User-Centered Platform on Antibiotics: Design and Usability Evaluation

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Abstract

This research aims to investigate the information patterns of antibiotic treatment using the MIMIC-III database. The study addresses three key Research Questions (RQ). RQ 1 examines the patterns of antibiotic treatment by analyzing the utilization and prescription trends of antibiotics within the hospital setting. RQ 2 focuses on understanding the patterns of adverse reactions to antibiotics by analyzing adverse events associated with antibiotic usage in the MIMIC-III database. Lastly, RQ 3 explores the design of a user-friendly interface to facilitate the acquisition and utilization of information on antibiotic treatment for physicians and other users. To address these research questions, the MIMIC-III database, a comprehensive dataset derived from a general hospital, will be utilized. The dataset contains detailed information on patient demographics, medical records, prescriptions, adverse events, and other relevant variables.

A Design Science research study of an application was conducted through five design iterations, resulting in an information platform on antibiotic treatment. A user-centered Design method was also integrated into the project to meet user requirements and ensure approval of the information content and design. The application is designed to serve both users with medical backgrounds and the general public using a web-based platform that can be integrated into various environments, including hospitals, health-promoting organizations, and patient organizations. A high-fidelity prototype has been implemented, where the main functionalities are medical and patient-oriented information that is structured around questions and quizzes. There is also a functionality that brings professional references to the official guidelines provided by the healthcare authorities as well as scientific articles. The development processes relied on design principles, usability testing, including a System Usability Scale (SUS), and Nilsen's heuristics to deliver satisfactory solutions. The evaluation gave the SUS of 62,75 from the users and 79,375 from the experts, as well as a Nielsen's average score of 4.1 from the experts.

The analysis of the information patterns using the MIMIC-III database suggests that antibiotics are often used in emergency cases for many indications, while the literature suggests how a lack of antibiotics relates to deaths and complications on an epidemiological scale. There is also ongoing intensive research to understand therapeutic and other dimensions of antibiotic treatment, including resistance to it that can be a consequence of frequent prescriptions. The artifact developed in this project presents one feasible way of informing physicians and the general public about antibiotics in a quick, straightforward, and adaptable manner.

Keywords: *Antibiotic treatment, Adverse reactions, MIMIC-III database, Informatics, User interface design, Digital health records, Interoperability*

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Acronyms

AGD Australian Government Department of Health. 26

AMR Antimicrobial Resistance. 8, 23, 25–27, 30

AMS Antimicrobial stewardship. 26, 28

AR Anbiotic Resistance. 8, 10, 12, 15, 23, 26, 27, 44

ASP Antibiotikasensteret for Primærmedisin. 63

CDC Centers for Disease Control and Prevention. 23, 26

CITI Collaborative Institutional Training Initiative. 29

DHR Digital Health Records. 29

DSR Design Science Research. 8, 11, 12, 16, 21

EHR Electronic Health Records. 29, 30

HCI Human-Computer Interaction. 54

HIPAA Health Insurance Portability and Accountability Act. 30

ICD-9 International Classification of Diseases Version 9. 29

ICU Intensive Care Unit. 26–28, 30

IS Information Science. 11

IT Information Technology. 8, 12, 13, 15, 22, 23, 30, 53, 54

MIMIC-III Medical Information Mart for Intensive Care III. 4, 6, 8, 9, 22, 29–31, 33, 39, 42, 62, 63, 89

ML Machine Learnings. 27, 28

RL Reinforcement Learning. 28

RQ Research Questions. 1, 9

SUS System Usability Scale. 1, 15, 18, 21, 54

UCD User-Centered Design. 16

UI User Interface. 13, 14, 16, 18–20

UIB University of Bergen. 29

UX User Experience. 13, 54

WHO The World Health Organization. 26, 27

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Chapter 1

Introduction

The emergence of Anbiotic Resistance (AR) has overshadowed the remarkable breakthrough of antibiotics in the 20th century. Microbes, with their extraordinary genetic capabilities, have capitalized on the excessive use of antibiotics, acquiring and transmitting resistance genes through various mechanisms. As each new antibiotic is introduced, microbes develop multiple resistance mechanisms, calling for innovative approaches to discover and implement novel antibiotics [12]. In the face of rising Antimicrobial Resistance (AMR), For instance, India deals with significant challenges, including high resistance rates and antibiotic consumption, attributed to the widespread use of Fixed-dose Combination (FDC) antibiotics and unapproved medications [45].

Simultaneously, the adoption of digital health record systems has experienced notable growth in hospital settings. For example, in the United States, the implementation of basic digital systems in non-federal care hospitals surged from 9.4% to 75.5% between 2008 and 2014. This highlights the benefits of digital health records [37]. Despite this progress, interoperability challenges of digital health records in medical settings are still many, hindering seamless data integration across different systems.

This research wants to help expand the spread of awareness of AR through designing a user-centered platform, draw analysis from digital records through the the Medical Information Mart for Intensive Care III (MIMIC-III) database and serve as valuable resource for exploring patterns of antibiotic treatment and adverse reactions.

The approach to provide a desirable functional prototype, methods from Design Science Research (DSR) has been applied, through interviews and evaluations with users and Information Technology (IT) usability experts.

It is worth mentioning that there are minor differences in the use of AMR and AR [9], throughout this research however, they are used interchangeably.

1.1 Research questions

- **RQ 1:** What are the patterns of antibiotic treatment in general hospital based on MIMIC-III database?
- **RQ 2:** What kind of information systems are available to support physicians with treatment?
- **RQ 3:** How to design an user-friendly interface for physicians and other users to acquire and utilize information and treatment with antibiotics?

1.2 Thesis Outline

Chapter 2: Methodology and Methods presents the methodologies and methods used in this research.

Chapter 3: Requirements describes the functional and non-functional requirements of the system and the technologies used for the prototype.

Chapter 4: Literature Review summarizes relevant literature in the field.

Chapter 5: Data Material describes the data sample of MIMIC-III provided for this research.

Chapter 6: Prototype Development presents the system architecture and workflow, and a detailed outline of the five development iterations of this research.

Chapter 7: Patterns of Antimicrobial Resistance Presents patterns based on the literature review and MIMIC-III database analysis.

Chapter 8: Artifact presents the resulting artifact produced by this research.

Chapter 9: Evaluation presents feedback from the evaluation with users and usability experts including usability scores.

Chapter 10: Discussion provides a discussion of the prototype development, artifact evaluation, and answers the three RQs.

Chapter 11: Conclusion and Future Work concludes and summarizes the work. Directions for future work are outlined at the end.

1.3 Background

Antibiotics have been crucial in preventing and treating bacterial infections, saving numerous lives. However, the global rise of AR is alarming. How resistance develops is through bacteria that undergo genetic changes in response to these drugs, rendering them ineffective. For instance, this affects its ability to treat common infections like pneumonia, tuberculosis, blood poisoning, gonorrhea, and foodborne illnesses. AR primarily affects bacteria, but can lead to more challenging infections in humans and animals compared to non-resistant bacteria [69].

