in a concise way where every tool of the Fab Lab is highly used within the Fab Lab users [7]. Additionally, the current users should conduct research and put more efforts to design new, low-cost genres of the Fab Lab tools so that these can be made entirely within the Fab Lab itself. An illustration of the usage of the tools in each Fab Lab, as well as both current and envisioned scenarios of usage of tools and Fab Labs, would make these ideas more concrete.

Being inspired by Josua Adeegbe's work, we identify the key objective of this thesis is to develop a Fab Lab documentation tool called "Protobooth Oulu app" for the next generation Fab Lab users based on the android architecture platform [10]. Students must also comply with rules and regulations on the use of an android platform, to enable each student to receive feedback from the instructor. The early stages of the prototyping will be easier and well documented for future usage by using this application [10]. Whilst they receive feedback from the teachers, the documents also serve to make this project meaningful for a group of students or individual students. They are able to capture and share while prototyping can boost the development of the designing process. Ongoing project status will also play a significant role from both teachers' and students' sides for developing the right time table. Students will be offered an innovative designing and implementing tool for their early stages of prototyping [11]. So, in this thesis, we introduce an augmented Fab Lab app called the

“Protobooth Oulu app” and develop various features for the Fab Lab students of the University of Oulu.

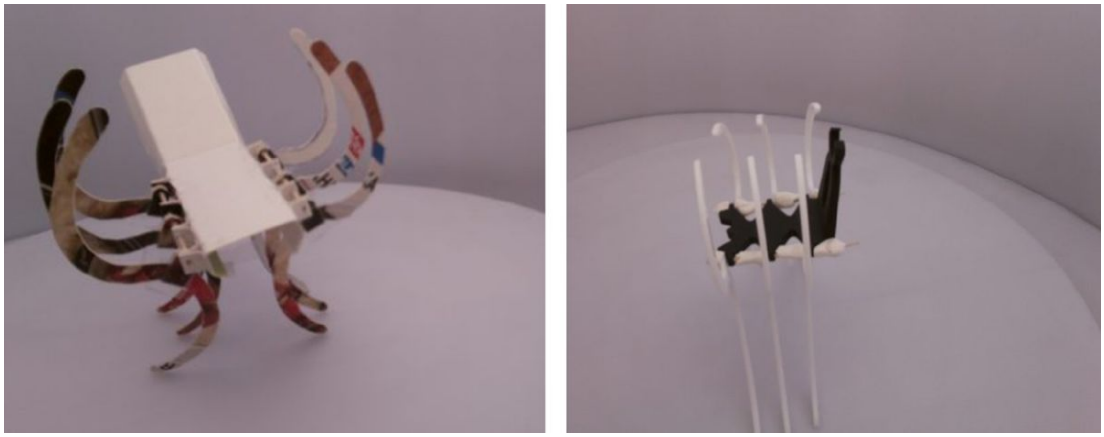

Figure 2. Example prototype in course (captured by ProtoBooth Oulu)

The principal scope of this thesis is to develop an android documenting app for designing the prototype in Fab Lab Oulu. Additionally, students will get a documented tool for multiple interactions within a group, for getting feedback from the teachers, and for knowing the scaling dashboard from their homepage; so that the students can know how unique and innovative is the concept of the prototypes that they have designed. On the other hand, Students will get a weekly individual assignment and also submit the assignment through this application. This app mainly enables the Fab Lab Oulu to serve the goals of providing unique documentation tools to the students for designing their prototype by doing their group and weekly projects. After that, from the admin’s side, we have also created a python admin tool for fetching the data from the database for future analyses and research.

2. BACKGROUND

2.1. Background Works

Sánchez Milara and Georgiev have discussed a documentation tool that will allow users to create documentation of their prototyping designing techniques [7]. Moreover, they proposed a solution that can help a lot manage proper quality documentation. "Build in progress" is a tool (invented by Tiffany Tseng at MIT) that can be an alternative solution to the existing problem of the Fab Lab documentation of the network [12]. The key reason to use it is its simplicity of usage. This tool consists of three essential elements) A mobile app, 2) a Server, and 3) a Web application. According to the authors, their developed mobile phone app allows collecting pictures with notes [7]. Moreover, their messaging can support voice messaging. The contents which are managed by the app will be functionally sent to a back end server, where these data will be saved and displayed into a website. Later, the contents of the site can be changed or edited by the web. For reflecting the "process-oriented" approach into the documentation, "Build in progress" is a software tool, the main task of which is reporting [7, 10]. Their designing principles that guide the algorithm of the site are 1) Designing process must be done with transparency; 2) Feedback in progress must be encouraging; and 3) For the reflection of the documentation, creating opportunities is a must. The framework supports to notice various paths taken during the manufacturing process. Maker and Do-Yourself groups are always trying to share their documentation work such as videos, pictures, or conceptual sketches. Doing proper documentation requires reasonable regulations to follow and to have descriptions with images so that any Fab Lab users can get an idea of the designing procedure [13].

In this thesis, we try to create a new way of documenting tools that will help users design their prototypes in the Fab Lab of Oulu. Improving upon the Sánchez Milara and Georgiev model, our app will perform several tasks to overcome their limitations, and it will have better features than that of the works of Josua Adeegbe. We will also do a usability testing for evaluating and system performance for the operational activities in the Fab Lab of Oulu.

2.2. Conceptual Art of Fab Lab

Professor Neil Gershenfield originated the idea of Fab Lab. He is the first person to establish the Fab Lab for managing different operations between MIT Media Lab and CBA in 2002. A Fab Lab is a tiny, physical workshop equipped with machines to perform rapid prototyping of personal production. It is also known as personal fabrication. Gershenfeld has broadened the idea worldwide, and now he looks for an organization to support this idea outside the CBA boundary [14]. The Fab Foundation is an umbrella organization of about thirty to forty Fab Labs all over the world. Lateral alignment has been implemented to collaborate among the Fab Labs closely. In the network, the character for the Fab Foundation is not evident. Different guidelines associated with the Fab Lab network have been explored for managing the daily operations of Fab Lab users. It is not a single, overarching hierarchical Organization. This includes tools to share knowledge and design production at the Fab Labs. Some

part of the software used for production in the Fab Labs is developed at MIT CBA. The other software is freely available as open-source software. The Fab Foundation is a distributed organization, has been using bespoke software for collaboration. The organization needs advice concerning the software directory and how these can be used to make the work easier for documenting the best practices. Developing Fab Labs worldwide raises a lot of questions pertinent to the scope of the organizations, different needs, cultural differences in different economic situations. The Fab Foundation is a global organization that seeks opportunities to communicate and share knowledge to collaborate across the different continents and time zones. Being embodied as a multinational organization, it supports its members to develop the technology and carries a high value(s) apart from only sharing information. Amongst other things, the shared knowledge could be utilized as a basis for education, which is not limited to any particular geographical, economic, or social borders [15]. A Fab Lab can be established in a metropolitan area such as, in Amsterdam or the countryside, e.g. in Bangladesh. The Fab Labs, operating in the rural areas, can become a base for introducing technology and technology-related education to the children or the whole population. The fundamental needs for education in the network should be aligned with the Fab Academy. Such a system of education will allow people to take part in school from any part of the world, regardless of other factors such as income, country, or place of residence [16].

2.3. Operation and Design Procedure in Fab Lab

Both hardware and software setup(s) of a Fab Lab is described for an overall understanding of some of the challenges for operating the technology in a Fab Lab. These are:

2.3.1. Staff of Fab Lab

The labs have several organizational wings; some are part of a university structure; others are the independent businesses having no organizational superstructure. The manager in the Fab Lab manages the economy, and the assistants' role is one of the creative tasks for operating the machines. If one person can perform both functions, it is a matter of personal interest and knack, but only one person working in the lab is vulnerable to illness, etc. [17].

2.3.2. Operation in Fab Lab

A Fab Lab provides access to the tools for rapid prototyping for digital fabrication (described later in this chapter). One of the unique characteristics of the connectivity between the users of the Fab Lab Global network is that the machine required for creating new artefacts in Fab Lab will be funded. Moreover, some of the people are associated with the areas without performing other technology adjacent to Fab Lab [14]. Generally, some of the lab equipment is found in technical universities or

larger companies dealing with product development. Fab Lab operations are performed involving three groups. The groups are described below:

2.3.3. Types of Users

User A: The inventor Who: For managing the disciplinary activities, an inventor is a person who handles all of the managerial discipline activities and provides the guideline but may not have in-depth knowledge for performing the operational activities in Fab Lab. What: The inventor has an idea, maybe well-considered with some drawings or 3D-models [8]. For example, an investor wanted a prototype to show if a concept for collecting waste materials worked. How: The inventor contacts the Fab Lab with his idea to produce a prototype. There are set up meetings between the Fab Lab and the inventor. The design of the product is discussed. If the resources or facilities are not in the actual Fab Lab, other people in the network can help. Prototype designing is a process of iteration, and several iterations are needed to make a final prototype that will be used by the inventor. Duration: Depending on the complexity of the prototype or the model, a task like this could require one week to several months.

User B: The Fab Lab designer Who: The Fab Lab designer is working at or having a close connection with a Fab Lab. He knows the global network and knows from where to get help. What: This person is working on his inventions, helping other people in the Fab Lab or other customers of the Fab Lab. The discipline of the work is commonly multifunctional through a reverse engineering [8]. For example, there could be sensors for controlling the surrounding states of a building and using for educational purposes. How: The Fab Lab designer's head discusses the ongoing projects, and later it will connect through a video conferencing, if needed, for further operations in Fab Lab. Duration: Generally, the period would be one day to a week.

User C: The customer Who: The customer Who: The customer needs a product, but doesn't know how or what. Even if the product requires low-level technology, there are not many places for the customer to get the product made [8]. What: The product could be a unique casing to brand a product or an acryl product to assemble the pieces of equipment in a stack. How: The customer expresses his problem to the Fab Lab. Customer feedback plays a vital role in solving the iterations problem within the Fab Lab network. If the customer is satisfied with the product, the Fab Lab can build the product in-house. Duration: The duration depends mainly on the two weeks until the end of the years through the productivity within the boundaries of a Fab Lab.

2.4. The Fab Charter

By providing access to digital fabrication tools, Fab Lab is constructed through a global network for innovating the core capabilities of making new artefacts. Procedures for making new artefacts and documentation can be shared with the users from different local Fab Labs following some set of objectives and guidelines.
Mission: The Fab Labs work as a global network for a few local labs, which enables

anyone to invent by giving access to tools for any kind of digital fabrication [16, 11].
Access: Anyone can utilize the fab lab to create anything (but should not harm anyone); the individual must learn to do it himself/herself, the individual must share the operational procedures of the lab with the other users.
Education: Doing projects together while learning from groups is the key to training in the fab lab. Every individual is expected to help document the instruction(s).
Responsibility: Every individual is responsible for some:
Safety: Users must know how to work in projects without damaging any people or any machines.
Cleanliness: Must keep and leave the lab neat and clean.
Operations: Helping with the conservation, maintaining, repairing and reporting on any tools, supplies etc. occasionally.
Secrecy: The processes of designs in fab labs need to remain accessible for everyone's use; while the intellectual property might be kept secret, how so ever the individual chooses.
Business: Any kind of commercial activities might be cultivated in Fab Labs, but these should never breach with the open access policy; these must grow across, instead of limiting in the lab; these are expected to help inventors and lab groups who worked hard for the success.

2.5. Common Challenges for Fab Lab

Distribution of the accumulated knowledge is one of the challenges that every organization will experience. Most organizations are concerned with the vital activity of sharing information and knowledge [18]. Organizations that are globally dispersed will approach subdivisions of the organization(s) in different parts of the globe—from big cities to rural areas, from less populated regions as well as from areas of zero population, or even with a minimal means of technical infrastructure. The return on investment (ROI) could be used as a cost metric for choosing between the alternative solutions in the life cycle of the software [14]. One of the barters that have to be accomplished is utilizing open-source, bespoke, or commercially available software. One organization that is facing these problems is the Fab Lab network. Fab Labs are a globally connected network which allows an individual for invention by providing access to the digital manufacturing tools. This network is an excellent example of a multinational non-profit organization based on the concept, much like an open-source community. The Fab Labs aim to share information and make knowledge available for all the people that wish to take part in the development of the city, regardless of their social background or geography [15]. The Fab Lab software tools should be used to aid the spread of knowledge and information. This organization will be beneficial for other organizations with similar needs [19]. Maintaining and creating the documentation while designing the artefacts in Fab Lab require much time [7]. The documentation might also create the following troubles for the Fab Lab students: 1) They spend huge time for making their documentation while designing. 2) They are less careful while discussing their crucial steps for Fab Lab machine learning customization [17] 3) They focus on successful actions, and later they forget what they did to overcome the problem. 4) They prefer to report recipe like a story for their

Fab Lab operation. Contra, ‘documenting while doing’ is a procedure in which each of the tasks is assigned and documented by the users of Fab Lab for documenting the designing process of the prototype.

The first two international Fab Lab sites were published in San Jose Costa Rica Vigyan Ashram with the mention of the challenges of the Fab Lab [8]. There was a particular challenge regarding the detection of the active Fab Lab users, i.e. who have much knowledge about the Fab Lab tools and designing technique. Considerable resources are devoted to innovating tactics for learning the development of tools that genuinely acknowledges the differences from human studies. Fab Lab education will continue to be an essential integral part of this project. Yet, it will not only fail to fulfil its purpose, but it might also lead to an understanding that grassroots approaches will not work.

Seeking help from an expert who has practical and material knowledge can assist in successful operation in Fab Lab, users’ accumulating experience, and overcoming any problems. Increasing the amount of Fab Lab facilities can be very useful for achieving the highest success for designing the prototype and figure out a different technique. Apart from this, the Fab Lab software used for commercial purposes, which was developed in the English language, has become very hard for the Boston Fab Lab. Because the English language is not currently spoken in Boston. Later, the next generation tools of Fab Lab can be made aligning with social and cultural issues [20]. [20]. User customization was a great feature in this regard. Preparing proper documentation will not only help for sustainability but also, sometimes, it raises the difficulty level for the seasoned researchers. We would like to acknowledge that we were provided Fab Lab with the tools which were used for making the documentation process simpler. Our main motto was to add research tools by getting some feedback from the Fab Lab students’ projects. The Fab Lab experts verify the works based on the input and cooperate with the users for creating the next generation fabrication tools [16].

2.6. Fab Lab Documentation Process

There are several ways for documentation of the Fab Lab operation. Tseng has presented two ways of doing the documentation [12]. The work has introduced "recipe-like" or "tutorial-like" documentation by mentioning the instructional guidelines and by setting up some steps that the users need to use these for their documentation. From the "recipe-like" approach, we need to figure out and write down the ingredients. As a result of these ingredients, we mean that we need to figure out the material and tools for writing the documentation. Also, we need to follow the illustration of the process step by step. The second step mentioned by Tseng is the "Process-like" or "story-like" approach. In this regard, the description must follow this guideline [7]. The users must perform each task, and the users need to focus on the process and then complete the next task in the Fab Lab. Every user must include information about the problems found, and they also need to write down a brief description of the problem-solving strategies. The strategies consist of some manners or acts such as changes in the original plan and so on. The process-oriented documentation is more beneficial to the Fab Lab community and also helpful for future researchers. If the project does not

work or stuck on a step that also requires documentation for future researchers as well as for the Fab Lab community, finally, some researchers or the developers in Fab Lab might not follow the complete documentation that we design through process-oriented documentation. However, they can follow some research questions or figure out some similar concepts which might be needed for developing their projects. Considering the above reasons, we aim to build a flexible documentation system in which anyone can utilize any of the two methods so that their tool will reduce the barrier for documenting while doing.

2.7. Fab Lab Documentation Tools and Platforms

Fab Lab is mainly designed for international networks and allows open access to several workshops based on individual digital fabrication [21, 15]. From manufacturing and technological perspectives, we need to maintain peer to peer learning with the standard machinery. Sharing contents as well as experiencing over time and across the distances, face to face communication depending on mediating technology etc. are a must. For creating project documentation and mentioning the designing process, Fab Lab is increasing the network at an exponential rate and has more than fifty labs for operation through shared knowledge.

