



LEAN Model Based Experimentation on UI Prototypes

Using Task Based Usability Testing



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I would like to *dedicate* this **thesis** to ...

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Abstract

The user interface (UI) layer is one of the essential aspects of software applications since it associates end-users with the functionality. For interactive applications, the usability and convenience of the UI are essential factors for achieving user acceptability. Therefore, the software is successful from the end user's perspective if it facilitates good interaction between users and the system.

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Chapter 1

Introduction

This chapter motivates the readers about the topic (see section 1.1), explains the problems faced by the companies during software development (see section 1.2), our research approach (see section 1.3), and finally, our solution approach (see section 1.4).

1.1 Motivation

Over the last decade, software development had a tremendous impact with increasing customer demand and requirements [2], which increases product complexity and ambiguity, significantly impacting software development. Therefore, the developers have come up with different techniques to meet this requirement criteria. Early user feedback from potential customers in the industry is crucial for creating successful software products because of the growing market uncertainties, and consumers' desire to receive integrated solutions to their issues rather than unique software developments [3]. With the increasing complexity of products, it becomes challenging to determine user requirements making it more difficult for developers to assess their opinions. As a result, the developers of these products are biased toward some requirements and can ignore what the user wants. So, the developers must detect the user's needs and requirements to reduce these risks early. Giving users a "partially functioning" system is the most excellent method to determine their requirements and suggestions [4]. This ensures that the developers with high uncertainties in the early product development phase can improve the product by testing the underlying assumptions [5]. Developers can use this feedback to validate the most critical assumptions about the software product. This validation can decide whether to add, remove or update a feature [6]. This process of determining the best fit for the product through user feedback is called experimentation. There has been an increase in interest in the types of experimentation that can take place in product development. Software products have shown the benefits

of conducting experiments in many use cases with incremental product improvement [7]. In experimentation, the product designers design different UI variants (e.g., buttons with different colors), and the developer integrates these variants and assigns them to a distinct group of users. As per some evaluation criteria (e.g., more clicks on the button), the variant with better results is deployed for the entire set of users. So, an experiment can be valuable when it improves the software products. Hence, for experiments to be successful, they should offer one or more solutions that will benefit users.

1.2 Problem Statement

The motivation section shows some gaps in software development between the developers and the designers. This section explains the problems and determines their research and solution approach.

Problem 1: Product designers create many UI prototypes, and the developers implement them. To determine the best variant, the developers create experiments with the users [6]. This concrete implementation of designs uses a lot of resources and time for the developers. Therefore, the product designers need to be integrated into the development process so that they would be able to create experiments independent of the developers.

Problem 2: When the product designers develop the prototypes, testing them with many users is difficult as the product is still not developed. Therefore, it is not easy to conclude a “winner” variant with a small amount of data as it is statistically difficult to prove one of the variants outperforms the others [8]. Therefore, it is necessary to develop an idea that the designers can use to determine the best prototype or variant with a small group of users.

Problem 3: Most often, the software application collects data from the experiments. Some data is used in qualitative analysis, while others are in quantitative analysis. Many companies fail to reap the benefits of using both qualitative and quantitative analysis. Similarly, not all the data is used in the analysis phase reducing the software applications to improve based on customer feedback [9]. Therefore, finding a solution that combines qualitative and quantitative data analysis is necessary.

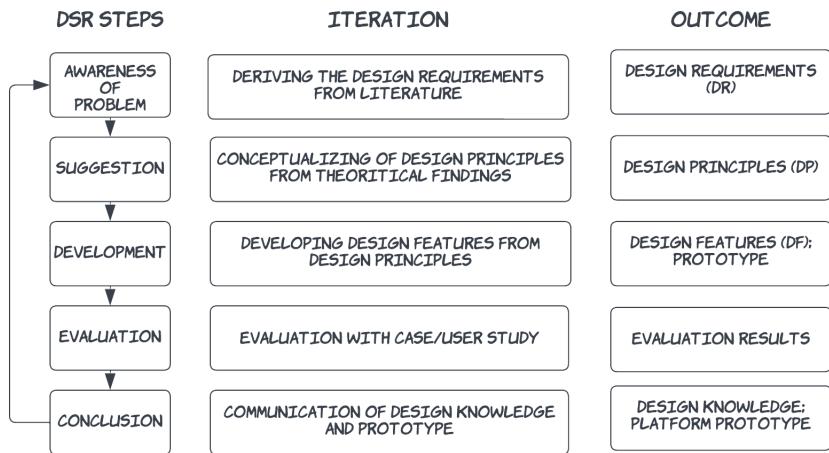


Fig. 1.1 Design Science Research Cycle [1]

1.3 Research Approach

The process of creating experiments and testing their variants is usually not systematically arranged, creating anomalies, and leading to unsuccessful experiments. Therefore, this section identifies the research question (RQ) and defines an approach to answer the question.

RQ: *How to develop a platform suitable for product designers to conduct experiments on UI prototypes, increasing its usability and, simultaneously, independent of developers?*

We will conduct a design science research (DSR) study to answer our research question and obtain abstract design knowledge and an implementation tool. From the abstracted knowledge, we will obtain some Design Principles (DPs) defined for the whole process of experimentation [1]. In this design, the product designers will iteratively validate their prototypes with the users (or the crowds). Here, DPs capture and codify that knowledge by focussing on the implementer, the aim, the user, the context, the mechanism, the enactors, and the rationale [10]. The DPs explain the design information that develops features for software applications. We propose to use the variation of the cycle of Kuechler and Vaishnavi [1] consisting of five iteratively conducted steps (see figure 1.1). Therefore through the use of DSR, a group of issues is resolved by concentrating on a single issue and abstracting the consequences of the resolution.

1.4 Solution Approach

To solve the problems mentioned above, the designers should be able to create UI prototypes and experiments on their own on a set of users. Since we do not have a large set of users for testing the prototypes, we use supervised task-based usability testing [11]. The fundamental principle of task-based usability testing is to have the users attempt to use the prototypes to do certain activities or tasks (e.g., Locate a movie M1) and get feedback (e.g., the time required for the task to be completed by the user). We propose to use Low-code or No-Code approach to achieve this. This approach helps to have a UI for the designers to understand, develop, and create experiments and tasks with the software prototypes [12]. So, the designers would be able to create the UI prototypes and their variants, assign them to the users in an experiment, get feedback from the users and decide on the best prototype. At the same time, the low-code has become more accessible for Model-driven development [13]. Therefore, we plan to create models for the UI prototypes and have the feasibility for creating experiments and tasks. Because of using the models, it is easier to store the prototypes in the database and conduct experiments with the users.