Addressing AR demands urgent and comprehensive global action as the consequences are profound. Developing new antibiotics alone is insufficient. Changing prescribing and usage behavior is crucial to curb resistance. Inappropriate use and over-prescription by healthcare professionals, veterinarians, and the public contribute to the problem [69]. Reassessing and modifying current practices are necessary, such as reducing unnecessary prescriptions, promoting appropriate dosing and treatment durations, and ensuring treatment adherence [69].

Behavior changes must extend beyond healthcare to reduce infection transmission. Stewardship programs aim to reduce the need for antibiotics. Practicing proper hand hygiene, safer sex, and good food hygiene minimizes bacterial spread and reliance on antibiotics and prevents a [69] post-antibiotic era. Mitigating the impact of resistance requires comprehensive efforts, including promoting appropriate antibiotic use, implementing robust infection prevention and control measures, and raising public awareness about responsible antibiotic usage. Only through concerted action can we preserve antibiotic efficacy and safeguard public health for future generations such that life-threatening can still benefit from antibiotic treatment.

According to a paper published by The Lancet from 2019 [47], with a comprehensive list of collaborating authors, analyses that the burden of antibacterial resistance on a global scale suggests that 1,27 million deaths were directly attributable to bacterial resistance.

Chapter 2

Methodology and Methods

This chapter displays methodologies and methods used to gather and analyze data for this research.

2.1 Design Science Research

According to Hevner et al. [28], DSR is dedicated to broadening human and organizational potential through the creation of innovative products. This discipline focuses on problem-solving, particularly in developing and evaluating IT artifacts that tackle known organizational challenges. The design process in DSR is iterative, encompassing various activities that continuously refine and assess a new product. Evaluating these artifacts yields insights and feedback, contributing to the enhancement of both the systems' quality and the design process [28].

In the context of artifact design, DSR considers three distinct cycles: the relevance (i) cycle, the design cycle (ii), and the rigor cycle (iii) [27]. The first, the relevance cycle (i), deals with the context of the intended artifact. Understanding the specific needs, requirements, and expectations of the target user groups is essential. Following this, the design cycle (ii) involves iterating between different design options and their evaluations to produce the artifact. Lastly, the rigor cycle (iii) utilizes existing knowledge pertinent to artifact design and scientific methods for its development, ensuring the validity of the research [27] (see Figure 2.1).

Hevner et al. (2007) also proposes **seven guidelines for DSR in Information Science (IS) research**, serving as core principles and values of the methodology [27] (See Table 2.1).

By adhering to these guidelines, this research aims to deepen its understanding of the problem space and guide the production of a functional artifact, demonstrating its utility through well-defined and rigorous evaluation methods. Hevner et al. (2007) also suggest a specific checklist to ensure researchers that key aspects of DSR being covered[27]. These questions can be seen in Table 2.2.

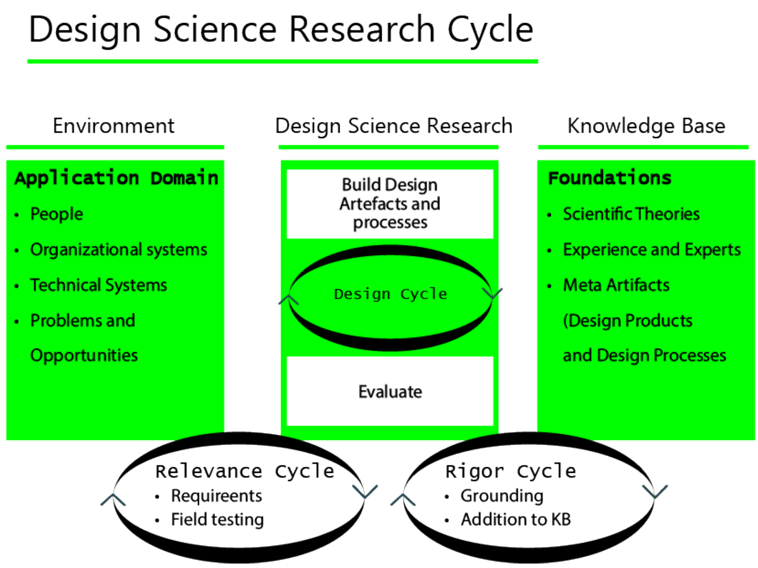

Figure 2.1: Design Science Research Cycles

Further Description of the Guidelines for DSR

Design as an Artifact

In the field of IT, artifacts are classified into constructs, models, methodologies, and practical implementations. This research focuses on the latter, covering elements like system design, prototype creation, implementation, and thorough assessment. The term 'instantiation' indicates the real-world deployment of a system's structures, models, or approaches. These real-world applications are crucial in proving feasibility and delivering concrete assessments of an artifact's effectiveness in achieving its stated goal [28]. The objective of this research is to construct a functional high-fidelity prototype, utilizing iterative design methods as prescribed by DSR. This prototype is aimed at enhancing awareness, aiding healthcare professionals and patients in accessing effective and engaging information, and serving as a dependable reference for those seeking to deepen their understanding of antibiotic use and the prevention of resistance.

Problem Relevance

Having a clear and determined problem space can help define how the artifact can potentially contribute to solving a problem [28]. For this research, the primary system is readability of information about AR for physicians and patients. The approach is grounded in a human-centric perspective with the objective of systematically organizing and subsequently enhancing the accessibility of information concerning Anbiotic Resistance (AR).

Design Evaluation

Hevner et al. (2004) [28] emphasize the significance of evaluation in DSR, with the initial focus being on the artifact's requirements. The evaluation encom-

Hevner's Seven Guidelines

Guidelines	Description	How did the research satisify the guidelines?
Guideline 1: Design as an Artifact	Design Science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.	The creation of the artifact was planned to be a funnctional high-fidcelity prototype website (app) with selective, strucutred information regarding antibiotic resistance for physicias and patients. key features such as Quizzes and references were implemented
Guideline 2: Problem Relevance	The objective of Design Science research is to develop technology-based solutions to important and relevant business problems.	The intention was to gather, structure and present relevant information in an engaging form and to spread information about antibiotic resistance for clinical physicians and patients. Highliting important guidelines presented from stewardships from several countries.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well executed evaluation methods.	Initially, our priority was to establish a thorough and authoritative understanding of the subject matter. Subsequently, we focused on creating and evaluating a tool that would effectively convey this knowledge to potential users.
Guideline 4: Research Contributions	Effective Design Science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.	The goal of the research was to make the knowledge transparent and exposit it to the public in both a scientific way (an artifact dedicated to highlight and encourage leearning for clinical physicians and patients. Furthermore, this artifact was to be assessed based on Design Science principles, taking into account the perspectives of potential user groups, IT usability professionals, and field experts.

passes various aspects such as functionality, completeness, consistency, accuracy, performance, stability, usability, among other quality metrics [28].