Moreover, some of the open-source web platforms, e.g. thingiverse.com, instructables.com, etc. which are not enough for serving the needs of the Fab Lab network [1]. Some of the keynotes are 1. These platforms are controlled by external bodies, and perhaps it has some commercial entities. However, they have the best intentions; it sometimes might become an issue for future development in Fab Lab. 2. Because of some of the economic problems, they are not provided for the installation and configuration to the user's computer. They are highly encouraged to make their system an open-source platform. In this regard, the customization and building of their documentation tools are not possible in that way. 3. They cover the feature where the distribution of knowledge is used to create new things, and it will become doubtful whether the task is outsourced to a third party or not. This will possibly hamper the future development of the Fab Lab community. For eradicating this issue, a series of "platform" workshops took place in August 2010 for covering some of the best online topics regarding the development of Fab Lab and for making the document sharing process. Various features for creating documentation are based on designing the prototyping in the Fab Lab, and they are 1. ProtoSpace is a documentation tool that was a website, and its platform was Drupal through conceptualizing for creating the documentation in Fab Lab [22]. 2. Swiss Fab Lab: This platform was WordPress for making the documentation in the Fab Lab, and it enabled sharing even when under development [13]. 3. The Fab Lab community tools website, fabfolk.com was accumulated to figure out the documenting elements from the primary sources [13]. From the kiosk tools, the documentation for Fab Lab was conceptualized as check-in and check out and also for completing the circle by another kioski tool for documenting other lab creations. Drupal is a web programming language for making the ProtoSpace, and it was customized for implementing custom desktop software for the Kiosk. Moreover, Drupal offers a modular that added new functionality on the "Protobooth Oulu capture system". The content manipulation

workflows, content type, and summary views were set up to fulfil the requirements. A log visitor for demographic information based on lab usage patterns was developed in a customizable manner. The content-type project description was fixed through developing an initial version including project title, description, product's picture, which was again captured by the WIFI enabled camera for avoiding the manual transfer from camera to computer. Moreover, several machines were used to control the device of different manufacturing processes. When the update version was released, this system would have the possibility of following the step by step illustration considered as a part of the documentation [23]. These content will be arranged in a systematic approach for increasing the flexibility of future needs [24]. [24]. After finishing the prototype, the challenges start to appear, such as, the lab visit logs documentation, which may sometimes be premature. Also, users need to express their aim to complete their documentation until the completion of the project [25, 26]. The lab assistants are facing hassle in the help desk as the documentation shorting process is managed using the existing physical station, even if the fixed input of the documentation content is achieved with a technical solution. However, in the beginning, the user interface phenomenon was widespread. It is similar to the more general education on the open-source hardware protocol, and standard type licensing, which is creative and is considered essential to the new visitors [13]. Wordpress blogging script is implemented for recording the documentation by the first swiss Fab Lab at Lucerne. In the beginning, the documentation is eventually visual, including photos of building principal of a textual chronological process. The process is not precisely numbered in several machine-readable points, and there is an absence of extra metadata held over where the standard set up of WordPress is logged. Any RSS feed can be generated using WordPress, no matter what it requires. Whole blog, tags, comments, themes, etc. are the primary feeds that every image holds, and are generally present in the post content. Eventually, the additional pictures, that are not placed into the post data but still attached are not part of the feed. An exact template that can formulate RSS feed consisting of all the images was built, which also uses the Media RSS Module 2.0 specification that matches the platform's element ability of RSS 2.0. This allows for more robust media grouping. For collectors, a function was added to enjoy the specific feed, and they can read it using fabfolk.com. There are two significant demerits of recording and grouping documentation with WordPress, which are: a) Including media other than pictures and b) Including metadata. Several media files can be used, such as, IANA media type, CAD drawings, and machine setting records, and copy files that might not support the IANA media type [13]. For implementing meaningful metadata, open-source hardware, including specific standard vocabularies and own digital manufacturing and ways of grouping the metadata needs to be routined. To collect and process feeds from primary sources, a prototype aggregator was built as the present module enables processing incoming data in an organized manner and lessons of the method by the collaborators. So, drupal was there too, but the platform was not set alone. The developers are working ordinarily on mapping out the presence of drupal sources for RSS and XML feed parsing, prioritizing the circumstances arising from the distributed content management. It is as if the fact of how to control the feedback to an aggregated content item and deal with the derivative aspects. The main challenge that grows from parsing the earlier unformatted RSS feeds for meaningful and exposable project information that provides the proposition of XML based documentation share

and boosts the method for using the content management system of individual labs that again enables RSS to feed in a customized way to any context that could be delivered using XML feeds with less effort. It is not late to validate prominent parts of production. Still, minor development is needed to enable cross lab share of projects in the heterogeneous environment of the Fab Lab network.

2.8. Fabrication Tools and Usage

Personal fabrication is the core concept for the Fab Lab users. Within Personal Fabrication, there are two commercial fabrication tools. One of the devices is responsible for the Roland 3D milling and scanning machine. Another one is Roland vinyl cutter. The mill and vinyl cutters are mainly used for multidimensional projects [27, 13]. Also, this tool can be used for the functional scale of 3D mechanical parts with 3D modelling tools on the computer. This device can work as an input device for scanning the 3D object on the computer. By using this tool, anyone can create a 3D digital model of the main objective, and this model can be edited in future modification. The mill can also be used for printing the circuit board to PCB for short. One of the most anticipated tools for Fab Lab is a vinyl cutter that can be used for cutting the circuit layouts or antennas implement it to a variety of curved plastic boards by using the 3D mill. However, the electronics fabrication process is not without the chips, and other components need to be ordered individually. But the PCBs of these chips and other parts are soldered for the Fab Lab, and later it will reduce the cost of the fabrication process. As the faculty members are inspired by the original prototypes created by Rich Fletcher, who is from Physics and Media group, the members are building their personal wireless environmental sensing modules, which is integrated with the Tower system for the agricultural educational applications. Some students at TEC are at an early stage of prototyping handheld devices for wearable medical applications. They are conducting their research in collaboration with other researchers. Their research will help villagers significantly, especially for monitoring some specific skin conditions. Also, some students of the Scientific high school have made new tangible modes, which are planned to aid in learning some concepts in physics and chemistry at the levels of high school with input from the members of the network with broad educational background.

At the Children's Museum, situated in Costa Rica, a group of students from Technical high school is on the verge of success exhibiting on Upthrust. These are not all of the stories of hope and dreams, a lot of other applications are imagined daily, and people are working hard on those. There is also a plan for creating databases of opportunities and economic challenges for developing technologies, which could result in a high social effect. A group of business students, studying in INCAE, are working on this project, maintaining constant interconnections.

2.9. Popular Designing Tools in FabLab

The software in the Fab Lab can be divided into three groups 1. Operating system; 2. General software. e.g., software for image processing, a word processor; 3. Supportive

software. Supportive software is needed for installation, and maintenance is required for installation maintenance.

Computer Aided Design (CAD) For designing different drafting products or drawing any design of prototyping, CAD tool performs for its usage in the development of a prototype in Fab Lab. Drawing can be completed in either 2D or 3D. Sutherland introduced a program for maintaining a computer graphical user interface by using a light pen, and it has 40 buttons to perform the drawing activities [28]. The 2D- 3D-drawings are analogous to the drawing table [15]. This was a time-consuming process both in 2D and 3D. The re-use of the drawings was strictly limited to the use of the pictures. Moreover, direct scaled measurement on the thesis was difficult. Various other drawings from different angels were needed to replicate the 3D-object meant to be produced. Even with unlimited time and workforce resources, the process had limitations in the design process. Nevertheless, the technique made it possible to plan for building the Eiffel Tower, Titanic, the T-Ford. The profound changes have occurred from the analogue process to the digital means in the 20th century [29]. The drawing board offered the engineer the possibility to make a flat representation. Modern CAD software works with model objects. By using the CAD tools, we can make the objects, modify the object, and scale it. For collaboration among the Fab Labs, it is possible to export the models to any vendors, customers, or other collaborating parties. This adds an extra value to the product, and the other parties can make proper use of the drawing, and can easily include this model in their pictures. Some vendors have this model as well as CAD generators so that they can allow customers to configure their products way before exporting the resulting CAD-files [30].

Computer-Aided Manufacturing (CAM) CAD is a computer program for designing; on the other hand, computer-aided manufacturing is the process of shifting CAD-drawings to physical models by controlling the machines [31]. The Unisurf system at the Renault made it possible to manufacture improved designs and print them faster in Styrofoam for easy prototyping – way before printing in the material required for the final model [32]. When CAD-CAM is combined in manufacturing, this is called CADCAM. The development can take place immediately after the files have been sent to other region.

Computer-aided engineering (CAE) The circuit simulator program that Sutherland lacked in Sketchpad could be a CAE-tool. CAE is an umbrella term for the various activities in computer-assisted planning, in CAD-CAM, in engineering activities, but it is not frequently used for software development [33]. CAE can be beneficial, especially for the prototyping of electronic circuits in the fab labs. The CAE-process is not the only machine centred; instead is a combination of computers, devices, humans. Users should benefit from the best characteristics of this combination. The outcome can be a problem-solving team. Products with complex subsystems materials still need physical testing to verify the software calculations. Simulation of a crash in the car industry is used to calculate structures and materials for their possible impact on human beings.

2.10. Prototyping Impact in Designing Process

Software prototyping can be explained as rapid software development for validating the requirements [15]. The main objects for the design of the prototype are the identification and validation of requirements. The process can give results such as figuring out the best improvement for the systems by reducing the risk of usability from an early stage. One such primary use of the prototype designing is that the development of a prototype which will ensure whether the new complexity of the concept will work or not and provide the adjustability of the original idea into the ongoing designing artefacts. The user will also get an idea of how the new designing prototype will perform to mitigate the risk.

2.10.1. Preparations

The requirement for prototypes is dependent on determining a need. The interview survey gave an outline of the challenges with the current software applications.

2.10.2. Accomplishment

The successful accomplishment requires Coding of a simple PHP tool for the project web-pages, the software for documenting the projects, Siteserver (Editing Websites with Siteserver), HTML knowledge for establishing and maintaining the project web-pages. A web-based application programmed in a PHP language was developed for academic purposes, for instance, the management system regarding the Fab Foundation server and its supported activities. This coding system design is a model-view-controller pattern, and this tool was published in a site server [15].

2.11. Thesis Goals

The main goal of this work is to create a documentation tool for the Fab Lab Oulu and provide a system for the students for designing their artefacts. Moreover, this system will make a relationship with students and teachers through scaling and feedback from the “Protobooth Oulu app”. Students will get a new way of viewing and submitting their weekly assignments of courses such as creative design and other courses in the Fab Lab of the University of Oulu. Multiple interactions and shared contents are one of the main features of this “Protobooth Oulu app”. Designing and documenting the process of making new prototypes in a "story-telling" approach is considered the best way for using this app. Individual dashboard for every student to know about the private comments and scaling part from the teacher side. SD scale, Likert scale, Rating and Satisfaction scale also indicate the scaling prototype based on the unique and useful concept of the designing prototypes. By using this app, students will get a new approach to doing the weekly assignments and group projects by capturing, sharing contents and interacting with their group members. Additionally, they will know the uniqueness and usefulness of the designed concepts of prototypes and also

get instant feedback while making the documentation and developing their prototypes. We also aim to create another tool called "Python admin tool" for the admin side where the data science researcher will get the data from the database and do some analytical research for their future analytics.

3. SYSTEM DESIGN

"Protobooth Oulu app" is mainly developed from getting inspiration of Onur Ozoduru's and Josua Adeegbe's works [7, 10]. Both works are improved upon and extended with different features for the application through our newly developed app called "Protobooth Oulu app". From Onur Ozoduru's work, a software tool was introduced for assisting the makers and hobbyists while doing the designing of the prototypes. In that system, this tool introduced options such as, taking pictures, grouping them and also interpreting with text and audio. During the designing of the prototypes, all the materials and contents are uploaded in the web server, and it can be viewed on the web. After that, the maker will change the content and update the content based on his designing requirements. But it has some limitations, e.g., instant feedback, scaling the prototypes and multiple interactions for the multiple types of users. Moreover, Josua Adeegbe introduced the "Protobooth Oulu capture system", which has some similar features such as, capturing images, uploading in the web server and creating content for design documentation of the prototypes. But it has some limitations like instant feedback, scaling the prototypes and multiple interactions for the multiple types of users. Moreover, Josua Adeegbe introduced the "Protobooth Oulu capture system", which has some similar features like capturing images, uploaded in the web server and creating the content for the documentation of designing prototypes. It also has some limitations like different types of user like teacher and student, instant feedback for ongoing project, multiple interactions, capturing multiple images for editing, delete and update, weekly assignments and also individual scaling dashboard for the University of Oulu students. "Protobooth Oulu app" is mainly combined with two modules – teacher and student. In this thesis, we have developed the "Student side of the Protobooth Oulu app" and integrated with the teacher module and also tried to make python tools for fetching the data from the app for future research on data science. Moreover, we have developed and overcome the limitations of all the previous works (e.g. Onur Ozoduru and Josua Adeegbe) by extending the features and usability of the system called "Protobooth Oulu app". Additionally, we did a usability testing by calculating the SUS score and proved that our system is ready to use for the students of the University of Oulu. "Protobooth Oulu app" mainly designs prototyping techniques, and it will work as a design assistant tool for documenting the process while designing and developing the artefacts. In this chapter, the Fab Lab autonomous process will be discussed based on the current practices of the Fab Lab of Oulu, and also the main feature for the Fab Lab student's documenting the process is added.

3.1. Proposed Model of the Protobooth Oulu App

Digital Fabrication is a process in Fab Lab where it used for creating the prototypes and discovering innovative artefacts following some guidelines. We have completely redesigned it and made it more usable with extended functionality for the Fab Lab daily operation. The main architecture of the "Protobooth Oulu app" has been redesigned based on the requirements for the Fab Lab of Oulu. The proposed design is based on the android architecture, and it is usable for the android devices which are running in

android version 6 or higher [23, 34]. Figure 1 shows that the proposed flow chart of the app below:

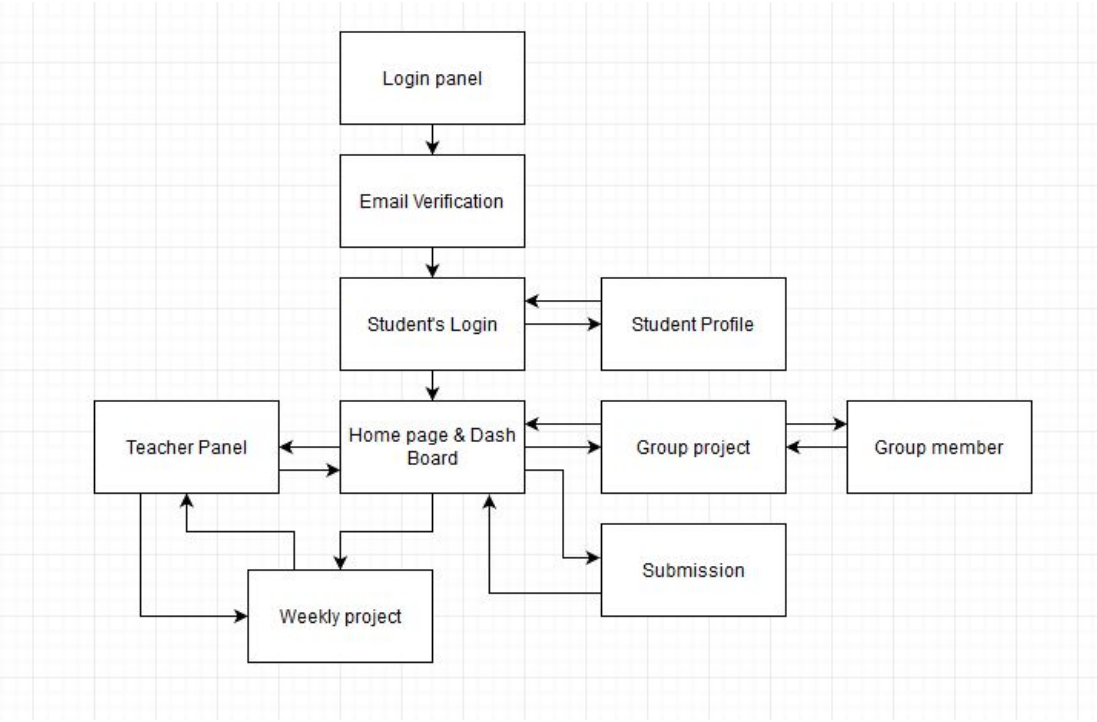

Figure 3. Proposed flow chart of the Protobooth Oulu app

Figure 3 shows that the Authentication unit has email verification features that verify the users, the students of the University of Oulu, before registrations. Student Login unit will be responsible for an individual's secured login for every student. Additionally, Private feedback and scaling, e.g. SD scale, Likert scale, Satisfaction scaling, Rating etc. will be visible on this homepage through an individual dashboard for every student. Weekly project unit is responsible for submitting and assigning the weekly exercises for the individual students. In this thesis, we have implemented all the student modules with extended features. Later, the teacher module is integrated with the student module. This proposed model has two logical separation units—a group project and weekly exercise. Being able to design and develop the group project through the individual dashboard for scaling, capturing, establish multiple interactions within a group, submit final project and feedback are the core features that have overcome the limitations of the previous works. Every unit is described having an application view along with the guidelines for the users of Fab Lab of Oulu. The design of the guidelines is briefly discussed below.