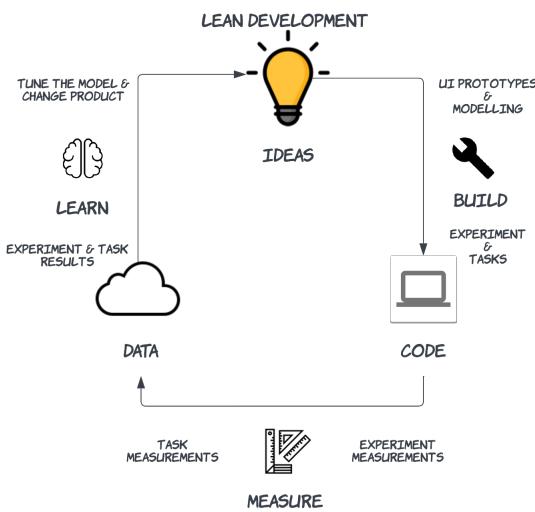


Fig. 1.2 LEAN Development technique

In our solution, we use the LEAN development technique (see figure 1.2) for development as it is used to develop customers friendly products [14]. Using LEAN, the company creates a Minimum Viable Product (MVP) throughout development, tests it with potential customers, and leverages their input to make incremental changes. While this technique can be used for every product, there are also approaches specific to software products. LEAN development

technique can be divided into a Build, Measure, and Learn cycle. In the (1) Build phase, we plan to create the UI Prototypes, Models, Experiments, and Tasks for the users. In the (2) Measure phase, we plan to assign the Experiments and Tasks to the users and measure the Task and the Experiment measurements and perform some analysis on the data received. And finally, in the (3) Learn phase, we display the Analyses results, Tune our models to decide the better variant among the others, and Modify the prototype. As per the figure 1.2, we complete one cycle of iteration and start a new one with the updated prototype.

Chapter 2

Foundations

The foundation of this research is built upon the existing knowledge and theories developed in the field of Software Engineering. This chapter provides an overview of the relevant literature and identifies the key concepts and theories necessary for the research. Firstly in section 2.1, we will discuss UI Prototyping explaining the creation of a user interface simulation and testing and refining the design ideas before implementing them in the final product. Then, in section 2.2, we explain Low/No-code methods and citizen development of the software products. Then, in section 2.3, we describe the MBSE approaches and meta-models. In section 2.4, we clarify Task based usability testing for reviewing and refining the product. Later in section 2.5, we define the concept of Experimentation and A/B testing. Finally, in section 2.6, we explain the LEAN development process, explaining the Build, Measure and Learn phases.

2.1 UI Prototyping

User Interface (UI) prototyping is an evaluation and testing technique according to User-Centred Design (UCD) methodology since the 1990s [15]. A UI prototype is a mock-up of the User interface. Before a real product is created, prototypes are used to test the usability and user experience of the interface. The evaluation of prototypes by users is a fundamental part of all iterative approaches for IT project management, especially agile methodologies [16]. And to build an exemplary user interface, a company must use iterative refinement: develop a preliminary version of the user interface, test it with people, and make as many revisions as possible [17]. Figure 2.1 shows a cycle that can be used for the iterative development of prototypes. The designers start the process by developing the UI prototypes, which stakeholders (e.g., customers and product managers) review. The UI prototypes are

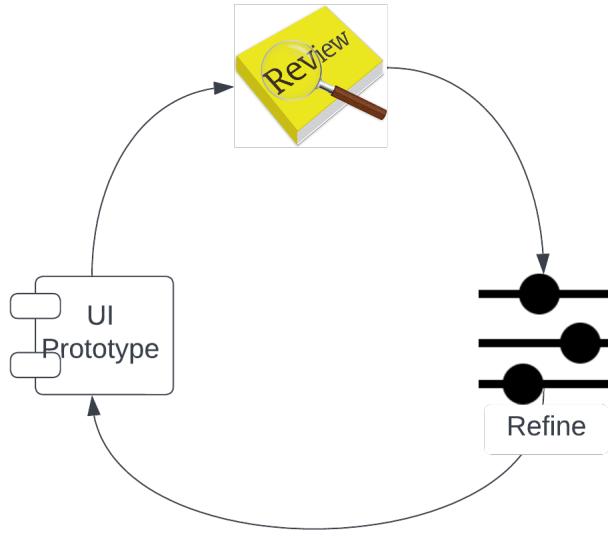


Fig. 2.1 Prototyping steps for an iterative development

refined from the feedback received, reiterating the cycle. Therefore, designing UI prototypes enables designers and stakeholders to communicate more effectively.

An interactive prototype helps visualize design concepts and communicate new requirements and expectations about a prospective system. Iterative design requires multiple updates to the design's execution. Since developing and updating the entire software system is

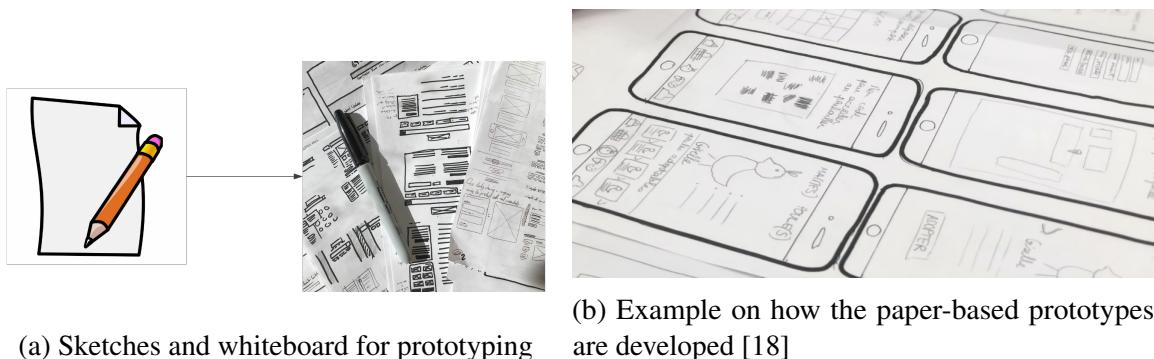


Fig. 2.2 Low fidelity prototyping

complex and expensive, prototyping is a crucial technique [19]. Simultaneously, software prototypes might exclude many requirements, making the software more accessible, smaller, and less expensive to construct and change [19]. Similarly, usability testing to validate user requirements and prototype functionality is part of the evaluation process for UI prototypes. When prototyping is used, there is usually more contact between the designers and users,

resulting in fewer usability flaws and corrections at the end of development. The main difference between a prototype and a software application is that in a prototype, the displays are designed images with no additional capabilities to display the design and flow. The mockups are converted into actual UI elements in a software application, and a flow is available.