The development process of the artifact included five design iterations, taking into account insights derived from the literature review and pattern detection through the data material MIMIC-III. These iterations included evaluations by users and IIT usability experts to ensure the quality of the system [28].

This research adheres to five design principles in prototype creation, as suggested by Rekhi [58]. These principles facilitate the development of a user-friendly design for enhanced UX.

- **Visibility**: Users should easily view all available options. User Interface (UI), being the link between human and computer interaction, should be intuitive and not conceal features, while also avoiding clutter for clarity [58].

Guidelines	Description	How did the research satisify the guidelines?
Guideline 5: Research Rigor	Design Science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.	The study adhered to the Design Science framework, utilizing methodologies appropriate for various iterative processes. These methods were well-documented in the literature.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.	Several iterations are carrried through different phases. The initial phase focuses on structuring the knowledge, while the subsequent phase is dedicated to the creation of an artifact designed to disseminate this knowledge. Throughout these iterations, feedback from IT experts and field experts will help to guide the artifact's progress, by modifying according to their feedback to ensure continuous enhancement and refinement of the artifact in every phase.
Guideline 7: Communication of Research	Design Science research must be presented effectively both to technology-oriented as well as managementoriented audiences.	The outputs of this research are intended to be accessible to both the scientific community and the general public seeking information on about antibiotic treatment and resistance.

Table 2.1: Overview of the seven Design Science guidelines with description, and how they relate to this research

- **Feedback**: Is for the user to understand that each action they perform has been accomplished. The user should never guess what the consequence of their action was. Feedback is essential in UI through visual, tactile and audio mediums. [58].
- **Constraints**: Limiting the user's options can reduce errors, as too many choices might cause confusion about the best course of action [58].
- **Consistency**: Uniformity in design for similar tasks ensures predictability and ease of use [58].
- **Affordance**: Utilizing familiar symbols, such as a house icon for the home page, provides intuitive cues for users about potential actions [58].

With these principles in mind and the iterative approach guided by the prototype's development, it can help aid the artifact to a point where it is both

Questions

1	What is the research question (design requirements)?
2	What is the artifact? How is the artifact represented?
3	What design processes (search heuristics) will be used to build the artifact?
4	Which evaluations are performed during the internal design cycles? Which design improvements are identified during each design cycle?
5	How are the artifact and the design processes grounded in by the knowledge base? What, if any, theories support the artifact design and the design process?
6	How is the artifact introduced into the application environment and how is it field tested? What metrics are used to demonstrate artifact utility and improvement over previous artifacts?
7	What new knowledge is added to the knowledge base and in what form (e.g., peer-reviewed literature, meta-artifacts, new theory, new method)?
8	Has the research question been satisfactorily addressed?

Table 2.2: A checklist for researchers.

functional and user-friendly.

Research Contributions

The primary contribution of this research lies in exploring how to build upon current research and help move the spread of information on AR and use various communication techniques to help physicians and patients comprehend the issue at hand. This insight is derived from a comprehensive literature review that was crucial for establishing the requirements. Further enrichment of information and feedback was garnered through evaluations. The tangible outcome of this research is the creation of a functional prototype.

Research Rigor

This study employed multiple evaluation techniques to examine the design of the artifact. The development of the prototype followed an iterative and flexible methodology, integrating a range of appropriate tools for design and development. During the testing phase, participatory observations, the System Usability Scale (SUS), and Nielsen's heuristics were applied to gather feedback from users and IT usability experts, aiding in the assessment of the final prototype.

Design as a Search Process

The outcomes of this research were significantly shaped by various elements: The evaluation of different development iterations, the assessment of the completed prototype, and the application of various tools and frameworks. These components collectively contributed to the findings of the research.

Communication of Research

Hevner et al. (2004) state that DSR should effectively communicate with both technology-focused and management-oriented audiences. For those with a technological focus, detailed information is necessary to facilitate the implementation of the artifact within a suitable organizational setting (Hevner et al., 2004). To ensure that these groups are adequately informed, specific requirements for the solution were defined. These requirements are elaborated in Chapter 3, and the implementation process of the solution is detailed in Chapter 6.

2.2 Methods

2.2.1 User Centered Design (UCD)

User-Centered Design (UCD) is a methodology that prioritizes the needs and perspectives of the end-user throughout the design process. While content is a crucial element, the overall functionality and simplicity of the system are equally important, necessitating a well-crafted UI. UCD encompasses four distinct phases, as illustrated in Figure 2.2. This process somewhat parallels the DSR cycles, but has is more focused on the design aspect. The initial step involves understanding the context of use, followed by defining both functional and non-functional requirements. The third phase focuses on developing design solutions, while evaluation of the design takes place in the fourth stage, though it may not necessarily be the final step. Each design iteration undergoes testing and evaluation to ensure it meets users' expectations. The process is iterative and repeats until it adequately addresses the users' needs [62] as it can be seen Figure 2.2.

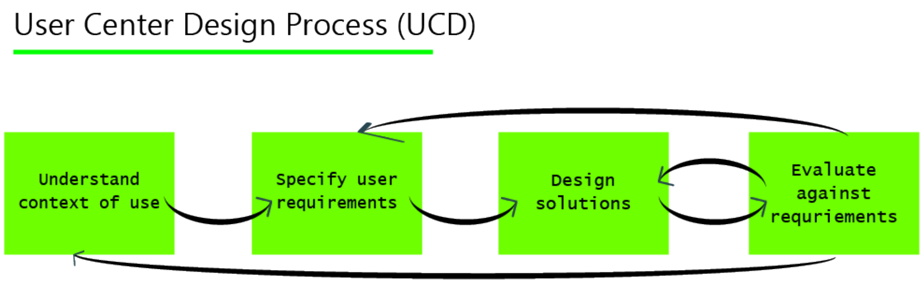

Figure 2.2: User Center Design Process

2.2.2 Data Gathering

In this research, data collection was conducted using a variety of methods. Qualitative data was obtained through extensive literature reviews, semi-structured interviews, and observations involving university professors, healthcare staff, university students, and experts in the field. Despite being a time-intensive approach, this method was chosen for its ability to uncover unexpected data [33].

Semi-structured Interviews

Semi-structured interviews use elements of both structured and unstructured interviews. These interviews include a predefined set of questions to help guide the conversation, with the purpose of gathering as much information as possible for a particular topic. The questions serve as a framework, but interviewees are free to respond openly, engage in discussions, and contribute their knowledge [26] (pp. 269-271).

In the second iteration of this study, semi-structured interviews were conducted to collect insights from experts in the field. The informed consent for this research, which was approved by "Kunnskapssektorens tjenesteleverandør" (SIKT), is included in Appendix A 11.2.