3.2. Authentication Unit

In this unit, Login panel and email verification work of the validated users are focused. Only the domain of the email, i.e. example@oulu.fi, is used for the teacher login, and example@edu.oulu.fi is used for the student to get the registration process. Without a valid email address from the University of Oulu, no user can complete the registration

process. The developed system “Protobooth Oulu app” will identify the person through his or her email address whether the user is a student or the teacher. This work is based on the student’s part and is improved upon the “Protobooth Oulu capture system” from Josua Adeegbe’s work. The application views for this unit are:

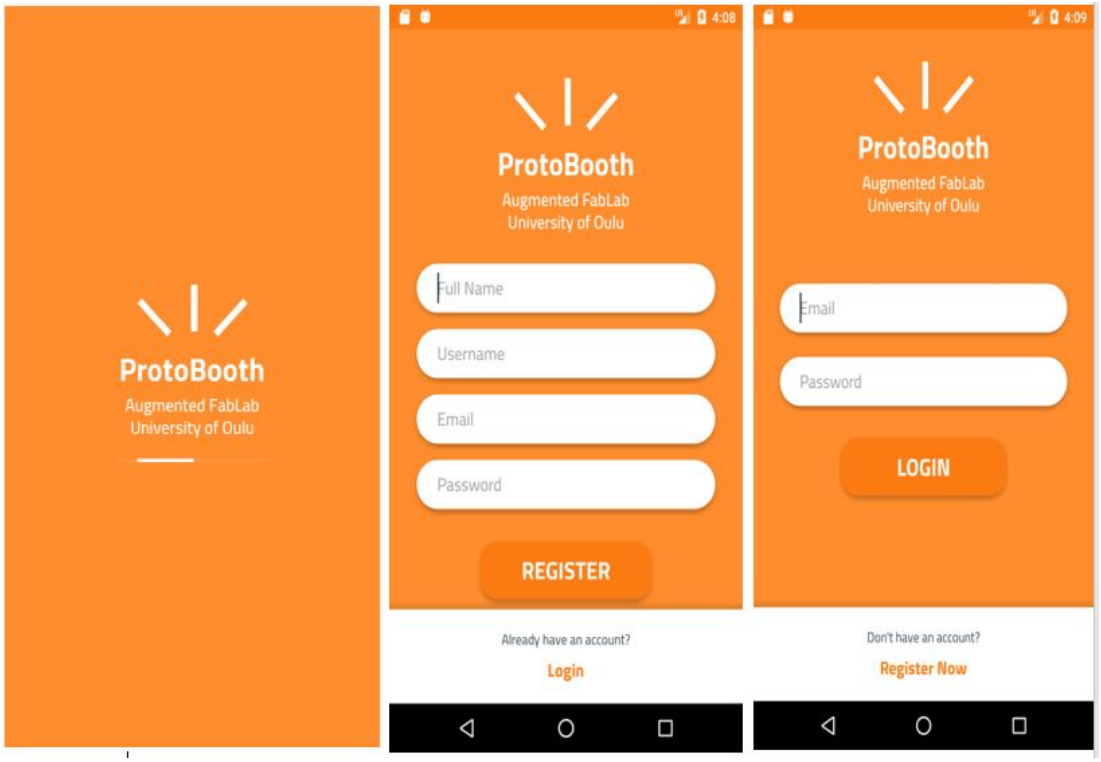

Figure 4. Authorization view of the Protobooth Oulu app

Figure 4 shows that the system will send an authorization email to the user—for the teacher and student for security validation. In this section, this system has used the Firebase email verification system, which will work after the registration process is finished [35].

3.3. User Home Screen

After the login into the “Protobooth Oulu app”, the system navigates to the home screen.

Figure 5 (below) shows that at the initial stage, no activity will be given. The navigation drawer is used to navigate different activities of the system, e.g., the weekly project, weekly view, profile update, and log out. When any user goes to task week 1, he or she may find nothing from the beginning. When the Teacher panel addresses the task on a weekly basis, they can do the weekly project and the submission.

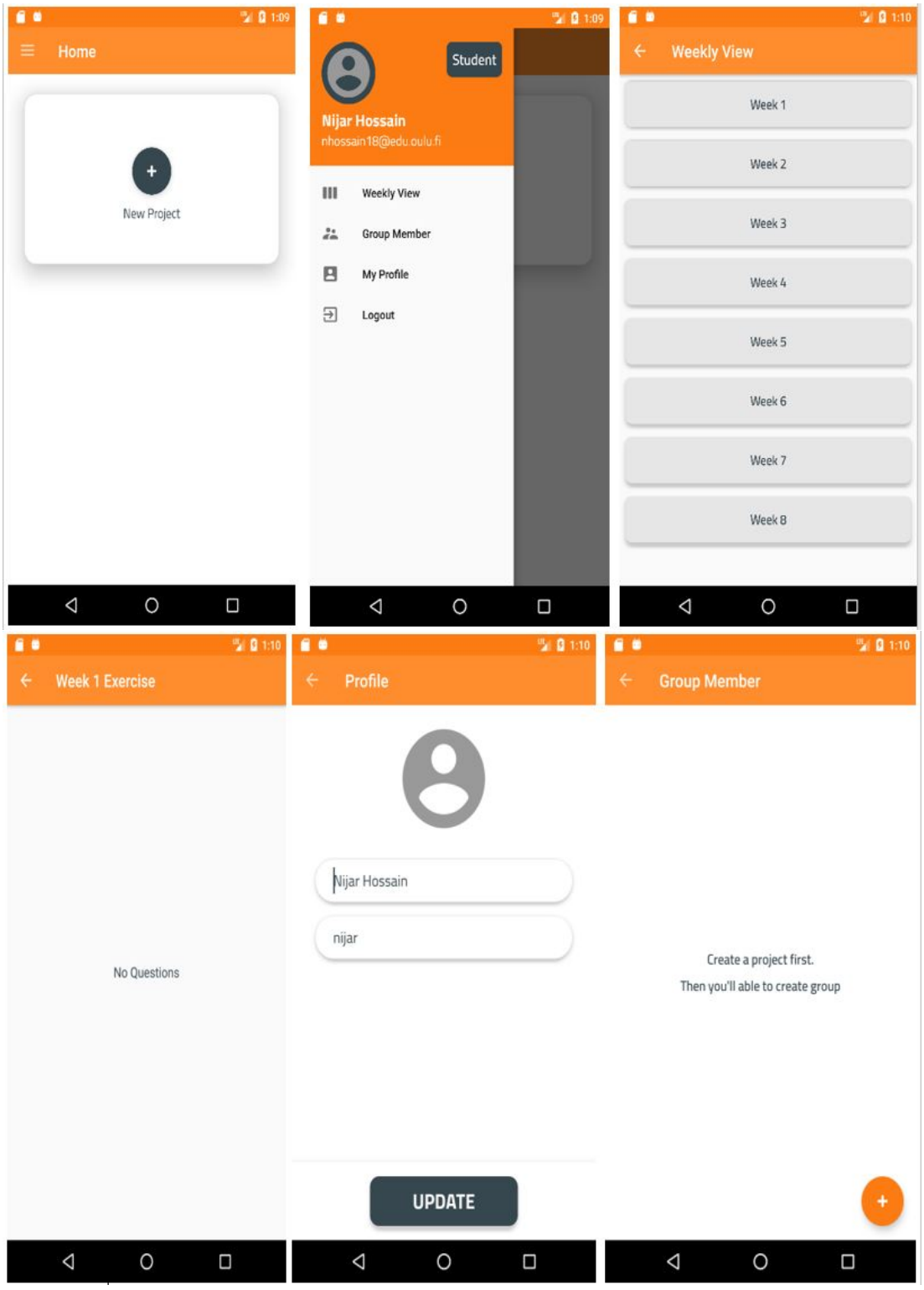

Figure 5. Home screen activity at the Initial stage

3.4. Group Project View

When this unit begins, the student will be able to find out his or her group mates in the Group member section. The application view of the group project activity in the home screen is represented below:

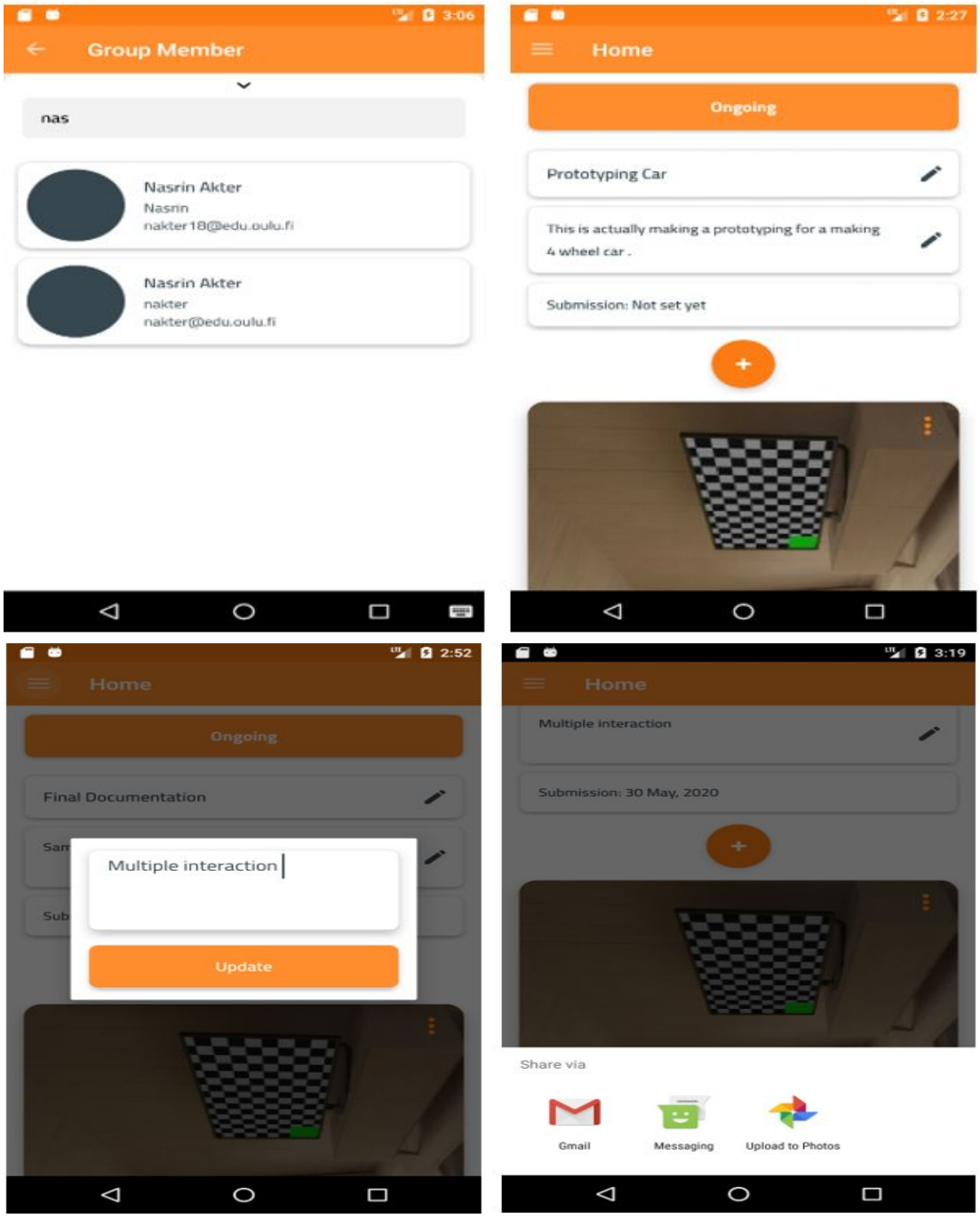

Figure 6. Group project activity

Figure 6 shows that the user name suggestion will be provided only for the authorized registered user. After adding the group member, the student will focus on the group project by inserting the title, description, and prototype images. Every image will be shared on any social media. The student's home page will work as a dashboard where the interaction between the groups and the teacher will be visible. Private comments from the teacher will also be noticeable in the Group project so that every student gets feedback on the prototype design. Students get every detail of their final project from this home page, such as private comment, the status of the project, Rating from the teacher, and also the Likert scaling. For this scaling and other features, teacher interaction is a must for the further actions of the group project. Once any users submit their projects in the due date, their group project cannot be modified within the group. The interaction will be completely stopped until the final submission of the project.

3.4.1. Feedback on the Group Project

Figure 7 shows the application view of the comment activity:

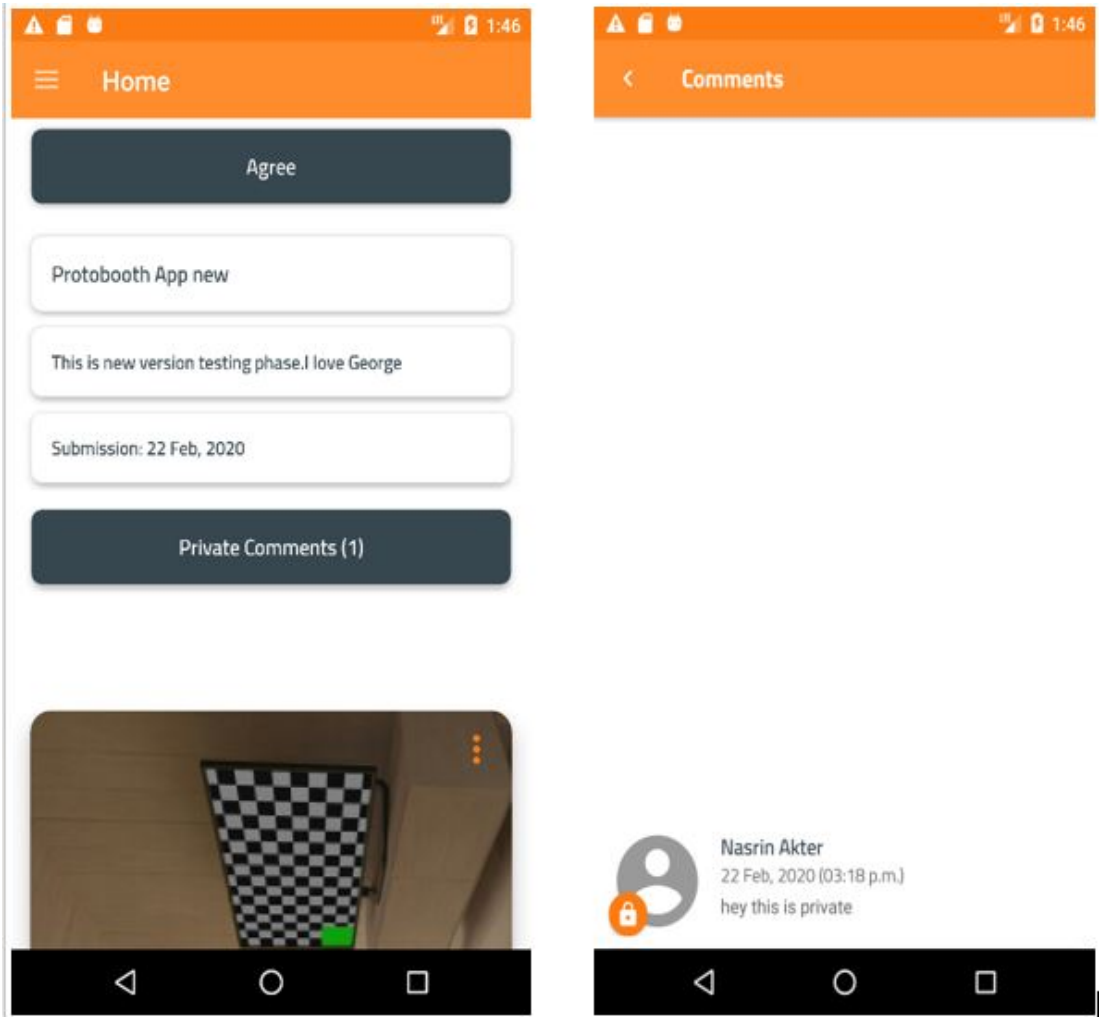

Figure 7. Private comments from student's side

Figure 7 represents that the private comment will be added to the notification area of the home screen. From this feature, students can receive valuable feedback from the teacher, and every group member can see the teacher's private comments. This feature adds uniqueness to the application app from where students can know which things must be changed based on the teacher's feedback.

3.4.2. Dash-Board Multiple Interaction

Each of the groups will get an individual dashboard based on the teacher's feedback in the following scaling methods. The scales are as follows: [36].

- **SD scale** - For scaling the connotative meaning(s) of prototypes.
- **Likert scale** - This scale is used to scale the degree of the desired opinions of the students by providing questionnaires.
- **Rating** - For ascertaining the teacher's opinions concerning the uniqueness and usefulness of the prototypes.
- **Project stage** - This indicates the stages of the project, e.g., ongoing project, early project and late project.
- **Satisfaction level** - This scaling measures the teacher's satisfactory level regarding the design techniques and creativity.

Figure 8 shows how the application view looks after submitting students' final project.