From a paper to HTML code, everything could be a prototype. Jim Rudd et al. [20] have compared high and low-fidelity prototyping, explaining the advantages and disadvantages. *Low-fidelity* prototypes (see figure 2.2a) are usually limited functions with little interaction prototyping effort. They mainly focus on explaining concepts, design alternatives, and screen layouts. Storyboard presentations, cards, and proof of concept prototypes come under this category. UI designers use simple text, lines, and forms to hand-draw concepts. Instead of aesthetics, the focus is on speed and many ideas. To simulate user flows (as shown by figure 2.2b), designers lay paper screens on the floor, table, or pinned to a board. These prototypes emphasize communicating, educating, and informing rather than training, testing, and codification. The advantages of low-fidelity prototypes are rapid development, lower development cost, addressing issues, and usefulness for a proof-of-concept. Similarly, the disadvantages include limited error checking, difficulty with usability testing, navigation, flow limitation, etc.



(a) Prototyping page of a cake company



(b) Prototyping page to customize a cake

Fig. 2.3 High Fidelity prototype: Model-based UI Prototyping [21]

Contrary to low-fidelity prototypes, *High-fidelity* prototypes (see figure 2.3) have full functionality and focus on flow, and the user models of the system [22]. The users can operate these prototypes, and the developers can collect information from the users through

measurements. Other advantages of high-fidelity prototypes are that they are user-driven, used for navigation and tests, and can also be served as a marketing tool for attracting potential customers [20].

Steps for creating UI Prototypes:

- **Learn about your consumers' requirements:** Here, our primary goal is to understand the principles that underlie our client's values to better our service to suit their needs. In this step, the design team meets with the product management team and brainstorms to develop some use cases and end-user needs. After the discussions, the team can present the customers to ensure they are on the right track and that the design matches their requirements.
- **Sketch out the product:** This is an important step for UI designers. In this step, the UI designers can develop low-fidelity prototypes, e.g., The design team can create the paper prototypes and start brainstorming different possible options. Further, the team can create high-fidelity prototypes by using some tools. There are some tools available like Figma¹, Invision², Adobe XD³, Axure RP⁴ and many more. Using these tools, the designer can develop some high-fidelity digital prototypes.
- **Develop into Software:** This step includes the software developers and the designers coordinating and developing the software in iterations. The designers would give feedback to the software developers, and they would be continuously developing the product.

After performing these steps, it is necessary to test if everything is working as expected by the user requirements. It is necessary to ensure that the product is usable for the end-users and that developers get all the essential features in the evaluation phase.

¹Figma: <https://www.figma.com/>

²Invision AG <https://www.invisionapp.com/>

³Adobe XD: <https://www.adobe.com/products/xd.html>

⁴Axure RP: <https://www.axure.com/>

2.2 Low Code / No Code Development Platform

Low code is a software development method that uses less human coding to enable users to construct and manage programs efficiently rather than writing extensive amounts of code [23]. It is a technique used by developers to help non-developers design and develop software applications using a *Graphical User Interface* (GUI) supported by a *Low Code Development Platform* (LCDP). An LCDP allows developers to create, deploy, and manage applications quickly and easily using high-level programming languages and techniques such as model-driven and metadata-based programming. It simplifies building and deploying applications using declarative programming abstractions and one-step deployments [24]. LCDP provides pre-built components, templates, and other resources that companies can quickly assemble to create functional applications. These platforms are designed to accelerate the development process and enable companies to quickly build and deploy custom software solutions. Similarly, there is another technique called *No-code development* supported by the *No Code Development Platform* (NCDP) [25]. Unlike low code, no-code platforms require no programming skills because they offer drag-and-drop techniques for building the apps. The non-developers can easily pick up the components which fit the UI and drag and drop them to the screen and finally create an entire application using this technique. Using the visual user interface and ready-made automatic tools on these application development platforms, it is feasible to create apps relatively quickly. Due to its simplicity, flexibility, and low cost, companies have started using this platform to meet the high demands of software development and digitalization [23]. Additionally, with its self-configurable components, it lowers the expenses associated with initial installation, training, distribution, and maintenance [26].

High-level architecture of LCDP: As shown in figure 2.4, an LCDP is divided into small modules independent of the other components. Bock et al. [24] have classified these modules according to the three main approaches to systems development: the static perspective, the functional perspective, and the dynamic view.

LCPDs typically allow data to be stored either in an internal database system or in external systems (see the first part of figure 2.4). Many of the features commonly found in LCPDs fall under the static perspective. Most LCPDs include a component for defining data structures, usually provided as a conceptual modeling tool that uses a classical data modeling language such as the Entity-Relationship Model or a Domain Specific Language (DSL). Some LCPDs allow data structures to be defined only through UI-based dialogs or lists. A common feature of LCPDs is the ability to access external data sources using various application programming interfaces (APIs).

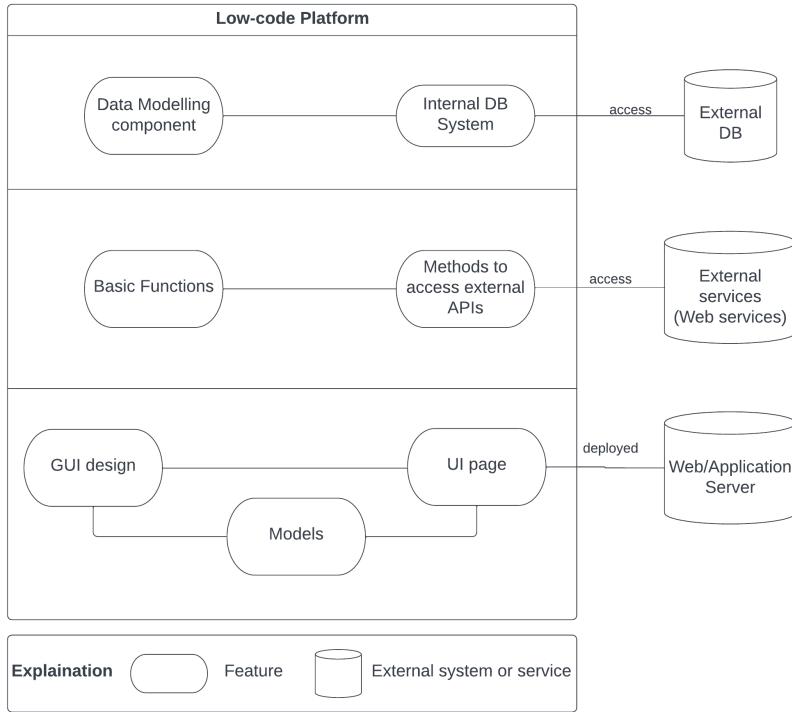


Fig. 2.4 High-level architecture of Low code Development platform

LCDPs also offer basic functional specifications (see the second part of figure 2.4). These typically include simple expression languages for decision rules and dialog-based methods for specifying program flow conditions. Each solution consists of a library of generic standard operations, such as mathematical functions. For example, LCPDs will enable the use of traditional approaches such as web services and RESTful (representational state transfer) services, and many modules provide support for a wide range of APIs from individual providers, such as Google APIs, and social media APIs [24].