Prototype: From Low-Fidelity to High-Fidelity in Design Development

A prototype serves as a tangible version of a design, enabling users to interact with it and assess its suitability. Prototypes can range from simple hand-drawn sketches to complex systems, essentially acting as a temporary form of the product. There are three stages of prototype development: low-fidelity, mid-fidelity, and high-fidelity. A low-fidelity prototype is a basic representation that is easy and inexpensive to produce, like a paper sketch of an app's frames. Mid-fidelity prototypes provide more interactive experiences than their low-fidelity counterparts, allowing users to engage more deeply with the interface. High-fidelity prototypes are highly interactive and feature-rich, closely resembling the final product in functionality, appearance, and feel. This level of prototype is almost indistinguishable from the finished product, minus the full development effort [62] (pp. 422-434). In this research, the objective was to develop a high-fidelity prototype.

Literature Review

A literature review involves searching for, gathering, and analyzing previously published materials on a specific topic. This approach usually includes scouring online libraries for articles, books, and other relevant documents by using specific keywords. Additionally, it can play a crucial role in defining the requirements necessary for the development of an artifact as shown in Section 4.

Evaluating Usability through Observations

Observations play a key role in gathering data to assess usability, encompassing metrics such as task completion time, body language, and comments related to artifacts arising from interactions with the researcher conducting the evaluation [62] (pp. 287-288). Observations of the participants provided valuable insight into how they perceived and interacted with the artifact. Throughout the evaluation phase, they were also motivated to explore it at their own pace, with the option to ask questions whenever they deemed necessary.

2.2.3 System Usability Scale

SUS consists of a set of ten questions, each with five response options based on the Likert scale, as detailed in Section 2.2.5. Responses range from 'strongly agree' (score of 5) to 'strongly disagree' (score of 1). It is important to note that the value of any single question in isolation is not significant; rather, usability is assessed through the correlation of responses across all questions. SUS is known for its quick and straightforward approach, without sacrificing reliable results.[64].

The ten questions used in the SUS are as follows:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

The SUS was a practical tool for assessing the usability of the prototype; however, its inability to allow user comments during evaluation renders it a more general method of feedback. In the scoring process, 5 is subtracted from the total of odd-numbered responses, while even-numbered responses have their total subtracted from 25. The final score is then multiplied by 2.5 to convert it to a scale out of 100. An empirical study suggests an average SUS score of 68, with scores below 68 indicating significant design issues that require attention and those above 68 suggesting the need for minor design improvements. Scores above 85 are considered excellent [64].

2.2.4 Nielsen's Ten Heuristics

Jakob Nielsen (1994) introduced a usability testing method to identify UI design issues as part of an iterative design process. In heuristic evaluation, a small group of evaluators assesses the interface against established usability principles. Given the challenge of having a single evaluator to identify all usability problems in an interface, this method initially seemed impractical. However, experiences from various projects have shown that different users encounter distinct usability issues. Involving multiple evaluators enhances the method's effectiveness [49]. Figure 2.3 indicates that employing three to four evaluators can uncover about 75% of issues [50]. Table 2.2.4 presents Jakob Nielsen's 10 heuristics for optimal UI design. As these principles provide broad guidance rather than specific usability rules, they are termed heuristics [48].

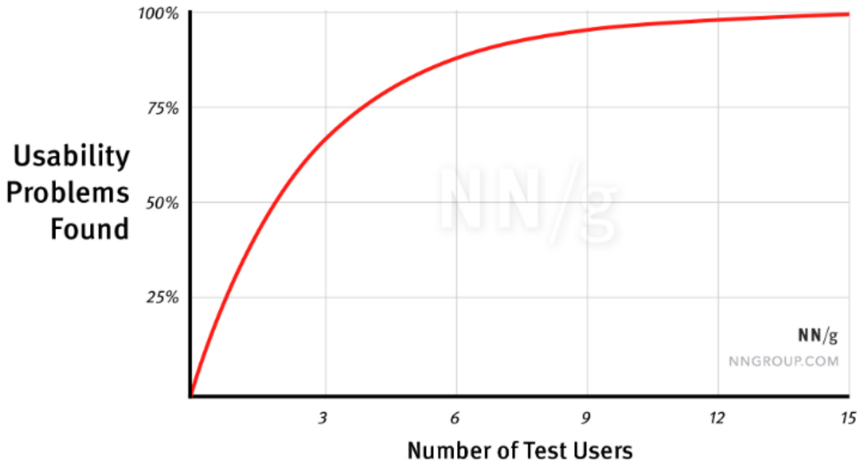

Figure 2.3: Relationship between the number of testers and the percentage of problems identified [50]

Nielsen's Heuristics

Heuristics	Description
Visability of the System	The system should always keep users informed about what is going on, through appropriate feedback within a reasonable time.
Match between system and the real world	The system should speak the users' language, with words, phrases, and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
User control and freedom	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
Error prevention	Even better than good error messages are a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
Recognition rather than recall	Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
Flexibility and efficiency of use	Accelerators — unseen by the novice user — may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
Aesthetic and minimalist design	Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
Help users recognize, diagnose, and recover from errors	Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
Help and documentation	Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Table 2.3: Nielsen's 10 Heuristics to follow for a good UI

2.2.5 Likert Scale

Likert scales are well-known tools for measuring user satisfaction with products and are used to gauge views, attitudes, and perceptions (Sharp, Rogers, and Preece, 2019, 280-281). The interviewee is supplied with a statement regarding a product using a Likert scale, such as the user's opinion about colors on a web page. The interviewee is offered five possible responses to the statement (i.e., strongly agree, partly agree, neutral, partly disagree, strongly disagree, or expressed as numbers 5, 4, 3, 2, 1) as shown in 2.4. This tool was utilized multiple times throughout the research, including when establishing specifications and evaluating the artifact using SUS and Nielsen´s heuristics (Section 9.1.3).

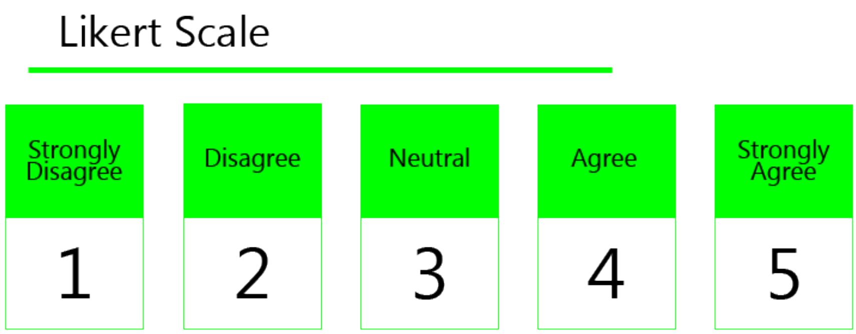

Figure 2.4: The likert scale.

2.3 Evaluation

The main goal of DSR is to create a useful and applicable artifact that clearly demonstrates its efficacy. Evaluation is a key part of the DSR process and is guided by established principles. These principles emphasize the importance of demonstrating efficacy, quality, and utility through rigorous and well-executed evaluation methods (Section 2.1). Throughout the research, relevant stakeholders and experts have helped to gain insights and help boost the progression and quality of the system through means of SUS, Nielsen's heuristics, and usability testing (Sections 9.1.3 and 9.1.2) to evaluate the design artifact. The evaluation process includes presenting and demonstrating the artifact as well as administering the SUS evaluation to validate its efficacy (Chapters 6 and 9).