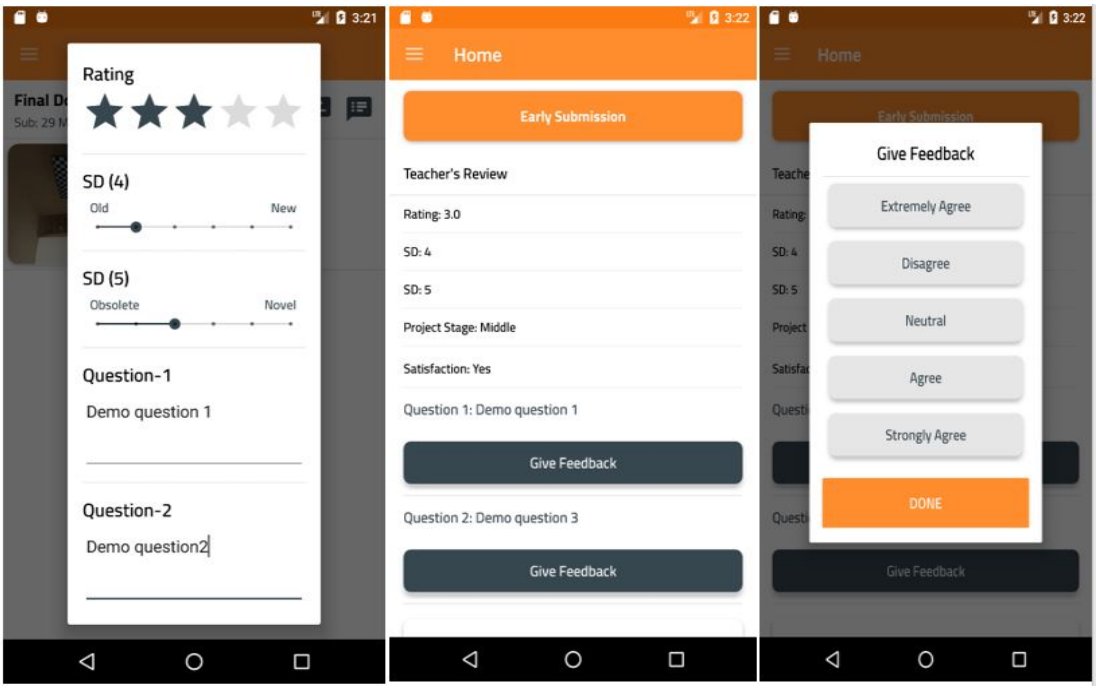

Figure 8. Dash board in home screen activity

Figure 8 shows that each of the teacher's feedback will be visible on the students' home page, and the students will also be able to view their current submission of the final project and answer the Likert scaling questions. In this unit, every group member will interact with one another and update the title, description, and image as per the requirements.

3.5. Individual Weekly Task

For doing any kind of weekly project, students need to navigate the weekly project section and select the weeks of which he or she wants to select for their assignment. Figure 9 shows the application view of the project.

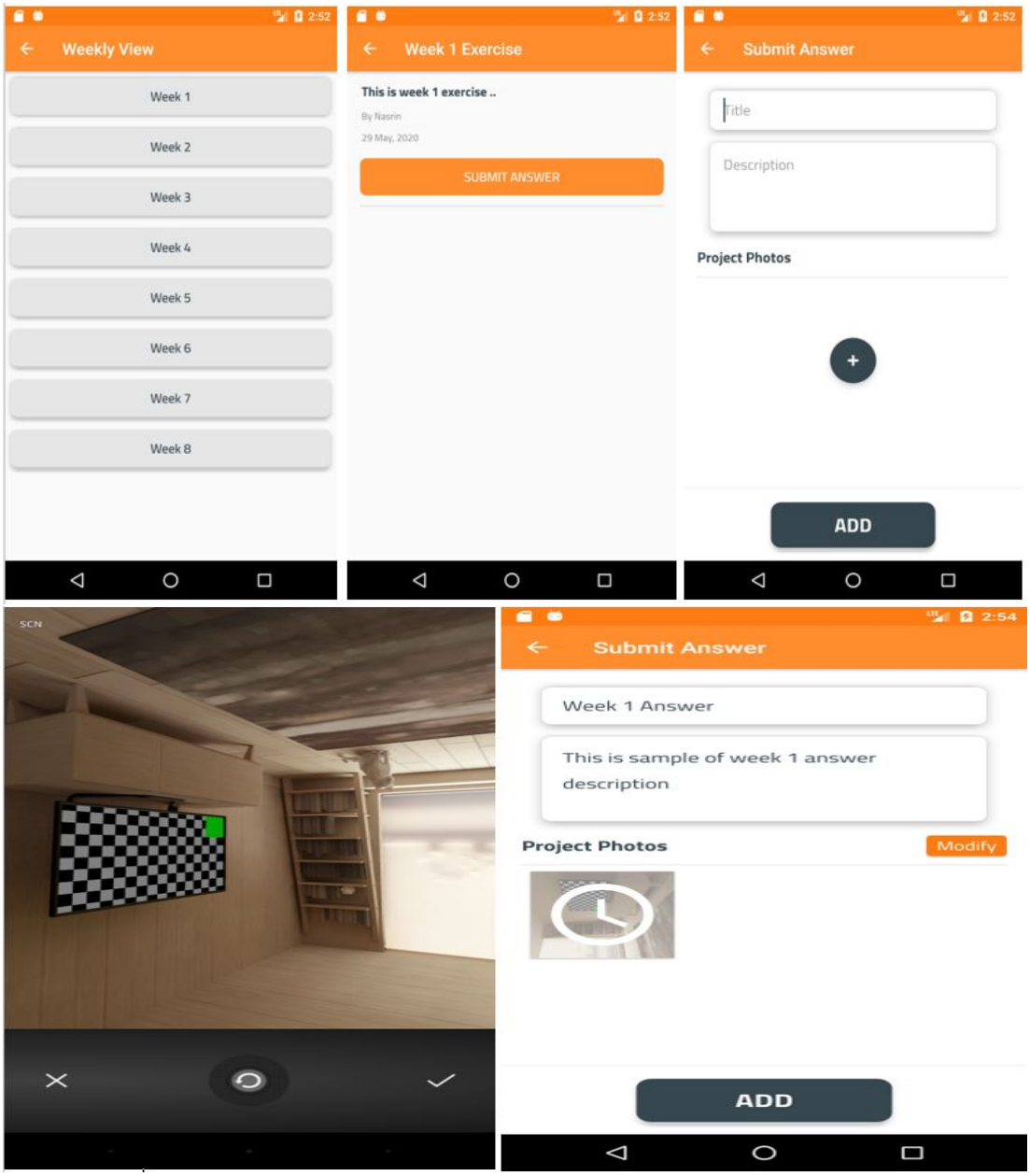

Figure 9. Weekly project activity

Figure 9 shows that the Individual weekly task will work when the teacher assigns the individual assignment for the weeks. When the teacher assigns any weekly exercises for the students, then it will appear on the weekly project. The student will get the same feature as he or she will get in the weekly project, and a group project. But the share option and Interaction option will not be available. After they submit the project, students will get a view of the current submission.

3.6. Security Rules of Firebase

Firebase database has different kinds of policies for reading and writing operations. Mainly, a JSON generated file has been found in the firebase console panel, which serves the security purpose of the database. Rules are generated by the developers as to how their developed database will work for the execution of any statements from the application.

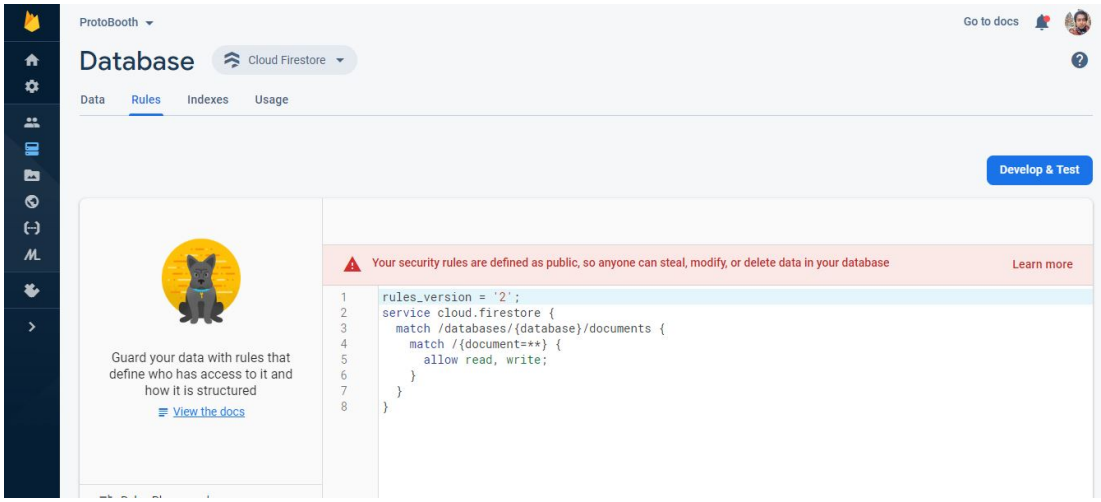

Figure 10. Security Rules of Firebase

Figure 10 shows that the read and write operations are allowed to store data into the database, which has been written in the JSON file. By default, the system allows the authentic users of this database to read and write.

3.7. Database Design

For maintaining the database and developing the apps, we used the firebase google database cloud storage. It is an authentic database with the cloud facility so that it does not require any physical server for storage database. Google has used their privacy for the database so that data must be private and restricted. There is a built-in feature in a firebase database called authentication sections where it stores the user's login credentials. For creating every user's account, there is an authentic, unique key that is automatically generated for the user for maintaining a relationship with the other tables [35].

In this implementation phase, we have designed and implemented nine tables for both the teacher and student modules. For the student's tables, we need to make a relationship with four different tables to better the operation.

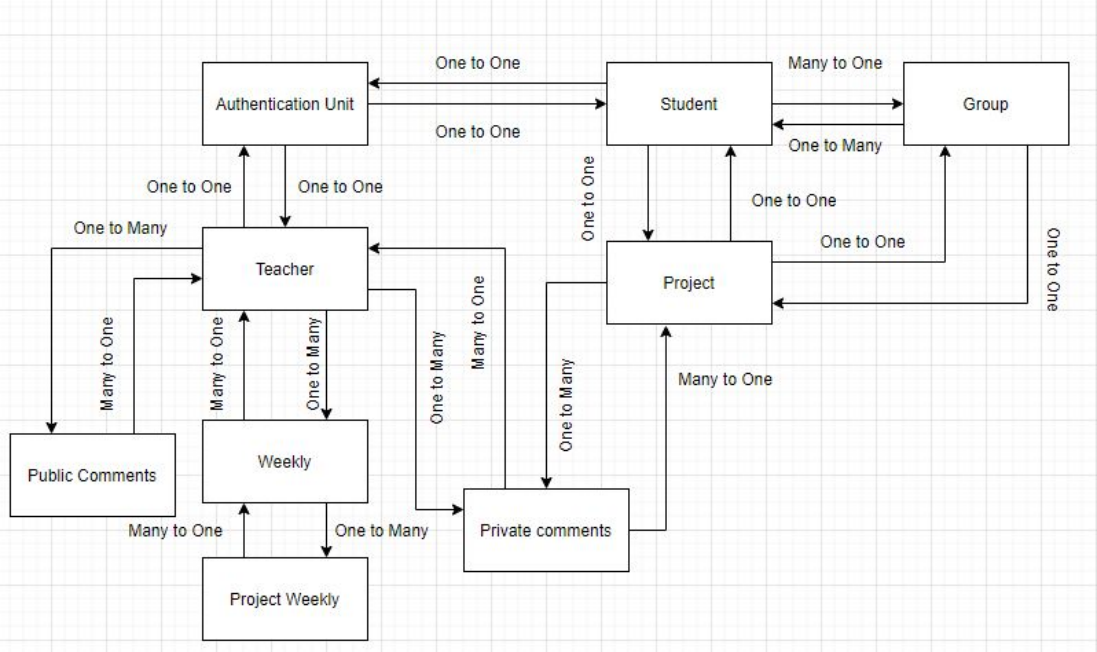

Figure 11. Firebase table relationships.

Figure 11 shows that the authentication unit has a unique feature for authenticating the users from the firebase cloud storage. Users must be registered for using this application further. Figure 11 also shows that once the system gets registered, the student's record will be added for the student user. Every table has a unique reference id that maintains the data relationship with the other tables. However, NoSql doesn't maintain the schema type relationship. It just maintains the data reference relationship with other tables. Once any student creates the group project, the table project will be created with the reference id of the project. This implies that one student can create one project at a time, and a project can also be created with one student. Similarly, one project has only one group, and one group has only one project. When any group is created, the group table will appear, and it will be created with a group reference id for creating and updating the group. Moreover, many students can join a group, and multiple groups can be joined by a single person. This indicates every student can join in multiple groups if he or she leaves that specific group and then joins a new group. When the teacher has assigned the weekly task into the system, the weekly record will be added so that the students can easily access their weekly assignments. Each of the weekly tasks has a reference id, which has a data relationship with the weekly-project table to show the operational results to the students. Firebase is a NoSql based architecture database. It has an object-related relationship with the data from the different tables, and it can be found as a tree node shape. But for better understanding and making it more precise, we designed our database as a schema layout for making this app in the pre-development database design phase conceptually. We chose the firebase platform mainly because it is more flexible, scalable, high-performing, and highly functional.

Name of the field	Type	Purpose
memberRefs	array	To save the references of group members
projectRef	string	This is the reference of the project which is assigned to this Group
ref	string	Reference to this group
title	string	Name of the group project

Table 1. Group table for the Protobooth Oulu app

Table 1 shows that the group table is formed when the students create a group for the final project. Here memberRefs column mainly points to the other data tables reference value so that the grouping will take place. The pojectRef column is responsible for holding the specific project reference id for a specific group. Each table of this system has created the reference so that other tables might be used for future operations. The title column contains the name of the group project.

Name of the field	Type	Purpose
date	number	Date created for weekly project
deadline	number	Project deadline issued by Teacher
desc	string	Project description
groupRef	string	Group reference of this project
info	string	Project info
isSubmitted	boolean	To detect if the project is submitted or not
lastUpdatedBy	string	Reference of the student who updates the project last.
photoUrls	array	Not needed
photos	array	Project photos urls

Table 2. Project table for the Protobooth Oulu app

Table 2 shows that for storing the project data, there is a table in the firebase called Project database which is actually dedicated for storing the details of the project. For keeping the images of the project, photo fields use only the path of the images. When the "Protobooth Oulu app" fetches the images, the firebase engine can identify where is the location of the images.

Name of the field	Type	Purpose
date	number	Created Date created for weekly project
deadline	number	Not needed
desc	string	Description of the weekly project
groupRef	string	Not needed
info	string	Not needed
lastUpdatedBy	string	Reference to the student who submitted the answer
photoUrls	array	Not needed
photos	array	Weekly project photos urls

Table 3. Weekly project table for Protobooth Oulu app

Table 3 shows that for storing the database for the weekly project, the firebase database table allows the same content as the final project tables column. But the group ref column is not used for not making any reference to the group table. Other columns such as deadline, info and other photoUrls are not required in this table for the current operation.

Name of the field	Type	Purpose
email	string	Email address of the student
fullname	string	Full name of the Student
groupRef	string	Group reference to which he/she is assigned.
photo	string	Profile photo url of the student
q	string	Keyword for searching student
ref	string	Reference to the student
username	string	Username of the student

Table 4. Student table for Protobooth Oulu app.

Table 4 shows that one of the main database tables of this app is student's one, where it stores the student's details, also searching field is here for the group member for fetching the student's information to the group member.

3.8. Description of the App Package

While developing the app, we made several packages for the application. Some packages are responsible for the login unit; some are for routing the activity for the user's different actions. Additionally, some packages are also responsible for handling the request for a firebase cloud storage database. Figure 12 shows the description of the packages that we developed for developing the "Protobooth Oulu app". (Consider only the focused area of the diagram.)

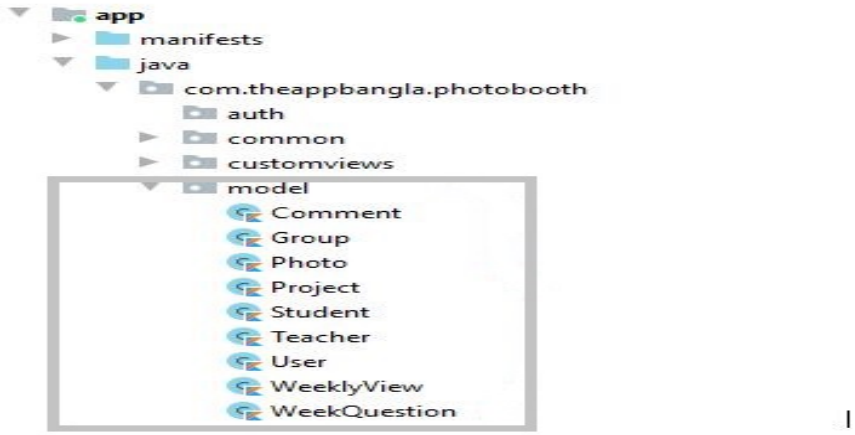

Figure 12. Model view

Figure 12 shows that the Model package of the project has major roles. This is the core of the background system.