The low-code platforms also include a GUI designer module (see the third part of 2.4), which allows for the development of graphical user interfaces (GUIs) and their integration with other implementation elements. The GUI designers module specifies pre-defined widgets, although the range varies. It is generally easy to link GUIs and data structures in most of these platforms, as it is optional to implement the model-view-controller (MVC) pattern manually. In addition, many of these platforms offer specific support for adapting the GUIs to different target environments, such as desktop browsers, tablets, and smartphones [27]. Another common feature is the inclusion of a component for defining roles and user rights, which is usually part of the platform's governing architecture and is deployed along with the custom application [23].

Main Steps Of Low-Code App Development as per [28]:

Building: In this step, the platform gives you the freedom to alter the provided code and add hand-written custom code to it to specify more complex features in the app as you create the app step-by-step using visual editors and drag-and-drop interfaces. Modules, components, and chart-builders are already incorporated into low-code applications. Charts may be used to display data from modules, while modules are used to specify the type of data that will be stored in the app. Components and pages provide the type of user experience the app will have. These platforms also have a provision for automating repetitive tasks in the app.

Testing: Testing a software application is an integral part of the development cycle. However, the low-code development platform decreases the requirement for testing. Pre-build modules and components on low-code platforms are created with a certain level of application security. The developers of the low-code platform constantly monitor these modules, and they have previously gone through several unit tests. But, in a low code platform, testing can be performed in several ways [29]:

- *Automated testing:* Some low-code platforms have built-in support for automated testing, which allows developers to create and run tests that validate the functionality of their applications.
- *Manual testing:* Even with automated testing, it is necessary to perform manual testing to ensure that an application functions correctly. In a low-code platform, manual testing can be achieved by developers or by dedicated testers who are responsible for verifying the functionality of the application.
- *User acceptance testing (UAT):* In some cases, it may be necessary to involve end users in the testing process. This can be done through user acceptance testing, which consists in having end users test the application and provide feedback on its functionality and usability.

Overall, testing in a low-code platform involves a combination of automated and manual testing, as well as performance and acceptance testing, to ensure that the application is functioning correctly and meets the needs of end users [29].

Deploying: In this step, the application is deployed across apps and to the final users. In LCDP, the packages for installation, configurations, and application setup are included. In terms of deployment, most of the considered solutions offer advanced support, although the specific forms vary. Some systems require the low-code platform environment to be installed on a web server to deploy individual applications. In contrast, others allow the developed solutions to be deployed as self-contained applications on various devices and machines.

This means that the LCDP gives freedom to the users in deploying the applications for the customers with just one click.

*Docker*⁵ is a widely used open software platform that allows applications to be deployed as containers. It supports libraries, system tools, code, and various runtimes, making it possible to build, test, deploy, and scale applications across multiple environments. In a low-code application platform, docker can be used to securely deploy frameworks, services, and platforms in separate containers that communicate with each other using protocols such as MQTT and REST.

Additionally, a variety of options are provided for developers with little programming experience, those with coding expertise and seasoned programmers who wish to expand the functionality of the current design [23].

⁵Docker: <https://www.docker.com/>

2.3 Model-based Software Engineering

Model-based Software Engineering (MBSE) refers to maintaining and developing software while reusing existing code. Similarly, Model-driven software engineering (MDSE) is the term used to cover various techniques for creating software using codified models. At the same time, for creating models, the Model Object Facility (MOF) has defined four levels separating the reality, models, meta-models, and meta-meta-models (as shown in the figure 2.5).

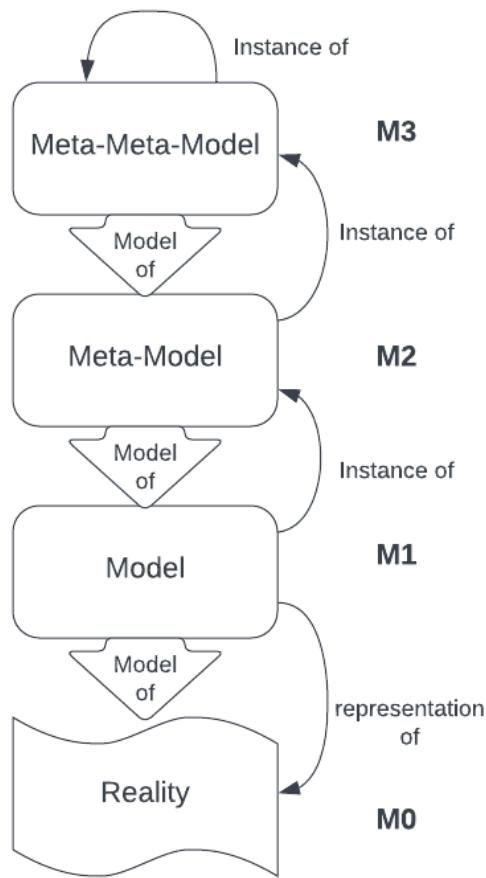


Fig. 2.5 Model Object Facility (MOF) levels

MOF is a standard that defines a meta-model for modeling information. It provides a common framework for creating and using models representing a system or part of a technique used to analyze design or document the procedure. MOF is part of the Object Management Group (OMG) [30] standards and is used in several different contexts, including software engineering, business process modeling, and enterprise architecture. It is based on

the Unified Modeling Language (UML) standard notation for modeling software systems. MOF defines a standard set of concepts and notations for creating and using models, which can represent different aspects of a system. This includes concepts such as classes, attributes, operations, and relationships, which describe the system's structure and behavior.

Meta Models: A meta-model is a model of a model or a simplified version of an actual model of a system of interest or a software application that formally represents the structure and behavior of a particular model type in a formal and standardized way. Meta models are often used in software engineering to describe the structure and behavior of domain-specific languages (DSLs) or other modeling languages [31]. They can be used to understand how a model works or to improve the performance of a model by making it more efficient or accurate. Meta models are often used in model-driven development, focusing on creating and using high-level abstractions to design and implement software systems [32]. By using meta-models, developers can create a high-level view of a system and then use that view to generate code automatically, which can help improve the development process's efficiency and reliability. A model is usually defined as an abstraction of real-world entities, and a meta-model is another abstraction of the models. Similarly, metamodeling is analyzing and developing the rules, theories, and models helpful in constructing meta-models.

After considering the information above, the meta-model can be further developed and refined. There are two approaches to designing a meta-model: top-down and bottom-up [30]. In the top-down method, we start with the overall process and then break it down into smaller steps. In the bottom-up approach, we begin with the individual steps and group them into more extensive procedures. Top-down development of a meta-model involves starting with a high-level representation of the structure and behavior of the models that the meta-model will describe (see figure 2.5). This high-level representation (M3 from figure 2.5) might include the overall design of the models (e.g., the types of elements and relationships that are allowed) and the rules and constraints that must be followed when creating and using the models. Once the high-level structure of the meta-model has been defined, it can be further refined and expanded upon by adding lower-level details (M2 and M1 and M0 levels). They include the attributes and operations allowed for each element, how elements can be related, and the semantics of the relationships between elements.