Chapter 3

Requirements

This chapter presents the ethical aspects and the necessary approvals acquired from the "Kunnskapssektorens tjenesteleverandør" (SIKT). It also covers the participation of users in testing, along with the involvement of medical and ITusability experts.

3.1 Ethical Considerations

This study received approval from "Kunnskapssektorens tjenesteleverandør" (SIKT) - The Knowledge Sector's Service, a consolidation of NSD (Norsk senter for forskningsdata AS), "Uninett AS og Unit" - "Direktoratet for IKT og fellestjenester i høyere utdanning og forskning" (Appendix A1 11.2). Prior to their involvement in interviews, testing, and evaluations, all participants provided informed consent. The documentation of SIKT's approval is included in Appendix A (11.2), while the informed consent forms and interview guides are available in Appendix B (11.2).

Participants were assured of their right to withdraw from the research at any time and were informed about the measures taken to protect their privacy. The research protocol intentionally avoided sensitive questions related to their personal lives.

3.2 Data Structure

To establish a data structure, the MIMIC-III database was utilized, that reflects different types of antibiotic treatment (among other treatments) and diverse patient profiles, along with their respective treatment outcomes. The database includes patient diagnoses, types of admission, prescriptions and medication types. The data structure reflects the clinical reality which is important to understand before developing any kind of artifact. The artifact should serve users working with the patients under restricted timelines. Chapter 5 illustrates main characteristics of the patients and treatment they receive.

3.3 Establishing Requirements

It is important to understand potential user groups, their needs and preferences, what to implement, and how to implement them. Two different sets of requirements should be defined to include functional requirements, which capture what the product should do, and non-functional requirements, which captures how the system should do it [63].

3.3.1 Antibiotics and Resistance in Medical Practice

Medical doctors often find themselves in situations where they must prescribe antibiotics, both in emergency situations and during routine patient consultations. In both cases, they must carefully consider the choice of medication that would be most effective for treating the patient, taking into account potential resistance to the prescribed treatment. The field of medical practice involving antibiotics and resistance is dynamic, constantly evolving, and necessitates regular updates to guidelines and instructions.

Physicians across different medical fields require ongoing education regarding AR and appropriate medications for various conditions and diseases. For instance, it is essential to provide guidance on the treatment of conditions such as influenza, inflammation, and gastrointestinal diseases [60].

AR is a critical concern that affects both the general public and medical practitioners. Informative resources on this topic are invaluable. For the general public, it is crucial to provide accessible information on AMR, and one such resource is available from the Centers for Disease Control and Prevention (CDC) [17].

For healthcare professionals, including physicians, detailed insights into antibiotic stewardship and the consequences of antibiotic overuse are vital. Resources like the one provided by Thermo Fisher Scientific offer valuable information to physicians and other healthcare providers [60].

Functional Requirements

It is necessary to understand what needs the user groups might want to meet using an IT based solution. Within the domain of antibiotic treatment and its possible adverse reactions, there are professional users such as medical staff and researchers, but also patients who would like to understand and know both efficacy of treatments and possible complications that come with it. In this research a broad number of sources such as literature and existing platforms and support systems have been studied. The content can be divided into medication and treatment recommendations, adverse reactions, training, and providing updates in the form of new references.

The information should contain the following features:

- Display essential information for users to stay updated on antibiotics, including therapy options, risks, adverse events, and recent updates.

- Present patient-targeted information in an accessible format.
- Offer interactive content like quizzes to engage users and enhance learning.
- Include links to relevant scientific resources and other helpful references.
- Provide contact details for further inquiries or support.
- Track their quiz progress
- Feature a section for the latest news and developments in the field of antibiotics, including new research findings, policy changes, and public health advisories.

Non-functional Requirements

The non-functional requirements are the aesthetics of the application, providing constraints on the system and the development [26]. With this in mind, a simple interface was designed with the following non-functional requirements: The interface needs to:

- be user-friendly (no extra buttons, fast responding time)
- be aesthetically pleasing to look at (modern and simple visual design)
- be designed for open public and lay readers
- be design with a high-fidelity prototype within November 1st of 2023

Chapter 4

Literature Review

4.1 Relevant Literature

The literature review encompasses an extensive collection of published papers based either on the search strings below or tracing well-cited papers to established faces in the AMR research field. Most of the papers are collected from Google's scholar database in relation to the formulated research questions:

- "antibiotics" AND "patterns"
- "antibiotics" AND "future"
- "antibiotics" AND "resistance" AND "epidemiology"
- "antimicrobial" AND "resistance" AND "mimic-iii"
- "antimicrobial" AND "resistance" AND "patterns"
- "patient|medical" AND "understanding|information"

The upcoming sections of this review capture the evolving landscape of AMR research. They span from examining general trends and future directions in antibiotic usage to addressing specific challenges and advancements in comprehending and managing resistance.

4.1.1 Epidemiological Dimension of Antibiotic Resistance

Due to the significant social impact of antibiotic treatment and its common indications, research has expanded to encompass entire regions and a variety of medical diagnoses. The study by Murray et al. (2022) [47] investigates the incidence of different infections treated with antibiotics across various world regions, including sub-Saharan Africa and Australasia. Such research aims to comprehend the societal burden and develop strategies to manage challenges in treating patients, thereby averting further devastating consequences. A notable challenge in low-income areas includes coping with limited laboratory capacities and data collection, leading to less effective management of infections treated with antibiotics [52]. Hence, understanding the broader epidemiological picture and primary disease patterns is crucial. Prompt and continuous data collection can significantly benefit society by enhancing understanding of the problem and providing resources for adequate treatment.

Additionally, there are other organized efforts to grasp the epidemiological dimensions of this issue, sometimes supported by companies focusing on raising awareness and imparting new knowledge. These initiatives could be pivotal in preserving human lives [60].

4.1.2 Antimicrobial Stewardship - Online resources, Tools and E-learning

Antimicrobial stewardship (AMS) is a coordinated program that promotes the appropriate use of AMR (including antibiotics), improves patient outcomes, reduces microbial resistance, and decreases the spread of infections caused by multidrug-resistant organisms [20]. When it comes to understanding how well healthcare professionals use and understand antibiotics, there is a bit of a mixed picture. According to a study from 2004 by Dr. Arjun Srinivasan and colleagues [65], confidence in using antibiotics among hospital staff, whether in the ICU or other areas, does not necessarily equate to a deeper understanding of these medications. This applies even to those who believe that a thorough knowledge of antibiotics is essential for their roles. Interestingly, regular users of antibiotics tend to score better on knowledge quizzes, indicating a somewhat better understanding. However, this pattern does not hold true in the ICU setting. In the ICU, staff who consult with more experienced colleagues about antibiotic choices often achieve higher scores on these quizzes.