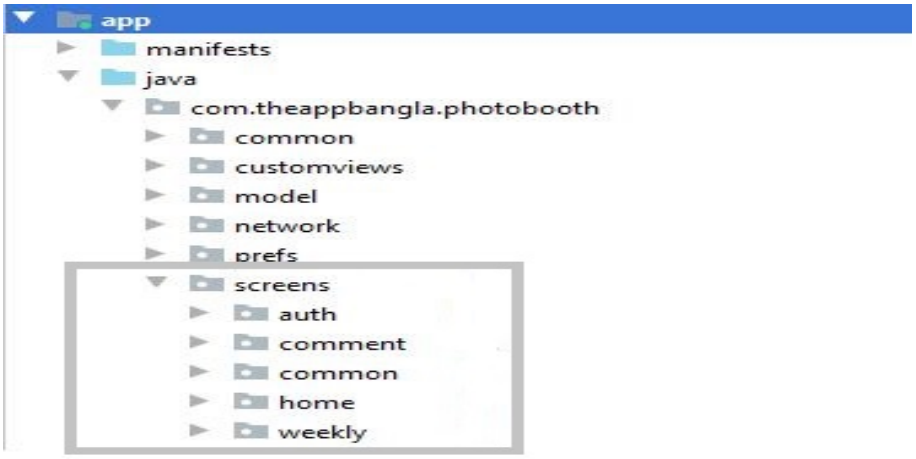

Figure 13. Screens view

Figure 13 shows that the "screens" package contains all the activities and fragments or our app. It also shows that activity routing occurs based on the user's activity.

Figure 14. Auth view

Figure 14 shows that there is also the auth class's screen package to maintain the authentication process with the firebase database. Also, email validation and admin privilege have been done in this model class.

Figure 15. Comments package view

Figure 15 shows that the comment package is responsible for submitting and showing comments in our app. On the other hand, "home" package contains the home activities of the user such as, dashboard, scaling, group project routing, updating and capturing image process.

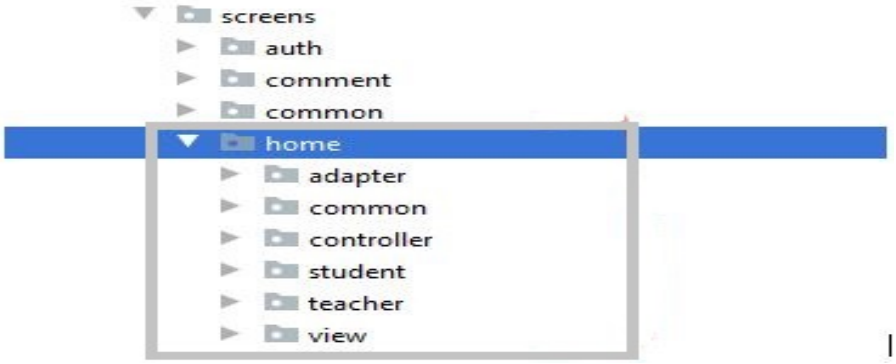

Figure 16. Home package view

Figure 16 shows that the home package contains the initial view after logging in the app for both teacher and student. The present thesis focuses on the student side.

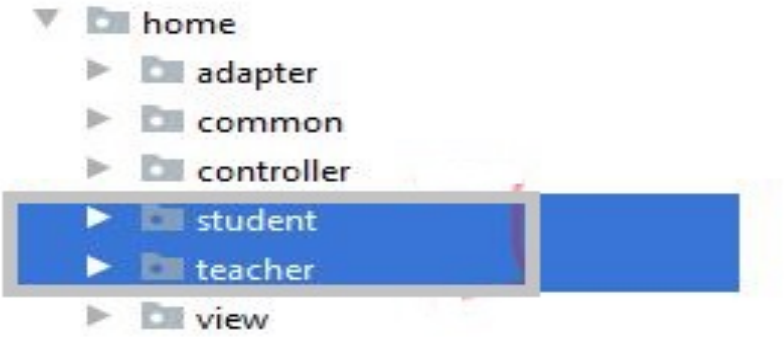

Figure 17. Student package view

Figure 17 shows that the student package contains the firebase database information of the students and also multiple interactions within the group member is written in that package.

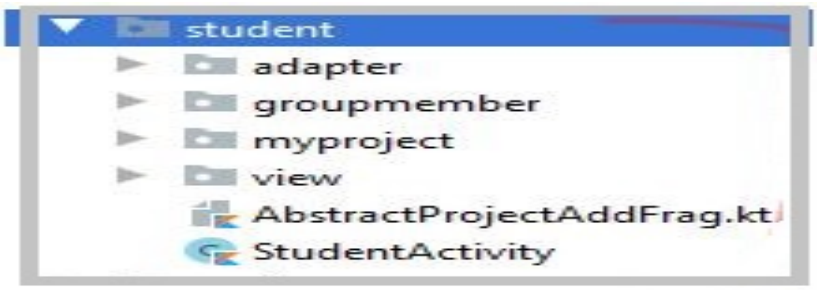

Figure 18. Student package details view

Figure 18 shows that the "groupmember" package contains views for group member panel from the students' side. Including the facilities of adding members and searching members within the group," myproject" package also contains the group project info and other references for maintaining the group's activity.

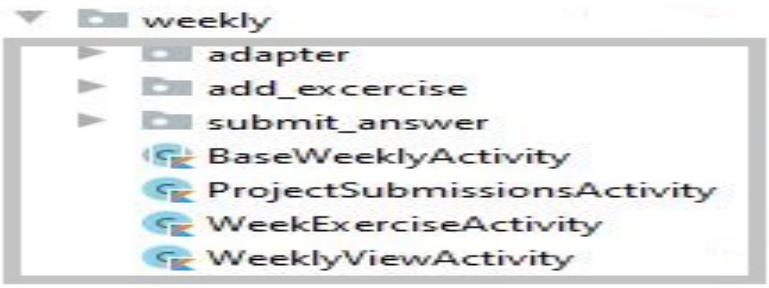

Figure 19. Weekly project package view

Figure 19 shows that the Weekly package contains the weekly project details, information of submitted projects.

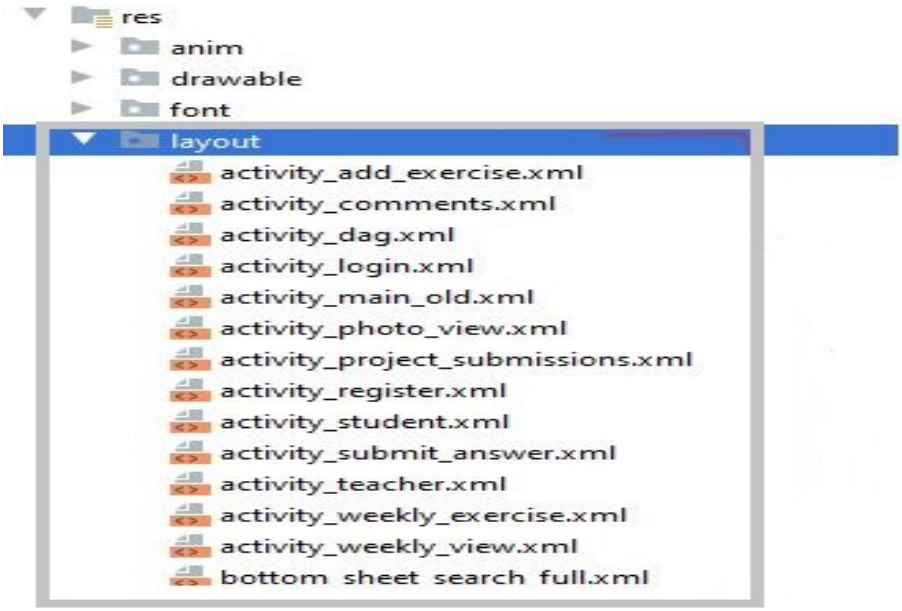

Figure 20. Layout package view

Figure 20 shows that functionality layout has been designed for maintaining the activity from the user's perspective. Every layout is responsible for routing different activity for user interface design phase of the application. Every layout of the XML files is responsible for the login, registration, submission, photo capturing, group project view, comments or feedback, searching group members, and other activities based on the user's needs.

3.9. System Implementation Architecture

Every package of this application consists of several classes. Each of the classes has several dependencies, and some classes have some subclasses. For successful implementation of this application, every package has several tasks to perform through different activities.

Figure 21 (below) shows that the common package is the root of all other packages. It initializes other packages by giving a unique domain of this application. For

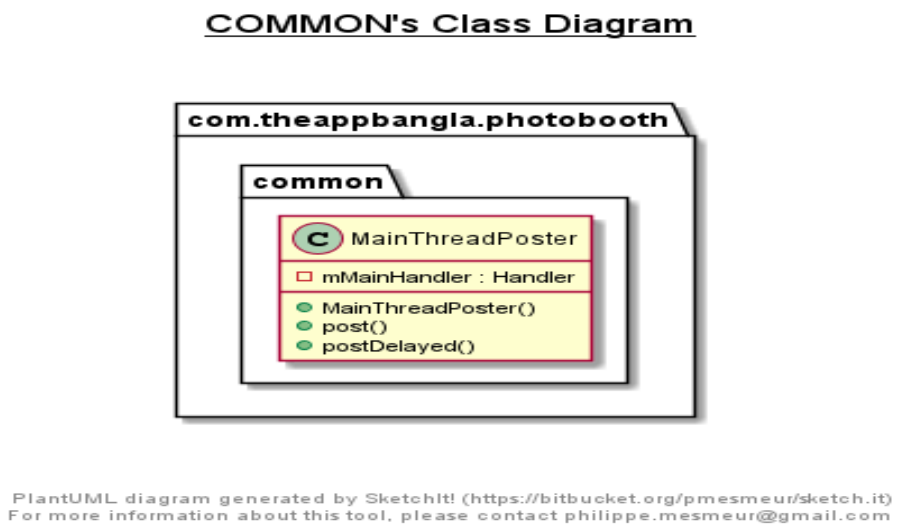

Figure 21. Layout package view

generating this class diagram, we used the plantUML and sketch it plugin in Intellij IDEA editor for this “Protobooth Oulu app”.

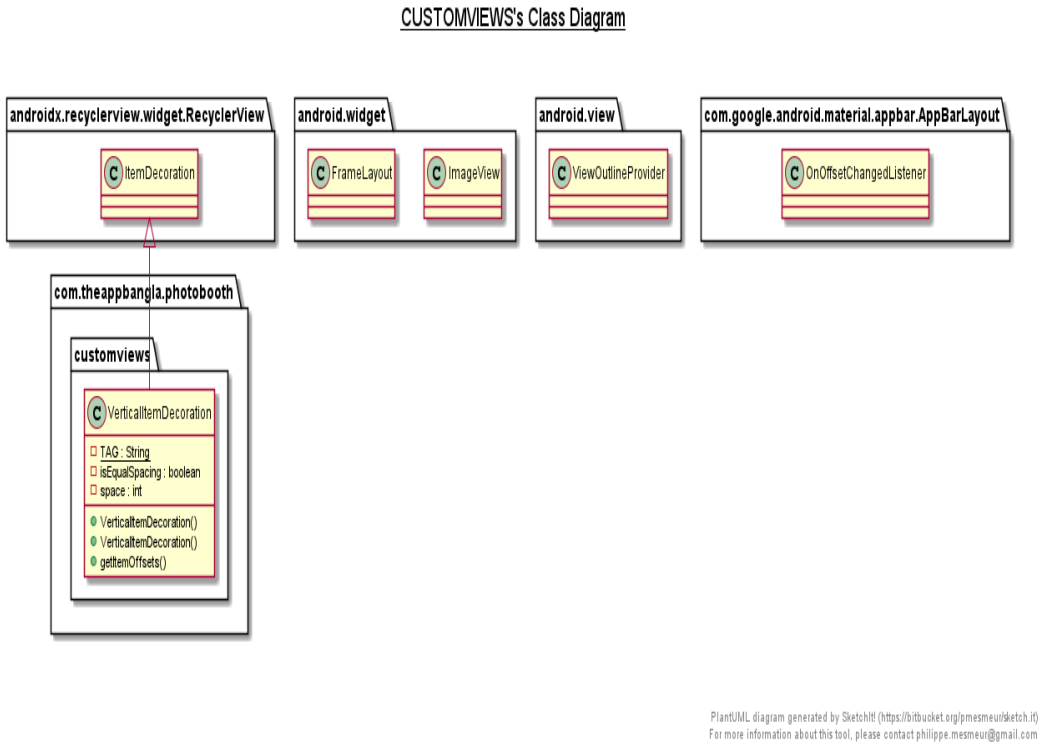

Figure 22. Custom view package of class diagram.

Figure 22 shows that all the UI custom design classes have been made for the application. We need to modify and make some custom design which is highly inherited with a base designing class for this app.

Figure 23 also shows that all the major classes represent our application’s data model and have several instances of the classes. Composable functions are responsible for reading the properties of the model class, and it recomposes when any properties

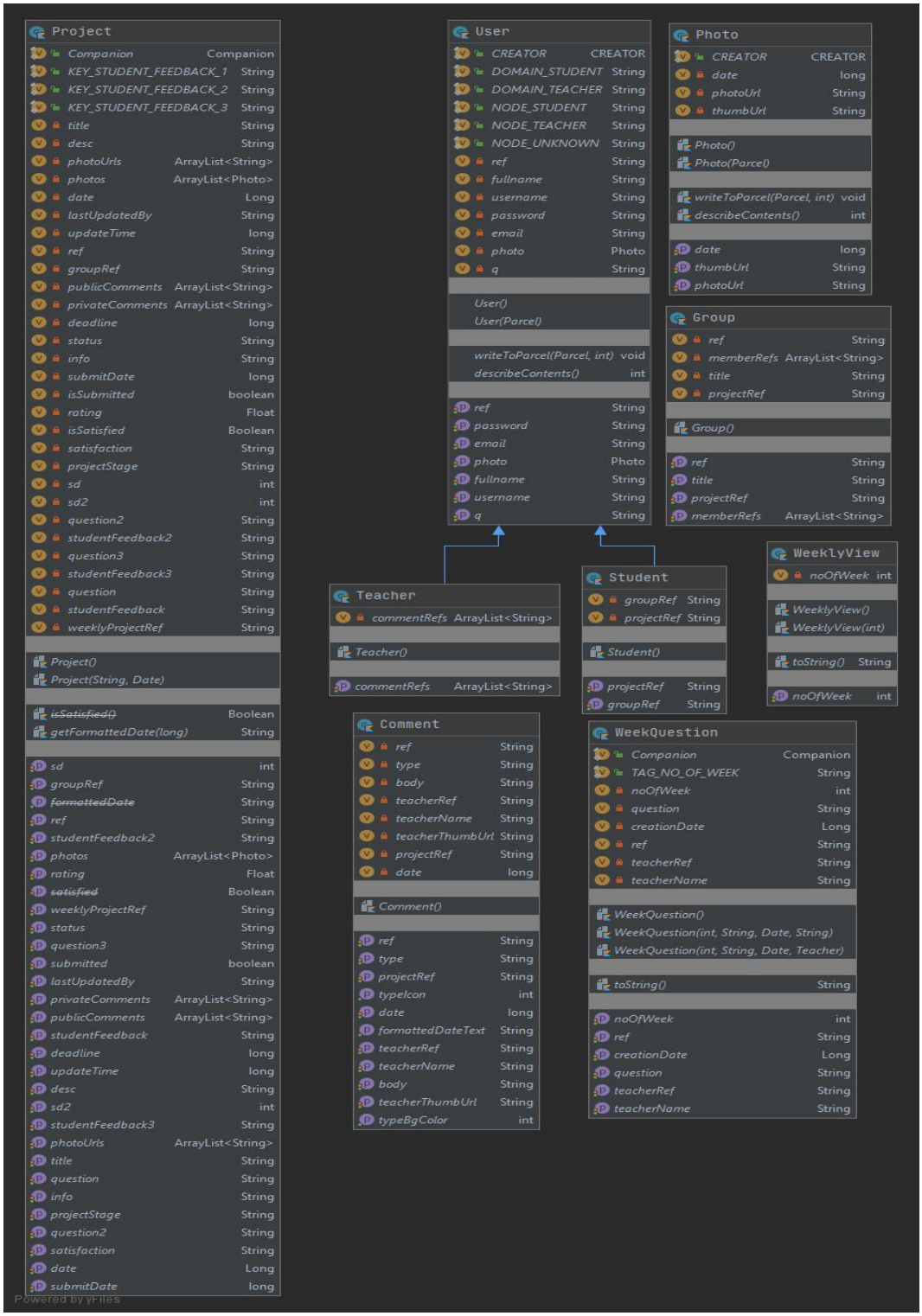

Figure 23. Class diagram of Custom view

are written in the model. Figure 23 shows that the User class has two children classes—Student and a Teacher. Students and teachers have inherited the User class for operational activity. Each of the classes holds private and public attributes. All the methods of the class have been shown in the figure within this model class diagram. Some classes have no inheritance from other classes, but when any activity is triggered,

then the specific class will be invoked and performs the specific data modelling tasks. In this application, there are other different classes which are needed for the operation. In this section, we show the basic conceptual infrastructure of the overall processes of this application.