Bottom-up development of a meta-model involves starting with the specific elements and relationships that will be included in the meta-model and gradually building up to a higher level of abstraction. Once the lower-level details of the meta-model have been defined, they can be organized and grouped into higher-level concepts and structures, such as classes, packages, or packages of packages, to form the overall design of the meta-model [30].

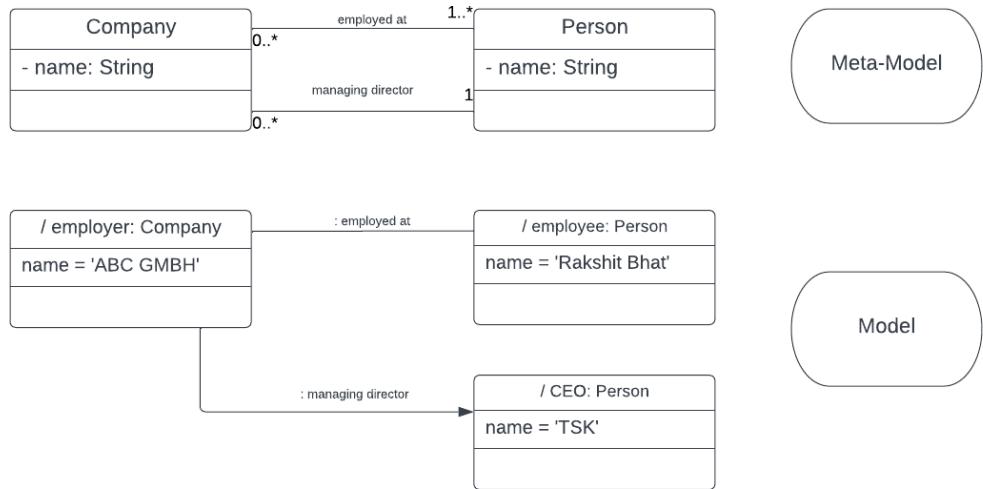


Fig. 2.6 Meta models and Models

Models: As shown in figure 2.5, a *Model* is a simplified representation of the real world or an unavoidable reality. Before any code is written, the model is a schematic that describes how the software system should function. In software development, a model is a representation of a software system. It can be used to visualize the structure and behavior of a system or to analyze the system for potential issues or improvements. Models can take many forms, such as diagrams, graphs, or mathematical equations, and they can be created using various tools and techniques. Models are often used in model-driven development, focusing on creating and using high-level abstractions to design and implement software systems. By using models, developers can better understand a system and identify potential problems or areas for improvement before they start writing code. From the example 2.6, we need to create models for every entity of reality (e.g., An employee and a CEO both are *Person* in meta-model but are separate entities in models). Using models, various adaptive model-driven user interface development systems are developed [33] and the authors defined twenty properties challenges for the Model-driven User interface and compared some tools that implement these properties. Similarly, modeling is a process and method of building models for some purpose or related to some domain. Therefore, models and modeling approaches are used to codify the UIs in different companies.

However, these models do not emphasize offering visual notations to aid non-developers in creating such interfaces. Therefore, for our research, we use a recent method [34], which illustrates how to use low-code and Model-driven approaches to close the gap between designers and developers.

2.4 Task-based Usability Testing

The main focus of usability testing is that seeing someone use an interface is the best approach to determine what functions well and doesn't. It would help if you offered the participants some assignments to observe them. The word "task" is commonly used to describe these assignments. Assigning tasks to the accurate number of participants can help determine the quality of the UI and the problems faced by the users. Overall, the UI design can be improved using the participants' feedback. Task-based usability testing is one way to determine the software's overall usability [35] by measuring the percentage of the tasks the users complete. These tasks need to be some scenarios, not just "*do something*", because it sets the users a stage for *why* they would perform the tasks. To get qualitative feedback from the participants, in [36], the authors provide *three good practices* and task-writing tips for designing better task scenarios.

(1) Make the Task Realistic: So, the participants should be able to execute the tasks which could be completed efficiently and with the freedom to make their own choices. The participants will attempt to accomplish the assignment without genuinely interacting with the interface if you ask them to do something they wouldn't typically do. Therefore, it is necessary to create realistic tasks.

E.g., from *Videostreamer* application: The goal is to offer some movies that the user should watch.

Bad task: Watch a movie if the actor 'Mr. T' and actress 'Ms. K'.

Good Task: Watch a movie with more than 6.5/10 ratings.

In the example, the participants should be free to compare movies based on their criteria.

(2) Make the Task Actionable: Here, the participants should be told what they need to do rather than how they would do it. These types of tasks help us determine if the task isn't actionable enough. E.g., if the participants tell the moderator, they cannot determine if they need to click on the link or if they are finding it hard to decide the next steps.

From *Videostreamer* application: The goal is to find a movie and show times.

Bad Task: You want to see a movie Sunday afternoon. Go to the app and tell where you'd click next.

Good Task: Use the app to find a movie you'd be interested in seeing on Sunday afternoon. Therefore, If a participant removes their hand from the mouse and tells the facilitator they would first click in a specific place and then follow a link to where they want to go, it is a sign that the task is not straightforward or actionable enough.

(3) Avoid Giving Clues and Describing the Steps: There are frequent hints about how to use the interface or the software in step explanations. These tasks must be more balanced with the users' behavior and give less valuable results. The participants should expose the navigation and some features on their own, giving accurate feedback about the interface. But, at the same time, we should try to include the words used in the UIs as they help the users navigate smoothly and would not lead to some confusion.

From *Videostreamer* application: The goal is to change the user's movie preferences.

Bad Task: You want to change your movie preferences. Go to the website, sign in, and change your movie preferences.

Good Task: Change your movie preferences from 'action' to 'comedy'.

Therefore, it is crucial to create a realistic test environment during usability testing [35]. It is also essential to provide the information required for the participant to complete the task without guiding them on specific actions. If the task scenario is unclear enough, the participant may ask for more information or confirm that they are on the correct path.