Further research shows that physicians are unlikely to change their treatment practices unless they are both aware of and agree with the proposed changes [42, 59]. Therefore, understanding what physicians know and believe about antimicrobial use and resistance is key to enhancing the effectiveness of interventions aimed at improving in-hospital antimicrobial use. Such interventions include the Centers for Disease Control and Prevention (CDC)'s Campaign to Prevent AMR in Health-Care Settings [55, 44, 61] for hospitalized adults.

In recent years however, low- and Middle-Income Countries like India, China, South Africa, Kenya, Argentina, Uruguay, Malaysia, and Colombia have taken significant steps in combating AMR by developing national action plans. These efforts, as documented by Cox et al. in 2017 [11], are part of a global initiative to enhance AMS. The World Health Organization (WHO) offers a comprehensive framework for these national action plans, emphasizing that establishing them is a crucial first step towards creating local AMS programs. [70].

In most high-income countries, a robust array of resources, including informative websites, organizations, foundations, and governmental initiatives, are dedicated to advancing AMS. For instance, in countries like Norway, Denmark, and Australia, there are specific platforms and resources that provide valuable information and guidance on this topic. In Norway, the Norwegian Institute of Public Health offers extensive resources on AR at [16]. Denmark has a dedicated website [32] managed by the Statens Serum Institute, focusing on antibiotic use and resistance. Similarly, in Australia, the government's initiative on AMRis well-structured and can be accessed at Australian Government Department of

Health (AGD) [5]. These platforms are instrumental in disseminating information, guidelines, and strategies to effectively manage and counteract AMR.

4.1.3 Presenting Information to Increase Patient Comprehension

Patients must adequately understand medical information to maintain a healthy lifestyle on a personal level. While this is a broadly understood aspect, many patients are not aware that both misuse and regular use of antibiotics can contribute to AR, a problem that extends beyond individual users [53]. A notable example is a survey conducted by the WHO, where close to half of the participants incorrectly believed that 'AR is only a problem for people who take antibiotics regularly'. This misconception can lead to dangerous practices, such as self-prescribing antibiotics or not completing prescribed courses, thereby contributing to the growing issue of AR infections. However, many healthcare providers use technical terminology without adequately clarifying it [8], and this can make it difficult for patients to understand important health information.

The Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) has created a publicly available survey [19], which can be distributed to patients post-hospitalization, and aims to evaluate the effectiveness of physicians in conveying information in a manner that patients can easily understand. This emphasis is crucial, given that healthcare providers frequently use complex technical terminology without sufficient simplification [8]. Such practices can significantly hinder patients from comprehending vital health information, highlighting the pressing need for more transparent and accessible communication in healthcare environments.

One form of language that patients are likely familiar with is metaphorical language. This includes the use of metaphors and analogies to draw similarities, preserving key information while linking it to concepts that may be more familiar to them. This sort of communication has been seen evident in healthcare communication and suggests that it has the benefit of increasing awareness and understanding. This method of communication has been evident in healthcare-related interactions, suggesting that it can boost patients' awareness and understanding [3, 29].

4.1.4 Advanced Computational Techniques in Critical Care: MIMIC-III Data and Machine Learning in ICUs

The use of Machine Learnings (ML) in healthcare is changing the way we tackle diseases that require antibiotics. ML offers a new way to handle the challenges of these diseases, including sepsis. With ML, doctors and medical staff can look at large amounts of health data more effectively. This helps them to choose better treatment plans and make quicker, more informed decisions, especially in urgent care situations like in ICUs. The goal is to make treatment more tailored and efficient, improving the chances of recovery for patients. This shift to using data and technology in healthcare is showing positive results in various areas, not just for diseases like sepsis. It is a step towards more personalized and efficient healthcare for everyone [40, 54, 10].

Distributional Reinforcement Learning for Sepsis Treatment

Böck M et al.'s study "Performance on Sepsis MIMIC-III Data by Distributional Reinforcement Learning" [7] showcases a significant advancement in treating sepsis using the MIMIC-III dataset. They employ distributional Reinforcement Learning (RL), an approach that surpasses traditional ML in handling the complexities of sepsis, a life-threatening condition demanding intricate decision-making. The study combines distributional RL with data imputation and state representation techniques, notably using a custom k-nearest neighbors model and clustering. This novel method has demonstrated remarkable results in sepsis treatment, achieving superhuman performance and significantly increasing recovery rates, highlighting the potential of RL in critical care.

Machine Learning in Empirical Antibiotic Therapy

The paper by Feretzakis G. et al. (2020), "Using Machine Learning Techniques to Aid Empirical Antibiotic Therapy Decisions in the ICU," [14] applies machine learning to assist in antibiotic therapy decisions in an ICU setting. The study aims to develop a predictive model using various algorithms, including decision trees, logistic regression, and artificial neural networks. Utilizing comprehensive patient data, the model is designed to support healthcare professionals in making informed empirical antibiotic therapy decisions, crucial before identifying specific pathogens. The model's high predictive performance in terms of accuracy, precision, recall, and F1-score demonstrates the effectiveness of machine learning in optimizing antibiotic therapy, potentially improving patient outcomes and infection management in ICUs.

Estimating Treatment Effects in Antibiotic Stewardship

Adding to the landscape of computational healthcare, a recent paper titled "Estimating Treatment Effects for Time-to-Treatment AMS in Sepsis" [41] provides insights into antibiotic stewardship in the context of sepsis. This study underscores the importance of timely antibiotic administration in sepsis treatment, a crucial aspect of patient care in critical settings. It emphasizes that the time-to-treatment is a key factor in sepsis management, highlighting the need for efficient and effective AMS to improve patient outcomes. The research presents a nuanced approach to understanding and optimizing the timing of antibiotic treatments in sepsis cases, contributing valuable knowledge to the field of critical care medicine [41].

Chapter 5

Data Sources and Materials

This chapter shows an outline of the primary data sources and materials that underlie this research, with particular emphasis on the MIMIC-III database. MIMIC-III is a comprehensive and well-regarded repository of clinical data from patients admitted to the Beth Israel Deaconess Medical Center in Boston, Massachusetts. Although we gained access to the MIMIC-III database through PhysioNet, our use was restricted to only the demo version, as full access required completing a training course offered by the Collaborative Institutional Training Initiative (CITI) Program. Unfortunately, the University of Bergen (UIB) was not affiliated with the CITI Program, preventing us from becoming credentialed users. Please note that whenever we refer to the MIMIC-III database henceforth, it pertains to the demo version, not the entirety of the database.

All figures in this chapter are based on data from the MIMIC-III database and are generated using pandas matplotlib. The implementation of MIMIC-III and the code is included in Appendix C 11.2.