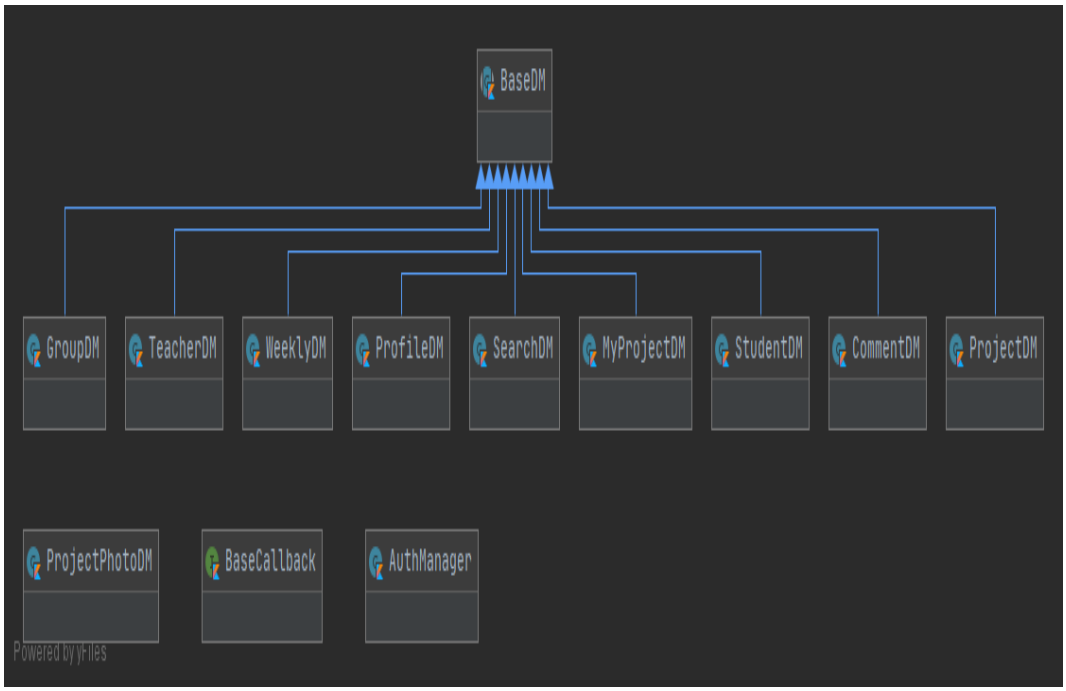

Figure 24. Network package class diagram

Figure 24 shows that the auth manager is responsible for making the authentication with the firebase database. BaseDM holds the public and private comments networking issues. CommentDM functions for fetching the students' and teachers' comments. Group reference is handled in the GroupDM. Other functionalities of the project such as project reference id and several other tasks have been done in different files under the network packages.

3.10. Scripting for Data Collection

In this application, data collection is needed for further study. For developing such a tool, python is used for fetching the data from the firebase cloud storage database [35]. A ServiceAccountkey.json file in the scripting directory is needed for making connectivity between these two platforms. For this, the scripting tool requires three things. These are:

- A firebase project for the "Protobooth Oulu app".
- A service account JSON file for a scripting tool.
- Configuration of the JSON file with the developer's user's credentials.

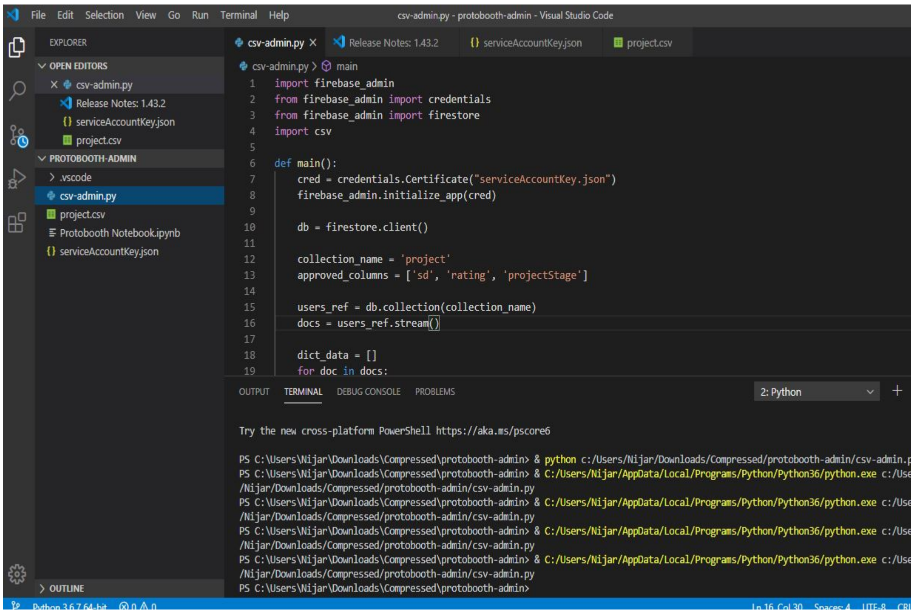

Figure 25. Python scripting for CSV file

Figure 25 represents that at the beginning of this application, we need to import all the firebase services and also import the default app. Later, we need to use the private key for authentication. Moreover, we need to use google Oauth 2.0 for getting and refreshing the token from the Google API. We also need to enter the client id in the scripting key for making the authentic connectivity. When the execution of the scripting language is performed, then a CSV file is also generated for getting the data.

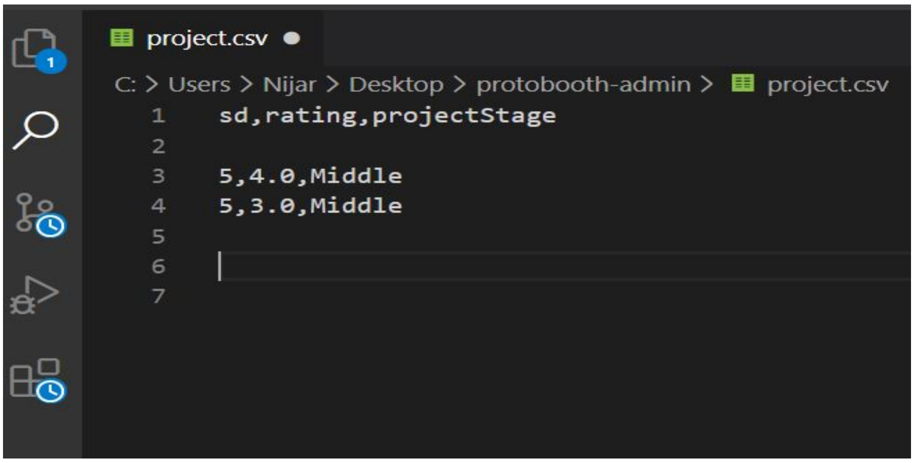

Figure 26. The CSV generated file

Figure 26 shows that the output of the file, compiled by the VS CODE, will be found in three parameters. Web admin tool has been configured with three parameters like SD scale, Rating, and Project stage. These parameters can be set based on the instructor's choices.

4. USABILITY TESTING AND EVALUATION

For detecting the bug and making it more usable, we did a usability testing for getting real interaction of the app and collected feedback from the test participants for improving different features of "Protobooth Oulu app", and to make the application more user friendly. Additionally, we compared both the teacher and the student modules with a SUS score, and it was proved that the system is ready to use for the University of Oulu. Our first aim was to figure it out the problem of the real interaction from the students' side and also from the admin's side. The participants tested the app and gave feedback based on the real interactional feeling for using this application. Then, we arranged an interview session with a questionnaire to know better about the experience of the test participants. After that, we analyzed the results with a SUS score for both the teacher and the student's modules by calculating the SUS score, and we could confirm that our system is ready to use for the Fab Lab of Oulu. For collecting data, we formulated a questionnaire for the student research participants from the University of Oulu for evaluating the upshot of the system. Each of the tasks set up for the research participants was individual, and these tasks were designed to evaluate the results of "Protobooth Oulu app". The study was carried out on test participants aged between 25-32 years for evaluating the upshot of the app. The participants were willing to test this app. The core concepts of this application were discussed with the participants for understanding the concepts better and to ensure that the participants do not have any confusion. The consent form is a formal proof of their voluntary participation, and we also provided the legal rights for testing our application. This legal issue serves the purpose of operational activities as well as for the evaluation of the result of the Fab Lab, Oulu for further research. This usability testing was conducted in two ways for two different types of users. One is for the students, and the other is for the admin. The first phase of this test needed completion of some specific tasks from students. For this, we made some test case scenarios for evaluating the functionality and the system. Secondly, when the student phase was completed, then we focused on the admin side for obtaining data from firebase in the CSV file. The essential item was set before asking the field that an admin wanted to have it in the CSV file. Here are some test case scenarios for the usability testing for the student user:

- Create an account for the student by using the University of Oulu's student email address.
- Go to your university's email address for finalizing the registration process.
- Open the app and log in the "Protobooth Oulu app".
- Click on the add button for adding a project by title, image and description.
- Also for adding group member(s).
- Customize the image selection and modify the Group project.
- Do the Group interaction within a home page as a group member for further actions such as updating title, description and images.

- Capture multiple images at once and then remove which is not suitable for the project.
- Leave the group and enrol a new one.
- Find out the private comments.
- See the teacher's feedback, e.g., Likert scaling and attend them.
- To know the rating, SD scale, Likert scale, satisfactory scaling from the dashboard.
- Go to the weekly project and complete the assignment task assigned by the teacher.
- View the weekly submitted project.

For the admin panel, we just set some test scenarios for generating the CSV file from the python-admin tool. This tool will help generate data from the firebase cloud storage database. Here are the test scenarios that have been given to the admin for testing the scripting tool:

- Open the scripting tools by using the Visual Studio Code.
- Compile the script and generate the CSV file.
- Access your CSV file to show the results.

Each of the questions was set up with a usability scaling technique, and we collected the user's performance timing based on usability testing. Besides, we also focused on the user's satisfaction level for performing the tasks as mentioned above. For getting feedback from the participants, we provided them with a script for getting proper feedback on the mobile application. The questions that were asked for the evaluation are given below:

- I think that I would like to use this system application frequently.
- I found this system application unnecessarily complex.
- I thought the implementation of this program was simple to use.
- I think I would need assistance in using this system application.
- I found that different functions of this system application were well integrated.
- I thought there were 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 using this system application.

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

Each of the feedback questions has five different individual rating choices from strongly agree to disagree strongly, i.e. Strongly agree, Agree, Neutral, Disagree and Strongly Disagree. The participants had to select one option per question based on the experience that they achieved through participating in the test. The participants were willing to do the test, and(this part is repeated). The participants marked the provided feedback based on their own experience.

After completing all the steps, we arranged for interview sessions with the participants. The sessions involved asking several questions for knowing further about the "Protobooth Oulu app". Based on the user experience of the app, the test participants answered spontaneously all the questions that we asked during the interviews. We designed semi-structured interviews for this empirical study. The questions that we asked the participants to answer are given below:

- Do you think the 'documentation while doing prototyping' is a good concept?
- How long have you been working in Fab Lab Oulu for making prototyping designing techniques and other activities?
- Do you have any difficulties concerning the complex designing techniques of prototyping?
- Which documentation technique(s) do you love to have in Fab Lab Oulu? I.e. storytelling approach or Recipe like approach?
- Do you agree that multiple interactions are an excellent idea for designing a complex prototyping technique?
- Do you find any irrelevant features?
- Do you find many features which are needed for better operation of Fab Lab Oulu?
- Do you think this app is highly required and recommended for the operation of Fab Lab Oulu?
- Do you have any previous experience of the documenting any mobile application tools similar to the Fab Lab operations?
- Gender
- Age
- Occupation

4.1. Analysis of the Results

In this section, we represent the collected data in bar graphs and analyze the results obtained as users' feedback. Every data record is considered as of the highly restricted one, and we managed to maintain the privacy of the participant users. The number of test participants was 07 (seven), and they provided with the feedback as per their experiences and perspectives. From our SUS scaling results, the average score was 71.071. This score indicates that our system is ready to use, and it further indicates that the system can be improved by/in future research and analyses. Figure 27. –figure 36. show the graphic representations of the results against questions Q1 to Q10, which are demonstrated by the analytical graphs from the SUS responses.

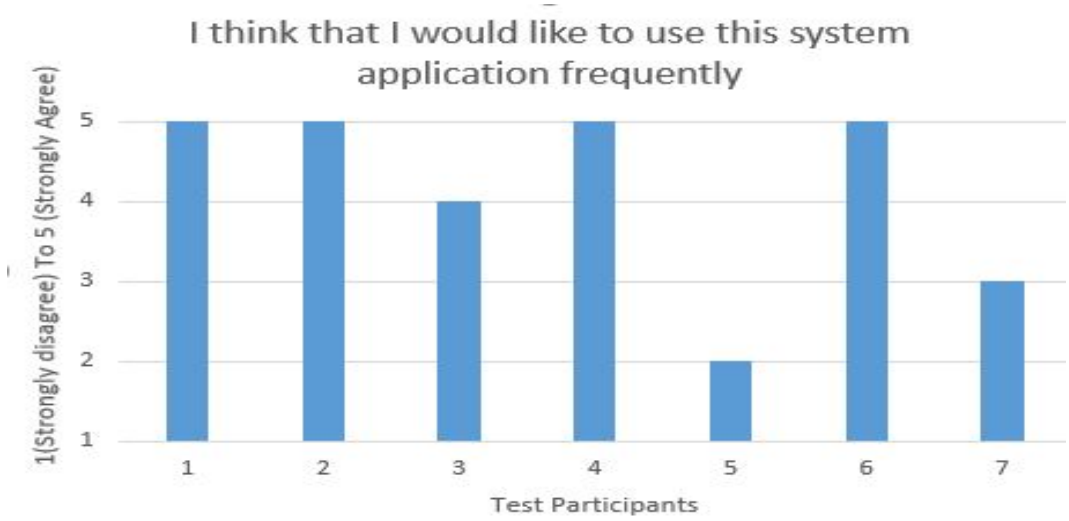

Figure 27. Q1 responses from the test participants.

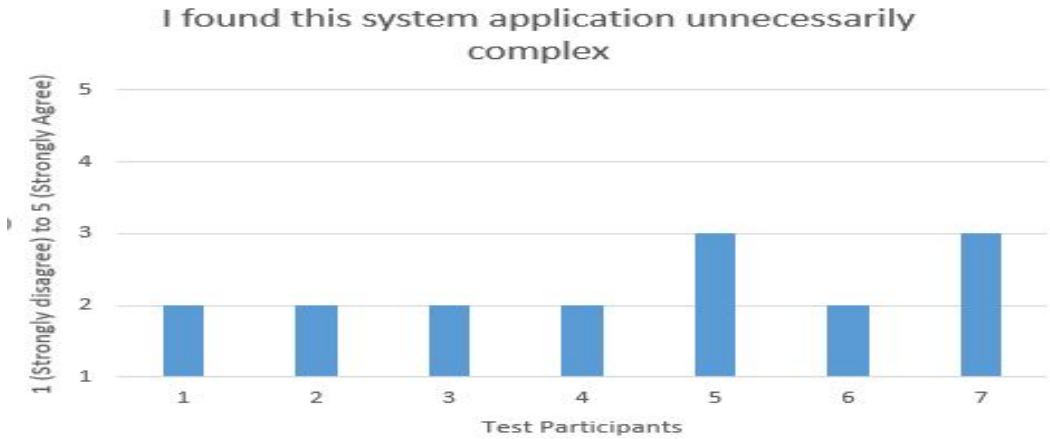

Figure 28. Q2 responses from the test participants

Figure 27 shows that the users expressed their opinions in Likert scale points (from strongly agree, agree, neutral, disagree to disagree strongly), by maintaining a degree of the scale. Each of the questions has a maximum of 5 points, and each score indicates a significant meaning. The number of research participants was seven so that the number of bar graphs is 7. Each query has a maximum of five points to respond to