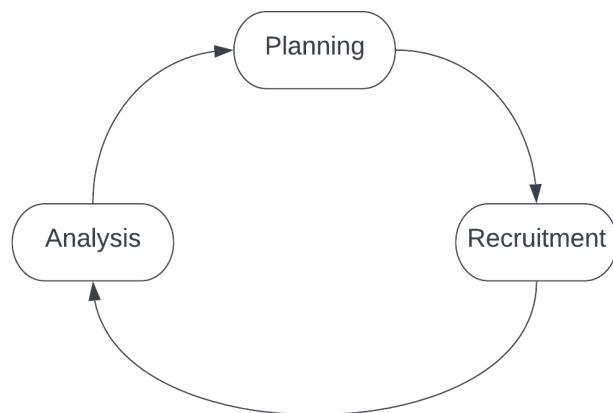


Fig. 2.7 Task-based Usability Testing steps

The fundamental principle of usability testing is to have actual users attempt to carry out essential tasks or assignments on your software, websites, mobile applications, or gadgets. For that, we divide the tasks into three steps.

Planning: In usability testing, planning is an important step. In this step, we decide on a process that fits our research question, hypothesis, and metrics. It is beneficial if we use mixed-methods services for a task-based usability study. The tasks and scenarios must be

well-defined in the planning phase. At the same time, we can create pre-study and post-study questions.

Recruitment: In this step, the users are assigned to the task as it is essential to select the correct number of user group sizes. There should be a proper way to interview the users before assigning them tasks so that the participants understand them correctly. The participants should also be able to ask questions or doubts while performing the honorarium tasks.

Analysis: Task-based studies analyze metrics, issues, and insights in great depth. For metrics, we calculate the task completion rates, task time, and task and test level perception questions. The problems that the participants encounter while performing the tasks need to be reported automatically to the development teams by sending screenshots, quotes, etc. There should also be a section to analyze some insights about the software that has worked well for the users while performing the tasks.

2.5 Experimentation

In this section, we discuss the role that experimentation plays in the software development process and how designers can “prototype with real data” to improve the usability of the UI. Experimentation is a vital part of the design process for user interface (UI) products. It involves testing different design solutions and variations to see which performs best in terms of usability, aesthetics, and other desired characteristics [7]. We can do this through various methods, such as usability testing, A/B testing, and rapid prototyping. Experimentation allows designers to iterate and improve their designs by creating different ‘*Software Variants*’ and gathering data and feedback from real users. It is an important part of creating user-centered designs that effectively meet the needs and expectations of the target audience [6]. Experimentation helps product teams test out ideas early in the process with real-world consumers rather than settling on a single solution and executing it in the final phase [37].

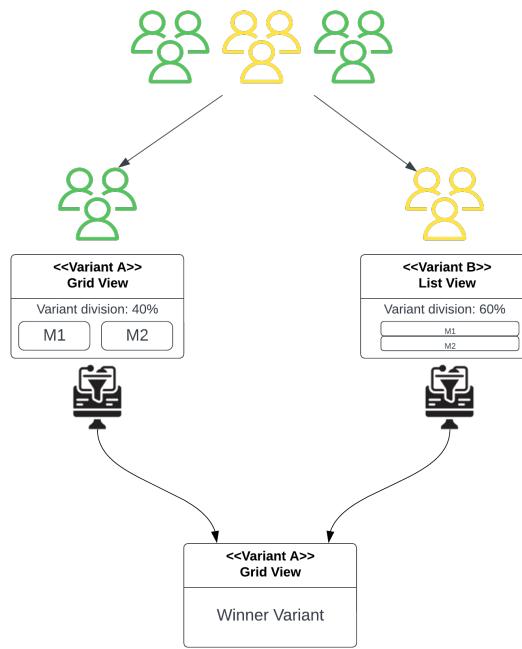


Fig. 2.8 A/B Testing

For conducting experimentation, various steps like *Users distribution*, *Continuous Experimentation*, *Variants distribution* exist.

User distribution: To conduct a successful experiment, the size of the study, or the number of participants, must be considered first. Statistics suggest that the more people you include in the investigation, the greater its statistical power, which impacts your level of confidence

in your findings [38]. Then, the participants should be allocated into groups at random. There are several levels of treatment given to each group (e.g., some prerequisites to the participants before experimenting). For assigning the subjects to groups, users are divided into a *between-subjects design* vs a *within-subjects design*. In a between-subjects design, individuals receive only one of the possible levels of an experimental treatment whereas, in a within-subjects design, every individual receives each of the experimental treatments consecutively, and their responses to each treatment are measured. In figure 2.8, a between-subject design is used where only one of the variants is assigned to the user.

Continuous Experimentation and Variants distribution: Continuous experimentation (CE) primarily aims to get users' feedback on the software product's evolution. As per figure 2.8, CE generally uses A/B testing in a primary case of comparing two variants, A and B, which are controlled and test variables in an experiment. First, the users or the participants of the study are separated into groups and are assigned one of the two variants. Since we have GridView and the ListView, one group of the users are assigned with List and one with Grid View (see figure 2.8). Then both users would be given some tasks (see Section 2.4), and the analysis of these tasks gives the winner among the variants. And in the end, developers make evidence-based decisions to direct the progress of their software by continuously measuring the results of multiple variants performed in an experimental context with actual users [39]. CE is an extension to the introduction of continuous integration and deployment, and all are summarized as constant software engineering [40]. Additionally, continuous experimentation can help designers and developers stay up-to-date with the latest design trends and best practices. By regularly testing and iterating on the design, they can learn from the feedback they receive and incorporate new ideas and techniques into their design. This can help keep the product or service relevant and competitive.

Overall, continuous experimentation is a critical approach to take when developing user interfaces for products and services. It allows designers and developers to gather valuable feedback and data and use it to improve their products' design and user experience.

2.6 LEAN Development process

LEAN development is a software development methodology that emphasizes continuous improvement and eliminating waste to deliver customer value as efficiently as possible. It is one method within Agile development. It is based on the principles of the LEAN manufacturing method, which was developed by Toyota in the 1950s and aims to eliminate waste and maximize value in manufacturing processes [41]. LEAN development's primary objective was to reduce loss, minimize waste, and encourage sustainable production. And therefore, as an MVP, in LEAN development, the product has the essential elements necessary to launch successfully and does not have to include any additional components.

In software development, we can apply LEAN principles to various aspects of the development process, including requirements gathering, design, coding, testing, and deployment [42]. The goal is to minimize waste and optimize the use of resources to deliver high-quality software products that meet the customer's needs.