5.1 Nature and Scope of Data

In the entire MIMIC-III repository, which comprises 26 tables, there are a total of 58,976 admissions involving 46,520 unique patients who have at least one medical record in the diagnosis history, prescriptions or laboratory tests [37].In the demo version, you have access to 101 unique patients and 130 admissions. The tables are linked through identifiers such as: *subject_id* corresponds to a unique patient, *hadm_id* to a unique admission, and *icustay_id* to a unique ICU stay. Diseases and procedures are encoded using the International Classification of Diseases Version 9 (ICD-9)) codes, and the mapping for these can be found in *diagnoses_icd* and *procedures_icd* tables. The full list of identifiers can be seen in Table

Digital Health Record

Digital Health Records (DHR), also known as Electronic Health Records (EHR), represent the digital transformation of traditional patient paper charts and are a crucial component of health IT. They comprehensively store patients' medical histories, including diagnoses, medications, treatment plans, immunization records, allergies, radio-logical images, and results from laboratory tests. EHRs significantly improve patient care by making it safer and reducing mistakes. They are also key in supporting medical research, boosting public health, and cutting down healthcare costs. [46].

Leveraging Open Data: Importance and Usage

The integration of open data into research and public policy is gaining momentum due to its vital role in driving transparency and fostering innovation and acts as a gateway to a wealth of diverse information, paving the way for groundbreaking discoveries and innovative solutions to intricate challenges [43]. The significance of open data is particularly evident in healthcare research, where it facilitates a comprehensive understanding of complex issues to conduct more extensive and diverse studies, drawing from a broader pool of information [43]. By making data freely available, it encourages collaboration among researchers from various disciplines and even across different countries. This collaborative environment can lead to novel approaches and solutions to longstanding problems, driving forward the fields of science and medicine. Policymakers can use insights gleaned from open datasets to design more effective health interventions, allocate resources more efficiently, and tailor public health strategies to specific community needs[71]. For instance, in the fight against AMR, open data can inform policies on antibiotic use, helping to curb the rise of resistant strains and shed light on territories of more careful needs (Section 4.1.2).

Restrictions and Inconsistencies in the MIMIC-III Database

In accordance with the regulations outlined in the **Health Insurance Portability and Accountability Act (HIPAA)** [30], the actual dates of birth for patients are safeguarded through a practice known as 'date shifting', (Section 5.1) As a consequence, the recorded ages may exceed 300 years. This deliberate measure is in place to ensure strict adherence to privacy standards while preserving the data for research purposes. This involves subtle adjustments to personally identifiable information by introducing randomized time adjustments, the dataset conceals these sensitive details, making them impervious to any attempts at identifying individual patients. Because, this date shift is consistent across all times for the patient, allowing users of the database to calculate their age as the time of their ICU admission minus their date of birth [22]. Figure 5.1 illustrates additionally aspects and steps related to the management of the database that was taken into consideration [36].

There are a few other issues reported by users of the MIMIC-III database, for example a small percentage of ICD-9 codes for diagnoses and duplicates were observed across different tables as reported by Angelina Prima Kurniati et al. [39]. We have also noticed some duplicates especially with respect to the admissions of the patients and have taken care of it as suggested through pre-processing of the data. as a part of the data cleaning process.

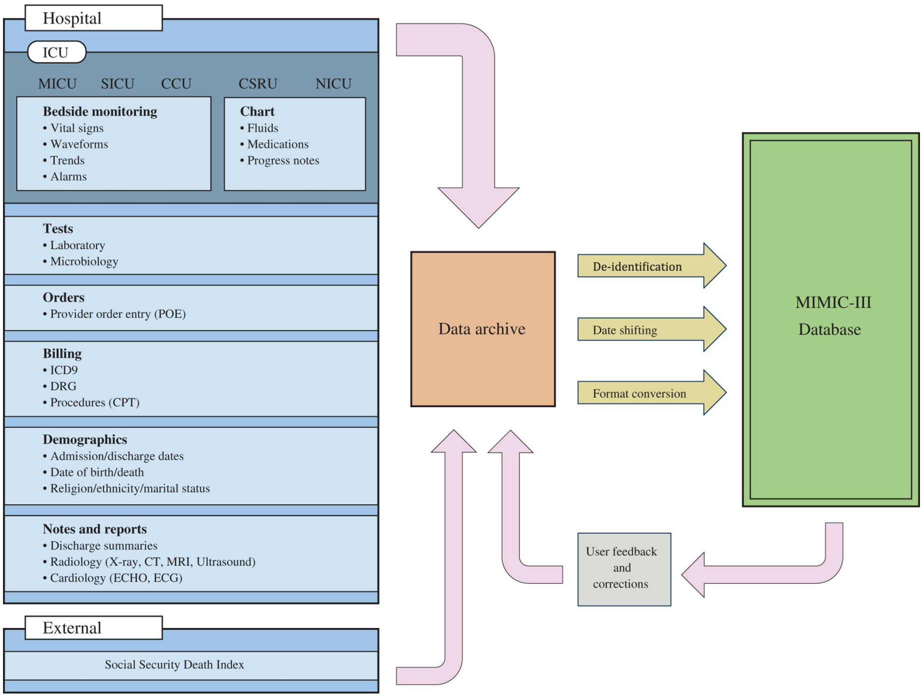

Figure 5.1: Overview of the MIMIC-III critical care database [37].

5.2 Summaries Statistics of MIMIC-III Database Sample

Figure 5.2 shows that the highest frequency of patients falls in the age range above 60. This indicates a larger representation of older patients in the database compared to those below 60 years of age.This skew towards older ages might suggest that the database is particularly rich in data pertaining to elderly patients. It can indicate a higher prevalence of hospital admissions or medical treatments among this age group, potentially reflecting the increased healthcare needs associated with aging.

Analysis of Antibiotic Usage Across Age Groups

Figure 5.3 reveals insightful trends about age-related prescription patterns. A key observation is the lower representation of patients under 30 years of age compared to the higher representation of patients between 70 and 80 years of age.

Limited Data for Younger Patients

- The scarcity of data on younger demographics may imply notable trend as the low representation can be attributed to either fewer health-related complications or a lesser incidence of hospital admissions.

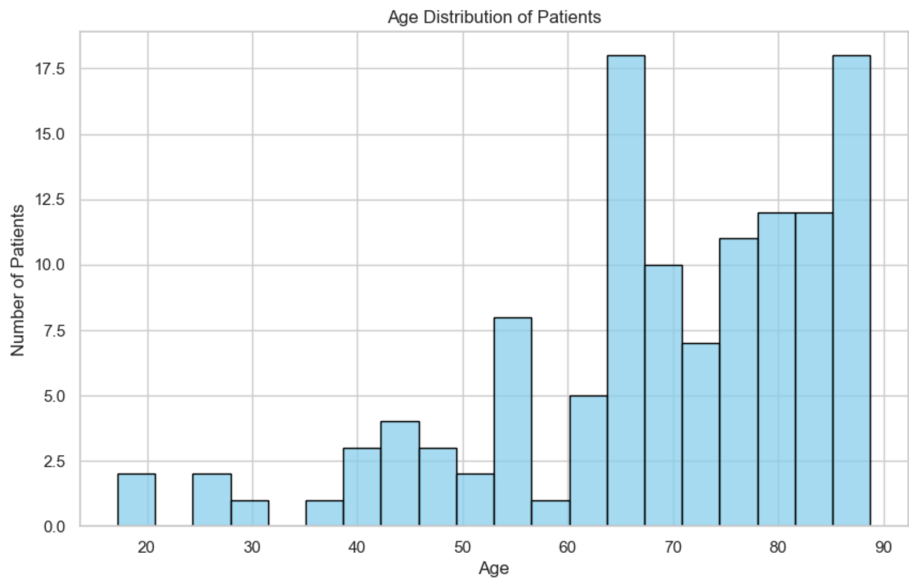

Figure 5.2: Present the age distribution in the database sample.