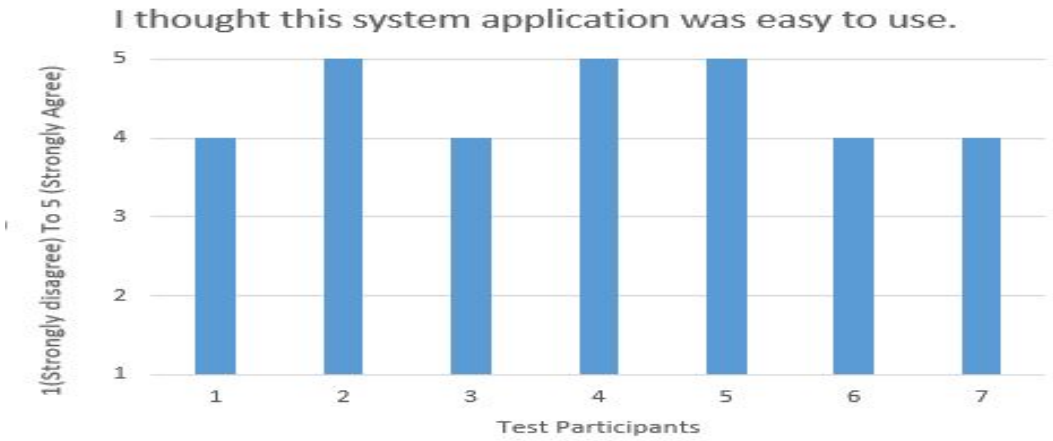

Figure 29. Q3 responses from the test participants

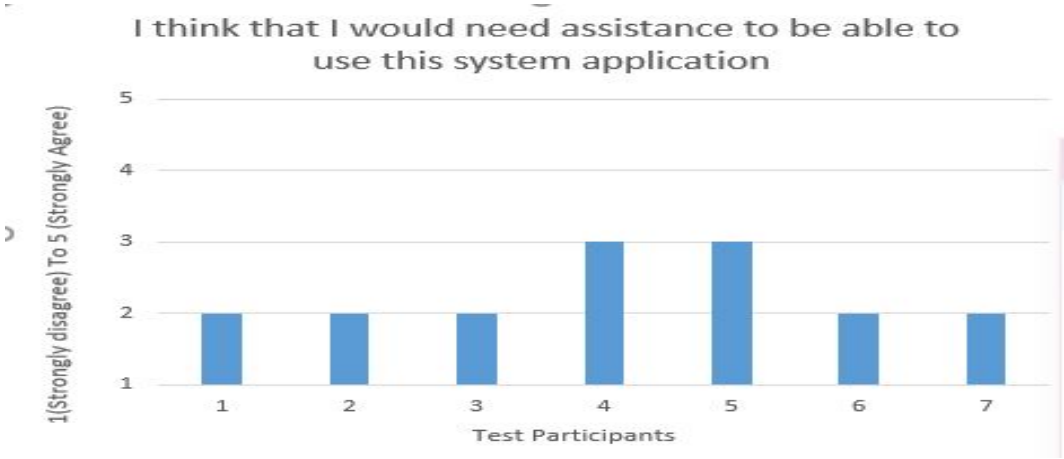

Figure 30. Q4 responses from the test participants

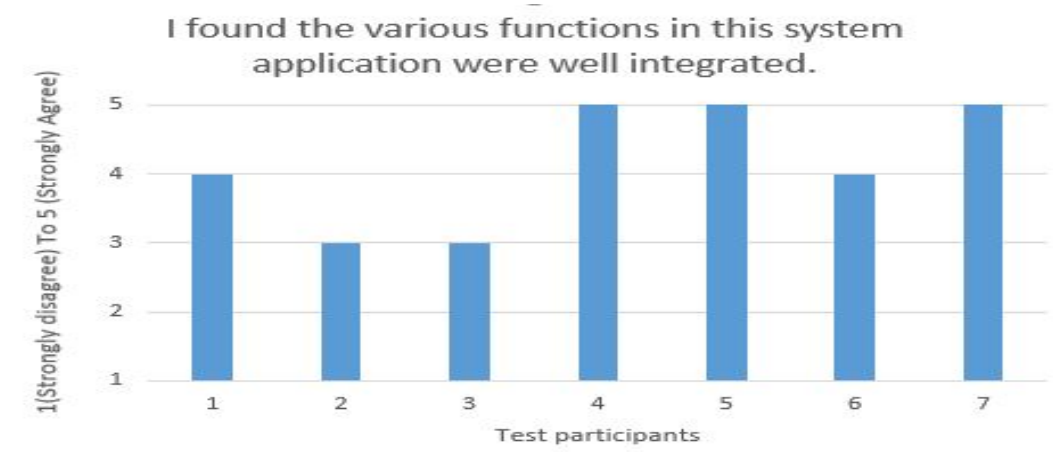

Figure 31. Q5 responses from the test participants

different values such as Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. Figure 27 also shows that the first research participant opted the 5th point in the scale, which means he strongly agreed with the question. Figures 28 to 36 represent similar results, as we analyzed in figure 27. From the above bar graphs, we see the number of responses from the SUS questionnaires. Our calculated SUS

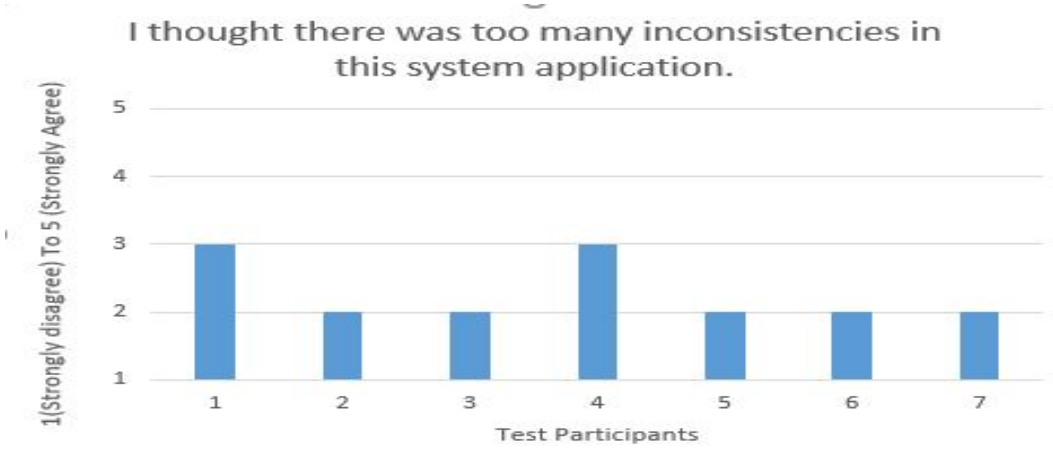

Figure 32. Q6 responses from the test participants

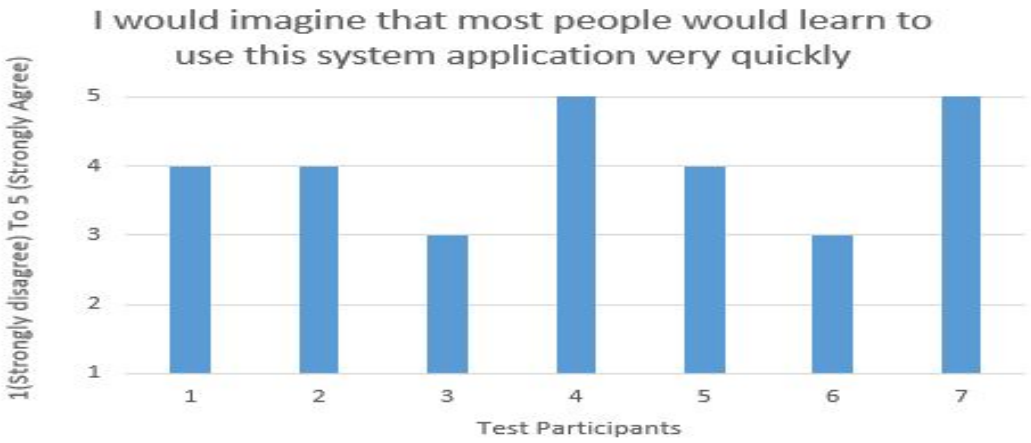

Figure 33. Q7 responses from the test participants

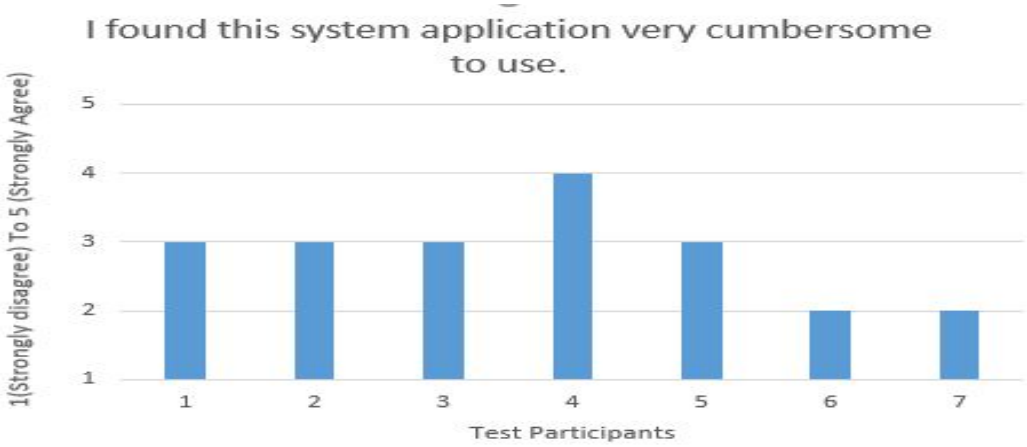

Figure 34. Q8 responses from the test participants

score determines that our system is ready for using any kind of documentation for the Fab Lab Oulu [37]. Moreover, this average score also indicates that it needs some improvement for further actions that will adhere to the instructors of the Fab Lab Oulu. Every user got 20 minutes to provide their feedback in the SUS evaluation method. Some questions have negative, and some questions have positive elicitation

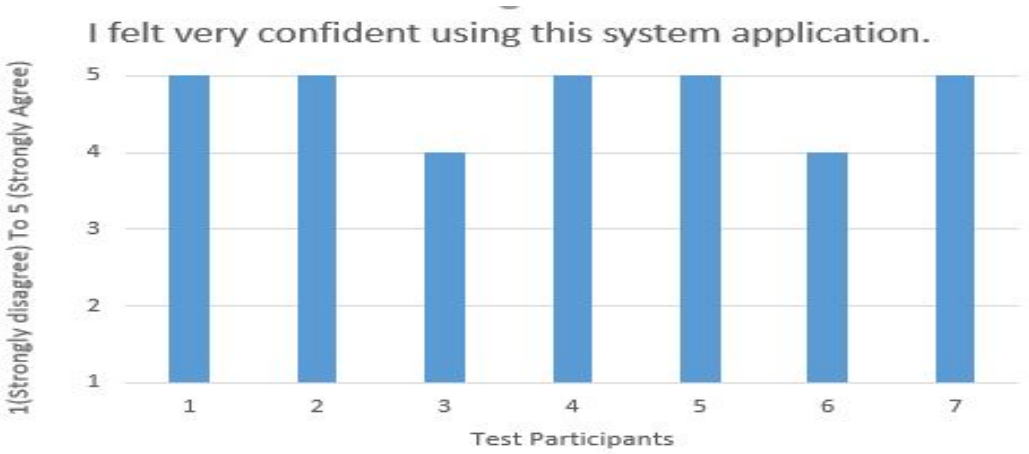

Figure 35. Q9 responses from the test participants

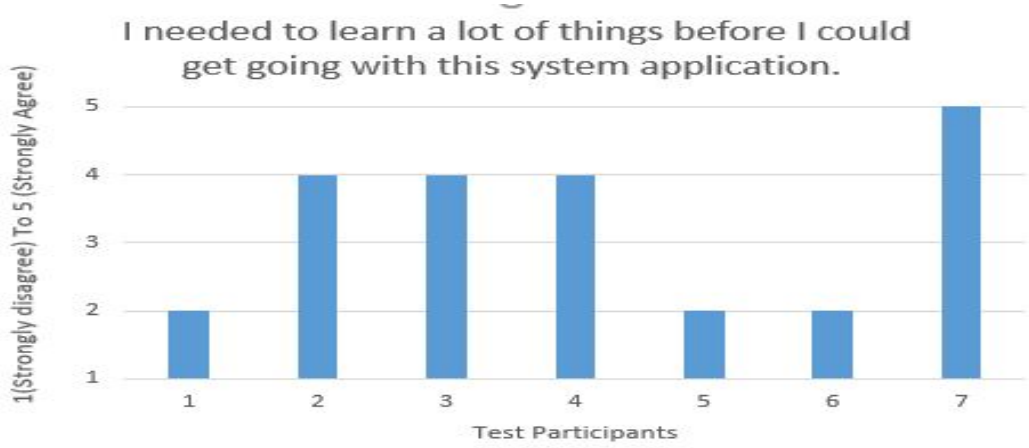

Figure 36. Q10 responses from the test participants

phrases for obtaining the exact feedback values from the user. So, this system is highly appreciated for the usage of the Fab Lab of Oulu, as well as future developers in the digital fabrication sector. Moreover, another Master thesis student from the University of Oulu, MS. Nasrin Akhter is performing the SUS testing for the teacher's module, and she found the SUS score 72.14 which was satisfactory, and it could be updated for future usage and modifications. This "Protobooth Oulu app" mainly combines two modules, i.e. the teacher's module and the students' module. Both modules performed great in the evaluation phase for calculating the SUS score. From the observational results of SUS scores of both modules, it is noticed that the teacher module is closest to the student module. This indicates that both modules will perform better in future in the Fab Lab of Oulu.

5. DISCUSSION

5.1. System Design and Evaluation

The main aim is to design a creative tool which will act as personal documentation tools for the Fab Lab of Oulu. Moreover, this personal assistant tool can collaborate with other members and can do the group project and weekly assignments. Before starting the designing phase, we focused on the lacunae of Josua Adeegbe's user interface from previous works. We tried to figure it out the practical problems while doing the creative design courses in Fab Lab of Oulu. The main focus of this app for the users of the Fab Lab of Oulu was to make the "Protobooth Oulu app" application more practical and user friendly while doing the documentation. Josua Adeegbe's works have some limitations. For eradicating those limitations, our system has entirely re-designed the system design, including the group project unit, weekly project unit and Dashboard unit. Each of the units has wholly eradicated the limitations of previous works of Josua Adeegbe and Onur Ozoduru through its new features and developments. We performed the evaluation testing based on responses of the 7 test participants. During the test, we observed the real interactions of the participants and arranged for an interview session with semi-structured questionnaires for evaluating the usability factor of the system. By calculating the SUS score and analyzing the feedback from the test participants, we have scrutinized our app "Protobooth Oulu app" and proved that the system is ready to use for the Fab Lab of Oulu.

5.2. Limitations and Challenges

We have faced several challenges for making this app functional for the Fab Lab of Oulu. Capturing images by different mobile devices with different resolution and uploading in a server were a bit challenging. Because when 100 students try to fetch the data, it could slow down the whole process. We applied an image resize algorithm for developing our app so that the image quality of the prototype would be perfect for designing the web application. Weekly project requirements of this app involved another challenge. Because when we developed the app, we had to re-design the firebase database for the group project. So, we needed to make other data table relationships with other tables and also maintained the logical activity flow for the weekly projects. Multiple interactions within group members are one of the challenging core parts of this app. Once any user creates the group and adds that specific member into the projects, he or she may leave the project any time. Moreover, the specific user will perform the multiple interactions for developing the app. In our developmental phase, we encountered the challenges for making the features of this app better for the users. During our back-end development, i.e. maintaining a relationship with the firebase cloud storage, it was difficult as well as challenging to combine both the teacher and the student modules. It has a JSON based data relationship with other tables instead of a relational schema. Once any students submit the weekly projects, he or she will not be able to edit or modify anything. For the feedback options, students will get feedback through the private comments, but students will not be able to send any messages to the teacher about the prototype

designing facts. Application testing is highly required to figure out the bugs and other problems. We performed the functional testing and regression testing while we developed the app and tried to make it more user-friendly. However, this app needs some other testing for enhancing performance. Of the other limitations, one student cannot perform in multiple projects for designing a prototype. Another main limitation is that the architecture of this app is android, which can run only in android devices. High-speed internet connectivity is highly required for doing any designing technique. This app can store data only to the Google online cloud service, and for this high internet connectivity is needed. The user interface of the weekly project could be improved for the user-friendliness.

5.3. Issues and Solutions of Protobooth Oulu App

From the very beginning of the development phase of this application, we encountered a problem with the user interface designing problem and tried to figure out which user interface had the best suitable design for the users. The concept of the “Protobooth Oulu app” application comes from Josua Adeegbe’s works. The main UI design of the application, e.g., the login screen, individual dashboard, group project, and weekly project are wholly redesigned and further developed on Josua Adeegbe’s work. Moreover, the main functionality of the application requires some complex functionality for establishing the Fab Lab Oulu. Sometimes, problems occurred when we tried to design the app and ensure its functionality for routing different logical activities. Google cloud storage makes it possible to maintain the online cloud storage database for the “Protobooth Oulu app” [35]. Integration of the API for the connectivity issues with the development of android studio created a problem. By following the authentic google documentation, the problem was eradicated. The image-capturing process needed much time to think about how we could store the image data in a smooth, logical way. After this, the whole system was developed with the android architecture and admin tools was developed by python scripting language for fetching the data from the firebase. It is sometimes difficult to configure the python scripting and its library dependencies with the “Protobooth Oulu app"” in a personal computer. The python requires configuring its path and the basic library such as CSV API is also needed to be configured for running the system. The concept of the Fab Lab Oulu is implemented in good shape, but for turning the app in the user-friendly mood, we first needed to develop a prototyping design for the app. Email authentication is one of the significant steps for app authentication. And without a valid email address, no one can use this app, and/or its feature. Multiple interactions needed privacy for the regular task. This system has been designed in better shape for differentiating between the weekly task and group task and for giving the user enhanced multiple interactions within a team. Scaling the ongoing project is a challenging part to implement for handling too much logical expression in server-side activities. This thesis contributes towards augmenting education and empowering the full potential of the most innovative concepts in the Fab Lab to materialise. [38]. This system has significant advantages for the users of the Fab Lab like a student will find out a proper documenting tool where they can do the multiple interactions within a group. Creating a group for the final project and getting private notifications from the teacher

will help to think creatively for the students. Capturing multiple images and store it in firebase cloud can easily access the document data by using this app anywhere in the world. Students can do the weekly online assignments and submit that within the app. Grouping in a project is much easier by using this app. One can easily make his team for the final project and can leave that project by the permission of the instructors. One of the significant features is the dashboard which is allowed to a user for sharing the content to the Instagram or other social sites. Moreover, students can submit their final project by following the deadline of the project on the dashboard. After successfully submitted the final project students will get the scaling and rating result within the dashboard and also participate in the Likert scaling feedback for the teachers' provided questionnaires. Additionally, Admin tool will access the database and make a CSV file for the future analyses of the scaling data.