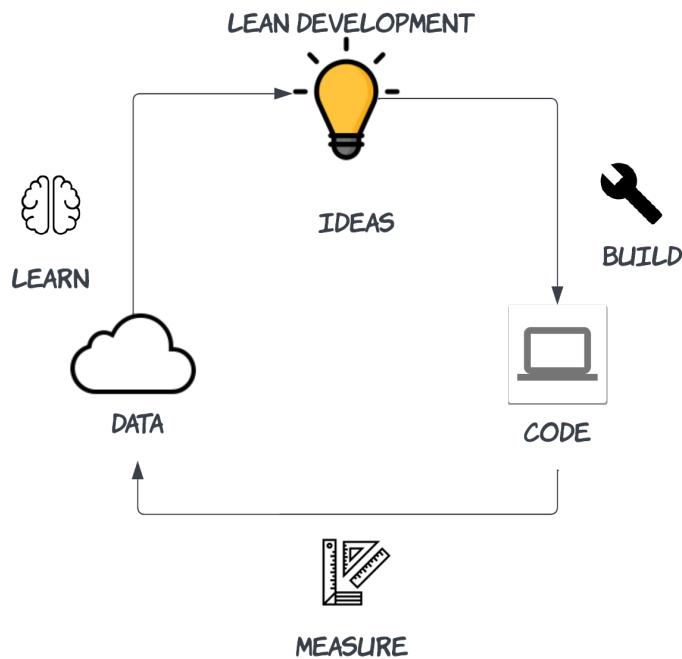


Fig. 2.9 LEAN development cycle⁶

⁶Image adapted from website: <https://www.agile-academy.com/en/agile-dictionary/lean-development/>

LEAN Development Cycle: The LEAN development cycle often includes three phases: *build, measure, and learn* (see figure 2.9). Steps like these are designed to help the development team continuously improve the product and development process.

Build: In the build phase of LEAN development, the development team works to build and deliver small increments of working software to the customer. This involves gathering requirements, designing, coding, testing, and deploying code [42]. The build phase's goal is to deliver customer requirements as quickly and efficiently as possible. To do this, the development team may follow model-driven development [43], continuous integration and delivery to ensure that the developed code meets the desired functionality and performance requirements.

Measure: In the measure phase of LEAN development, the development team collects data on the product's performance and the development process to identify areas for improvement [42]. It involves collecting data on customer usage and feedback, as well as data on the performance and efficiency of the development process. The measure phase aims to understand how the product is being used and its impact on the customer. It also identifies any bottlenecks or inefficiencies in the development process. The development team may use various tools and techniques, such as user testing, customer surveys, analytics data, and performance monitoring tools, to collect this data [44, 45]. They may also conduct regular reviews of the development process to identify improvement areas.

Learn: In the learn phase of LEAN development, the development team uses the data collected in the measure phase to identify areas for improvement and make changes to the development process and the product [42]. It may involve making changes to the product roadmap, adjusting development practices, or implementing new tools or techniques [46]. The goal of the learning phase is to improve the product continuously and the development process to deliver value to the customer more efficiently and effectively.

The final step in the cycle (see figure 2.9) would be to repeat the process, starting with identifying customer requirements and iterating through the *Build, Measure, and Learn*⁶ phases again. Thus, the development team can constantly improve the product and the development process to deliver value to the customer more efficiently and effectively.

⁶<https://www.einstein1.net/build-measure-learn/>

As per [42], there are some key practices in LEAN development. These principles can be used to guide the discussion on which product development practices might be suitable for an organization, based on its specific circumstances.

Continuous delivery: Continuous delivery is the practice of regularly delivering small increments of working software to the customer rather than waiting until the end of the project to have a complete product. This allows the customer to see the project's progress and will enable them to give feedback and make changes as the project progresses. Continuous delivery helps to ensure that the software being developed meets the customer's needs and reduces the risk of delivering a product that does not meet their requirements [46]. It also allows the development team to identify and fix problems early in the process, saving time and resources. To practice continuous delivery, the development team must have a process for automatically building, testing, and deploying code changes [47].

Continuous improvement: Improving build quality in LEAN development refers to continuously improving the quality of the software being developed through effective coding practices, testing, and quality assurance processes [48]. To improve the build quality, we can use *Code reviews* [42], i.e., conducting regular code review sessions to help identify problems early on and ensure that code meets standards for readability, maintainability, and performance. Similarly, implementing *Quality Assurance* processes, such as testing, to catch and fix defects before they reach the customer can help improve the overall quality of the product.

Lean planning: It is a practice in LEAN development that focuses on maximizing value and minimizing waste in the software development process. It involves continuously prioritizing and reevaluating the work based on customer feedback to ensure that the team is first working on the most valuable features. As per [49], Lean planning aims to quickly identify and deliver the most valuable features to the customer while minimizing time and resources spent on non-critical tasks. This helps to ensure that the team is working on the right things and that the product meets the customer's needs.

Thus, LEAN development can help organizations deliver high-quality products to customers more efficiently and effectively.

2.7 Design requirements

Prescriptive knowledge about the design of artifacts, such as software techniques, models, or concepts, is what design science research (DSR) aims can provide. Due to this design knowledge, future projects can design artifacts methodically and scientifically with the aid of study and practice. As a result, this design and application may provide design-focused information that adds to the DSR knowledge corpus [50]. Every element within a DSR project is built upon and systematically analyzed to add to the overall DSR knowledge corpus. Several scientific methodologies are employed in the DSR to ensure that this information is presented practically using design requirements (DRs). There are various ways to retrieve the DRs as explained below.

Systematic literature reviews: Systematic literature reviews establish a solid basis for knowledge creation. They help create theories and identify areas that require more research. By identifying existing literature and highlighting areas to explore, they also assist in the understanding of the problem space in DSR. Therefore, a comprehensive DSR project must include systematic literature reviews [51].

Interviews: Interviews are regarded as empirical research to obtain primarily qualitative insights from individuals, such as specialists in a particular subject. Suppose the interviewers are a part of the problem's stakeholder group. In that case, they may be utilized to establish requirements (or meta requirements) for the solution space that have a solid foundation for the problem space. For example, artifacts can be designed based on design principles (DPs) generated from interviews. Furthermore, the interviews can also be used to improve and evaluate the designed artifacts [52].

Other Methods: Design requirements can also be generated using other methods or combinations of methods. Other methods include simulations, experiments, case studies, ethnography, and the grounded theory approach [53, 54].

For our approach, we are using the systematic literature review technique to generate the Design Requirements (DRs).

- **DR1 Heterogeneous Users:** While using the prototyping, we should use different users for better research results in the research [55, 5, 56]. This is because different users may have different needs, preferences, and levels of technical expertise. By including a diverse group of users, you can get a broader range of feedback and insights into how the software performs for different users.
- **DR2 Different stakeholders for designing and developing software:** Involve project stakeholders by providing them with the necessary communication tools for exchanging and codifying knowledge [55, 57]. Stakeholders will have their perspectives and requirements, and their input can help shape the product's design.
- **DR3 Diversity in the GUI:** Do not use the commonly used GUIs for testing. This provides diversity while creating the prototypes and gathers requirements from prospective users [55]. CE should be added
- **DR4 Diversity in testing:** Testing of the GUI must be automated, and use functional and usability tests. Functional testing helps ensure the GUI works according to specification and usability testing helps ensure users can use the GUI effectively. And this helps in the identification and preliminary validation of user requirements in the early stages of development [55].
- **DR5 Governance Mechanisms:** The solution must incorporate governance elements into the process so the platform owner can take the appropriate action against developers and users who abuse the validation process. Therefore, good governance will make sure that the users stay with the platform for a longer period [58, 59].
- **DR6 Different UI Properties:** The UI should be clear, concise, familiar, responsive, consistent, attractive, efficient and forgiving [55]. If the UI has the following properties, then it gives a better User Experience (UX).
- **DR7 Provide users with tasks:** Having users perform specific tasks and observing how they interact with the application helps improve the usability of the software applications. So, we can use task-based usability testing for achieving this.
- **DR8 Design Models for software:** The model should be complete, consistent, and correct. Thus, modeling can help developers better understand the project's requirements, identify potential problems and design solutions, and communicate their ideas to other

development team members. This helps in creating model-based prototypes with many benefits.