5.4. Results and Innovations

We have achieved the results from the SUS score calculation process, and it showed that the system is ready to use, and further improvement is possible for future usage. The results indicate that the goals were achieved and it has more satisfactory features than the previous works. From Josua Adeegbe's works, we noticed that his "Protobooth Oulu capture system" was a mobile application, and it mainly worked as documenting tools with some limited features such as capturing images, single interactions, online submission and the view from the websites [10]. In this works, we have just presented the students' module involving capturing multiple images, multiple interactions, sharing the final content to the social sites, individual scaling dashboards, feedback panel for private comments, and weekly projects for individual students. In order to obtain the firebase data for future scientific experiments and analysis, We have also developed a python admin tool. Other associated works such as Sánchez Milara and Georgiev from the University of Oulu, represent appropriate models for making documenting tools for Fab Lab [7]. But their application lacked the option of a feedback system, which was the limitation of their works. But in this work, we overcame this issue and integrated feedback by combining both teacher and student modules.

5.5. Future Work

The usability testing proved that our system is ready to meet all the users' needs [37]. But one of the main features is the user-friendliness and getting quick familiarity with the app. The app is built for the Fab Lab of Oulu, and the minimum knowledge about the prototype is highly needed. An online tutorial can be developed using flash animation to guide the users to digital fabrication and the main functionality of the app. Moreover, machine learning can be added for designing future prototyping techniques. The machine learning development tool will act as a personal assistant for a Fab Lab users, who will do the scaling of the different methods of designing the prototyping and instant feedback similar to the current projects. Moreover, this app can help future data engineer in collecting data through the python script from the firebase for data

science research [39]. Future developers will also make this app for IOS operating system so that every IOS user can also run this app.

5.6. Reflections on This Thesis

This app is an entirely new documentation tool based on the Josua Adeegbe's work and highly inspired by the paper of Sánchez Milara and Georgiev. This works updated the previous application of Josua Adeegbe's " Protobooth Oulu capture system" and makes the new modern documenting tool for the Fab Lab Oulu called "Protobooth Oulu app". For research purposes and also for the data collection methods, there is a python script needed for getting the data from the database and also using the python CSV library to make CSV file based on the fetching data.

Development of this work needed a complete android programming language for making the mobile app "Protobooth Oulu app". Every student gets a dashboard where they can get feedback from the ongoing prototyping designing process. Every dashboard has the characteristics of SD scale-like Old to New, SD scale-like Nobel to Obsolete, Rating, Likert scale where students need to perform the questionnaires maximum three for research purposes. Additionally, students need to get the notification from the teacher side regarding the project status through Private comment feature. Submission date will also be visible in the dashboard, and satisfaction scaling is responsible for scaling student's projects like satisfied, maybe or dissatisfied. Students can capture images from add button in the home page maximum seven images can be captured in the images through input the title and description. A group member can do multiple interactions like editing the image, title or description. If someone in the group wants to participate in his or her documenting technique, the user can do this within-group interaction. In dashboard functionality, students can interact with the teacher through scaling their group works like a Likert scale. The main issue arises for the different perspective of the students through interactions, but team documentation can overcome this issue. Additionally, students can share those images to Instagram or other social sites. Every student will get the weekly project functionality like title, description and images are for the weekly assignment submission and also get notified while the new weekly task has generated. Additionally, every student will get weekly task From the researcher perspective; some researcher needs to collect the data from the database by using the developed tool of this thesis called python-admin script and later they will able to make the CSV file for the database.

Aspects of Ideation: This thesis idea has generated from the works of Sánchez Milara and Georgiev and previous master's thesis student Josua Adeegbe's work. According to Sánchez Milara, students need to much time for making the documentation. For eradicating this approach, this thesis work will help create documentation while designing a prototype.

Motivation: Fab Lab Oulu needs a document tool while doing the prototyping for less consuming the time of documenting the process through storytelling approach and also need a documenting tool for documenting all the challenges and obstacles that have faced during the early designing stage of the prototypes.

Decision: Users will make the decisions by using this tool that eradicates the complexity and follow the team documentation process guideline. Every decision of

this tool is followed by Fab Lab guidelines and instructed by the supervisor.
Implementation: It is an android based mobile application. The database is used in this work that is a firebase cloud store database. Python scripting language for creating CSV from the database.
Testing: This system performs the Usability testing to calculate the SUS score, and it satisfied the result accepted as a ready to use the documenting tool for the Fab Lab of Oulu. For this testing, we interviewed the seven test participants and also taking feedback during the sessions. Later, we collected the data and analyzed the bar graph for improving and fixing different features of the app.

6. CONCLUSION

The purpose of this thesis is to create a documentation tool for Fab Lab of Oulu, using which users from the University of Oulu can perform several tasks that adhere to the Fab Lab Oulu authority regulations for designing prototyping, for doing the group project and weekly project. This app can create a unique documentation tool for the future students of the University of Oulu. They want to perform the creative designing course and other Fab Lab training courses. For designing a sophisticated prototype technique, a student must design and develop a documentation process, following either a story like an approach or a recipe like an approach. "Protobooth Oulu app" works as a documentation tool in a story like an approach where all the complicated situations will be documented and multiple interactions will add extra privilege for the future development of the documentation by a group. For the development of the server-side, this system puts less pressure on the server because all the logical parts have been written in android packages. Creating documentation is a must for any Fab Lab user who wants to create an intricate prototyping designing. Sometimes users forgot how they overcome the complicated situation. When they do the post documentation process, they may not remember the problems and challenges they faced. And later, they may forget to mention how they coped up with the challenges. So documentation while doing is highly recommended for the Fab Lab users for future research and for designing complex prototyping. Besides, the future users of this app will able to share their sophisticated prototype designing techniques with DMI and other community makers based on their interest. In this thesis, our main contribution is that we have developed an application called "Protobooth Oulu app" for supporting personal of students' module, and it's extended features through evaluating the system with the usability testing for Fab Lab of Oulu. Additionally, we also emphasized the data collecting approach by making an admin tool for future data science researcher.

7. REFERENCES

[1] Schoffelen J. & Huybrechts L. (2013) Sharing is caring. sharing and documenting complex participatory projects to enable generative participation. Interaction Design and Architecture (s) 18, pp. 9–22.

[2] Leifer L.J. & Steinert M. (2011) Dancing with ambiguity: Causality behavior, design thinking, and triple-loop-learning. Information Knowledge Systems Management 10, pp. 151–173.

[3] Georgiev G.V., Taura T. et al. (2015) Using idea materialization to enhance design creativity. In: DS 80-8 Proceedings of the 20th International Conference on Engineering Design (ICED 15) Vol 8: Innovation and Creativity, Milan, Italy, 27-30.07. 15, pp. 349–358.

[4] Smith R.C., Iversen O.S. & Hjorth M. (2015) Design thinking for digital fabrication in education. International Journal of Child-Computer Interaction 5, pp. 20–28.

[5] Blikstein P. & Krannich D. (2013) The makers' movement and fablabs in education: experiences, technologies, and research. In: Proceedings of the 12th international conference on interaction design and children, pp. 613–616.

[6] Caldwell G.A. & Foth M. (2014) Diy media architecture: open and participatory approaches to community engagement. In: Proceedings of the 2nd Media Architecture Biennale Conference: World Cities, pp. 1–10.

[7] Milara I.S., Georgiev G.V., Ylioja J., Özüduru O. & Riekki J. (2019) " document-while-doing": a documentation tool for fab lab environments. The Design Journal 22, pp. 2019–2030.

[8] Mikhak B., Lyon C., Gorton T., Gershenfeld N., McEnnis C. & Taylor J. (2002) Fab lab: an alternate model of ict for development. In: 2nd international conference on open collaborative design for sustainable innovation, vol. 17, vol. 17.

[9] Stager G.S. (2013) Papert's prison fab lab: implications for the maker movement and education design. In: Proceedings of the 12th international conference on interaction design and children, pp. 487–490.

[10] Adeegbe J.M. (2019) A System Supporting Analysis of Prototyping in Fab Lab Education. Master thesis, University of Oulu.

[11] McKay C. & Peppler K. (2013) Makercart: A mobile fab lab for the classroom. In: Position Paper at the Interaction Design for Children Conference (IDC).

[12] Tseng T. & Tsai G. (2015) Process products: Capturing design iteration with digital fabrication. In: Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction, pp. 631–636.

[13] Määttä A. & Troxler P. (2011) Developing open & distributed tools for fablab project documentation. In: OKCon.

[14] Troxler P. & Wolf P. (2010) Bending the rules. the fab lab innovation ecology. In: 11th International CINet Conference, Zurich, Switzerland, pp. 5–7.

[15] Grøthaug H.E. (2011) A software roadmap for the fab lab network. KTH Computer Science and Communications, Rpyal Institute of Technology, Stockholm, Sweden .

[16] Stacey M. (2014) The fab lab network: A global platform for digital invention, education and entrepreneurship. Innovations: Technology, Governance, Globalization 9, pp. 221–238.

[17] Ludwig T., Stickel O., Boden A., Pipek V. & Wulf V. (2015) Appropriating digital fabrication technologies—a comparative study of two 3d printing communities. IConference 2015 Proceedings .

[18] Alavi M. & Leidner D. (1999) Knowledge management systems: issues, challenges, and benefits. Communications of the Association for Information systems 1, p. 7.

[19] Mostert-Van Der Sar M., Mulder I., Remijn L., Troxler P. et al. (2013) Fablabs in design education. In: DS 76: Proceedings of E&PDE 2013, the 15th International Conference on Engineering and Product Design Education, Dublin, Ireland, 05-06.09. 2013, pp. 629–634.

[20] Marantos C., Paraskevas I.S., Siozios K., Mothe J., Menou C. & Soudris D. (2017) Fabspace 2.0: A platform for application and service development based on earth observation data. In: 2017 6th International Conference on Modern Circuits and Systems Technologies (MOCAST), IEEE, pp. 1–4.

[21] Zimmerman J., Stolterman E. & Forlizzi J. (2010) An analysis and critique of research through design: towards a formalization of a research approach. In: proceedings of the 8th ACM conference on designing interactive systems, pp. 310–319.

[22] Oosterhuis K. (2005) Protospace 2.0. In: Disappearing Architecture, Springer, pp. 218–235.

[23] Abrahamsson P., Hanhineva A., Hulkko H., Ihme T., Jäälinoja J., Korkala M., Koskela J., Kyllönen P. & Salo O. (2004) Mobile-d: an agile approach for mobile application development. In: Companion to the 19th annual ACM SIGPLAN conference on Object-oriented programming systems, languages, and applications, pp. 174–175.

[24] Teng C.K., Chuang M.C. & Hsu C.C. (2015) Planning a design course for play experience and fablab. Universal Journal of Educational Research 3, pp. 751–756.

[25] Kohtala S.M., Erichsen J.A.B., Sjöman H., Steinert M. et al. (2018) Augmenting physical prototype activities in early-stage product development. DS 91: Proceedings of NordDesign 2018, Linköping, Sweden, 14th-17th August 2018 .

[26] Lorenzo C. & Lorenzo E. (2018) When learning happens through a cycle of invention, design and digital fabrication as students bring their ideas to life. In: INTED2018 Conference Proceedings, vol. 1, vol. 1, pp. 7836–7844.

[27] Cautela C., Pisano P. & Pironti M. (2014) The emergence of new networked business models from technology innovation: an analysis of 3-d printing design enterprises. International Entrepreneurship and Management Journal 10, pp. 487–501.

[28] Myers B.A. (1998) A brief history of human-computer interaction technology. interactions 5, pp. 44–54.

[29] Naranje V. & Kumar S. (2014) A knowledge based system for automated design of deep drawing die for axisymmetric parts. Expert Systems with Applications 41, pp. 1419–1431.

[30] Sundar S., Selwyn S.T. & Elanchezhian C. (2005) Computer Aided Manufacturing. Firewall Media.

[31] Fay C.D. (2020) Computer-aided design and manufacturing (cad/cam) for bioprinting. In: 3D Bioprinting, Springer, pp. 27–41.

[32] Bézier P.E. (1971) Example of an existing system in the motor industry: the unisurf system. Proceedings of the Royal Society of London. A. Mathematical and Physical Sciences 321, pp. 207–218.

[33] Godhia P.K. Cost reduction in cast components manufacturing .

[34] Barhoush Y., Mustonen M., Ferreira D., Georgiev G.V., Nguyen D. & Pouke M. (2018) The gravity of thought: exploring positively surprising interactions. In: Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct, pp. 333–338.

[35] Khawas C. & Shah P. (2018) Application of firebase in android app development-a study. International Journal of Computer Applications 179, pp. 49–53.

[36] Hamon C.L., Green M.G., Dunlap B., Camburn B.A., Crawford R.H. & Jensen D.D. (2014) Virtual or physical prototypes development and testing of a prototyping planning tool. Tech. rep., United States Air Force Academy Air Force Academy United States.

[37] Orfanou K., Tselios N. & Katsanos C. (2015) Perceived usability evaluation of learning management systems: Empirical evaluation of the system usability scale. The International Review of Research in Open and Distributed Learning 16, pp. 227–246.

[38] Georgiev G.V., Sánchez Milara I. & Ferreira D. (2017) A framework for capturing creativity in digital fabrication. The Design Journal 20, pp. S3659–S3668.

[39] Dhar V. (2013) Data science and prediction. Communications of the ACM 56, pp. 64–73.

8. APPENDICES

Appendix A Usability testing “Protobooth Oulu app”
Appendix B Test participants’ interview questions

Appendix A

An Application Supporting Personal and Team Documentation of Students' Design and Prototyping Processes in Fab Lab Education Context

Test participant ID : ——————————

Name :——————————

Signature :——————————

Date :——————————

1. USABILITY TESTING OF PROTOBOOTH OULU APP

1.1. Purpose of Usability Testing

"Protobooth Oulu app" is a mobile application for designing and developing the prototype of the Fab Lab of Oulu. It will be helpful for the students of the University of Oulu to create, update, make a group(s), do final projects and weekly assignments for the Fab Lab of Oulu. Besides, it has lots of features for designing the prototype and getting feedback from the instructor of the lab. On the other hand, a web admin tool is developed for the admin panel, which will also evaluate the data fetching and analyses of the results. In this empirical usability testing phase, the user will perform several tasks to evaluate the user-friendliness of this application and also give feedback concerning what kinds of features should be added or improved.

1.2. Conditions and Procedures

This test will be performed only in the English language. Collected data will be analyzed, and several tasks will be performed for further development of this application. By doing this evaluation test, the test participants will share their opinions, and SUS score data for developing the Fab Lab of Oulu. The test will take approximately 30 to 40 minutes, and the procedures will be clarified during the interview session.

1.3. Privacy Rights of the Users

Data from the users and feedback will be collected in two different phases. Before the experiment, the guidance of this application will be explained so that the users are familiar with the "Protobooth Oulu app". These are mentioned below:

1.3.1. Questionnaires for SUS Score

This questionnaire is used to collect the SUS score, which will determine the usability of the features of the app.

1.3.2. Users Interview Phase

This is the post-development phase usability testing. Test participants answer some questions to evaluate the system and other related topics of Fab Lab of Oulu.

I agree with the terms and conditions for doing the evaluation test.

Signature :———————————

Date :———————————

1.4. Participants' Test Questions

Instructions: Please, fill up the circle that indicates your opinion about the performance of the "Protobooth Oulu app", and web admin tool concerning System Usability Scale testing. Also keep in mind that, 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree.

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

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
(1)	(2)	(3)	(4)	(5)

Q2.I found this system application unnecessarily complex.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
(1)	(2)	(3)	(4)	(5)

Q3.I thought the implementation of this program was simple to use.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
(1)	(2)	(3)	(4)	(5)

Q4.I think I would need assistance in using this system application.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
(1)	(2)	(3)	(4)	(5)

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

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
(1)	(2)	(3)	(4)	(5)

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

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

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

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

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

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Q9.I felt very confident in using this application.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

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

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

2. PARTICIPANTS' TEST INTERVIEW QUESTIONS

Appendix B

2.1. Interview Questionnaire

Q1.Do you think the 'documentation while doing' prototyping is a good concept?

_____

_____

_____

Q2.How long have you been working in Fab Lab Oulu for designing prototyping techniques and others activities?

_____

_____

_____

Q3.Do you face any difficulties regarding the complex techniques of designing prototype?

_____

_____

_____

Q4.Which documentation techniques would you like to have in Fab Lab Oulu? I.e. storytelling approach or Recipe like approach?

_____

_____

_____

Q5.Do you agree that multiple interaction is a very good idea for designing the complex prototyping technique?

_____

_____

_____

Q6.Do you find any irrelevant features?

_____

_____

_____

Q7.Do you find any features that are needed for better operation in Fab Lab Oulu?

_____

_____

_____

Q8.Do you think this app is highly needed for the Fab Lab of Oulu operation?

_____

_____

_____

Q9.Do you have any previous experience of the documenting any mobile application tools similar to the Fab Lab operations?

_____

_____

_____

Q10.Gender

_____

Q11.Age

_____

Q12.Occupation

_____