- **DR9** *Diversity in feedback mechanism:* Including qualitative and quantitative feedback when evaluating a product or service is generally a good idea. Qualitative feedback is based on customers' or users' opinions and perceptions, providing insight into their experiences and feelings about the product. This type of feedback can help identify areas where the product is excelling and areas where it can be improved. Quantitative feedback, on the other hand, is based on numerical data and measurements, and it provides a more objective view of the product's performance. This type of feedback can help track trends and make comparisons over time.
- **DR10** *Software product should be easily built:* Using Low/No-code, we can use the visual interfaces and pre-built modules to create software without writing code. This can help users build simple software applications without programming knowledge. This approach can make it easier for non-technical people to build software and automate tasks.

In conclusion, the background section of the thesis is an integral part of the overall content. It provides context and background information on the topic being discussed and helps the reader understand the purpose and significance of the thesis. This section ensures the reader has the necessary information to understand and engage with the rest of the document completely.

Chapter 3

Related Work

3.1 State of the Art Research

3.2 Comparison

3. Do not use ‘ditto’ signs or any other such convention to repeat a previous value. In many circumstances a blank will serve just as well. If it won’t, then repeat the value.

Table 3.1 A badly formatted table

Dental measurement	Species I		Species II	
	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04

Table 3.2 Even better looking table using booktabs

Dental measurement	Species I		Species II	
	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04

Chapter 4

Design

4.1 Solution Design

4.1.1 Design Requirements

4.1.2 Design Principles

4.2 Solution Concept

4.2.1 Build

4.2.2 Measure

4.2.3 Learn

Chapter 5

Solution Implementation

5.1 Design Features

Chapter 6

Evaluation

6.1 User Case Study

6.2 Limitations and Risks

Chapter 7

Conclusion

7.1 Conclusion

7.2 Future Work

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Appendix A

How to install our Low-code Application

Windows OS

TeXLive package - full version

1. Download the TeXLive ISO (2.2GB) from
<https://www.tug.org/texlive/>
2. Download WinCDEmu (if you don't have a virtual drive) from
<http://wincdemu.sysprogs.org/download/>
3. To install Windows CD Emulator follow the instructions at
<http://wincdemu.sysprogs.org/tutorials/install/>
4. Right-click the iso and mount it using the WinCDEmu as shown in
<http://wincdemu.sysprogs.org/tutorials/mount/>
5. Open your virtual drive and run setup.pl

or

Basic MikTeX - T_EX distribution

1. Download Basic-MiK_TE_X(32bit or 64bit) from
<http://miktex.org/download>
2. Run the installer
3. To add a new package go to Start » All Programs » MikTeX » Maintenance (Admin) and choose Package Manager

4. Select or search for packages to install

TexStudio - T_EX editor

1. Download TexStudio from
<http://texstudio.sourceforge.net/#downloads>
2. Run the installer

Mac OS X

MacTeX - T_EX distribution

1. Download the file from
<https://www.tug.org/mactex/>
2. Extract and double click to run the installer. It does the entire configuration, sit back and relax.

TexStudio - T_EX editor

1. Download TexStudio from
<http://texstudio.sourceforge.net/#downloads>
2. Extract and Start

Unix/Linux

TeXLive - T_EX distribution

Getting the distribution:

1. TeXLive can be downloaded from
<http://www.tug.org/texlive/acquire-netinstall.html>.
2. TeXLive is provided by most operating system you can use (rpm, apt-get or yum) to get TeXLive distributions

Installation

1. Mount the ISO file in the mnt directory

```
mount -t iso9660 -o ro,loop,noauto /your/texlive####.iso /mnt
```

2. Install wget on your OS (use rpm, apt-get or yum install)

3. Run the installer script install-tl.

```
cd /your/download/directory  
.install-tl
```

4. Enter command ‘i’ for installation

5. Post-Installation configuration:

<http://www.tug.org/texlive/doc/texlive-en/texlive-en.html#x1-320003.4.1>

6. Set the path for the directory of TexLive binaries in your .bashrc file

For 32bit OS

For Bourne-compatible shells such as bash, and using Intel x86 GNU/Linux and a default directory setup as an example, the file to edit might be

```
edit $~/.bashrc file and add following lines  
PATH=/usr/local/texlive/2011/bin/i386-linux:$PATH;  
export PATH  
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;  
export MANPATH  
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;  
export INFOPATH
```

For 64bit OS

```
edit $~/.bashrc file and add following lines  
PATH=/usr/local/texlive/2011/bin/x86_64-linux:$PATH;  
export PATH  
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;  
export MANPATH
```

```
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

Fedora/RedHat/CentOS:

```
sudo yum install texlive
sudo yum install psutils
```

SUSE:

```
sudo zypper install texlive
```

Debian/Ubuntu:

```
sudo apt-get install texlive texlive-latex-extra
sudo apt-get install psutils
```

Appendix B

Installing the CUED class file

\LaTeX .cls files can be accessed system-wide when they are placed in the $\langle\text{texmf}\rangle/\text{tex}/\text{latex}$ directory, where $\langle\text{texmf}\rangle$ is the root directory of the user's \TeX installation. On systems that have a local texmf tree ($\langle\text{texmflocal}\rangle$), which may be named "texmf-local" or "localtexmf", it may be advisable to install packages in $\langle\text{texmflocal}\rangle$, rather than $\langle\text{texmf}\rangle$ as the contents of the former, unlike that of the latter, are preserved after the \LaTeX system is reinstalled and/or upgraded.

It is recommended that the user create a subdirectory $\langle\text{texmf}\rangle/\text{tex}/\text{latex}/\text{CUED}$ for all CUED related \LaTeX class and package files. On some \LaTeX systems, the directory look-up tables will need to be refreshed after making additions or deletions to the system files. For $\text{\TeX}{}^{\text{Live}}$ systems this is accomplished via executing "texhash" as root. MIK \TeX users can run "initexmf -u" to accomplish the same thing.

Users not willing or able to install the files system-wide can install them in their personal directories, but will then have to provide the path (full or relative) in addition to the filename when referring to them in \LaTeX .