- It is noteworthy however, that within this limited dataset, a relatively high proportion of young patients are receiving antibiotics.

Peak Usage in Elderly Populations

- There is a significant peak in antibiotic usage for patients aged 70-80.
- This trend could be due to the higher incidence of chronic conditions and a weakened immune system in older adults.

Decline Beyond 90 Years

- A noticeable decline in antibiotic usage is observed in patients over 90.
- This could reflect a more cautious approach to antibiotic use in very elderly patients, or a shift towards comfort-focused care.

Implications for Healthcare Policy and Practice

- These trends highlight the need for age-specific considerations in antibiotic prescribing practices.
- For the elderly, particularly those aged 70-80, careful antibiotic stewardship is crucial.
- The decline in usage for those over 90 prompts further research into healthcare practices for the very elderly.

In Figure 5.4, the bar chart illustrates the distribution of antibiotic prescriptions across genders. This visualization categorizes patients into two groups

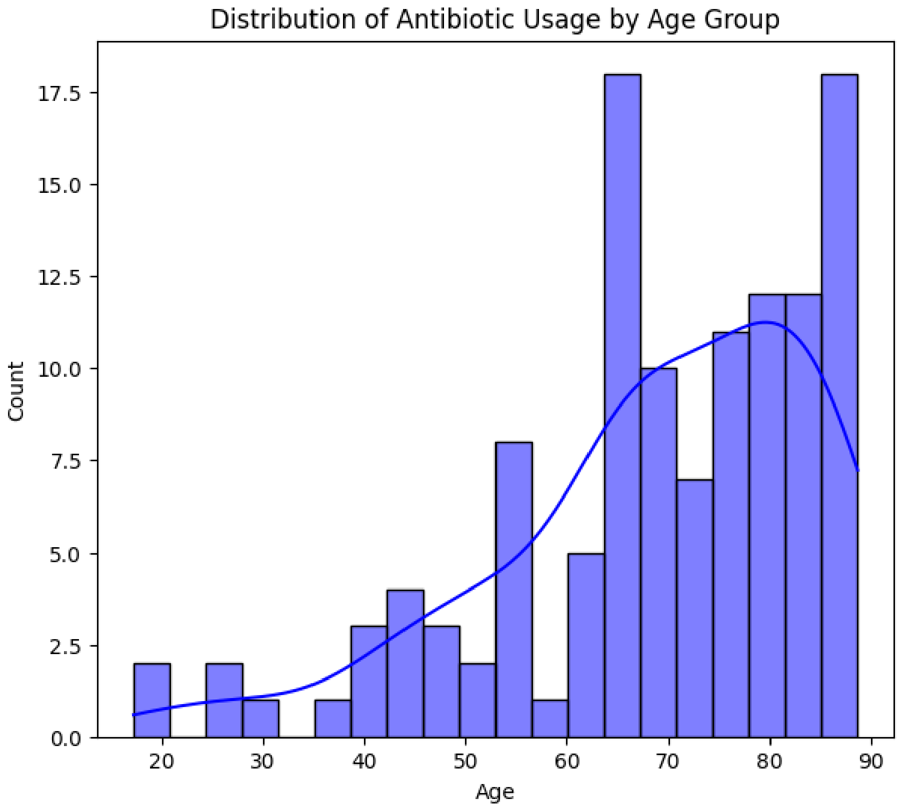

Figure 5.3: Shows the distribution of antibiotic use in different age groups.

based on their gender – male and female – and further subdivides these groups based on whether they were prescribed antibiotics. It is a straightforward and informative depiction of antibiotic prescription patterns by gender, potentially enhancing our understanding of gender-based differences in healthcare treatments within the MIMIC-III database.

Analysis of Antibiotic Prescription Patterns

Figure 5.5 illustrates the distribution of various antibiotic prescriptions across genders. It highlights dominant antibiotics and reveals significant gender-specific differences in prescription patterns.

Dominant Antibiotics

As shown in Figure 5.5 Vancomycin, Levofloxacin and Metronidazole are the most frequently prescribed antibiotics for both genders, where Vancomycin and Levofloxacin with an even higher prescription rate in males. This suggests that these antibiotics are widely used in the healthcare settings of MIMIC-III, possibly due to their effectiveness against a broad range of infections or their suitability for the types of conditions most commonly treated.

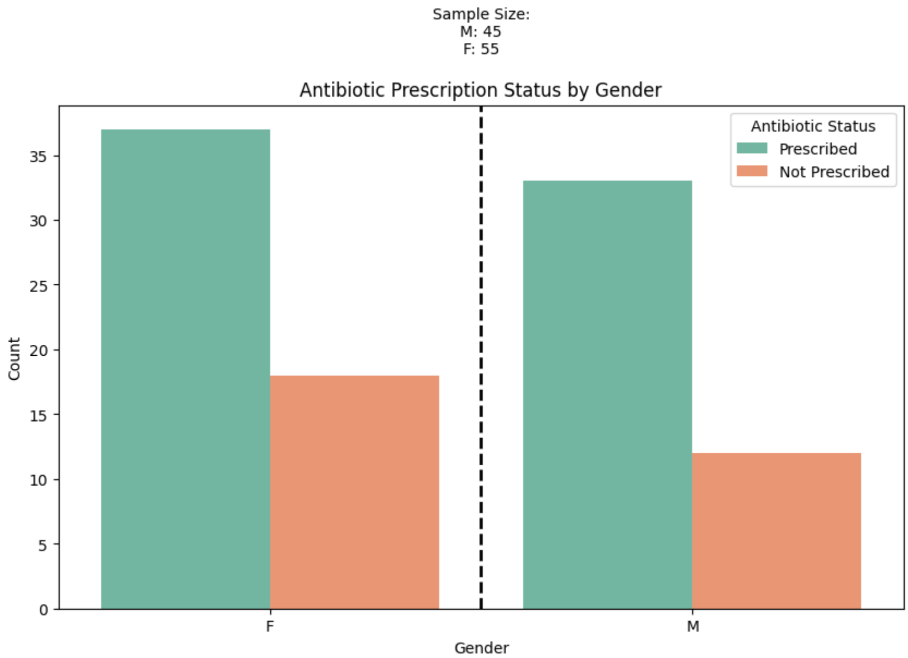

Figure 5.4: Shows the number of patients who have received antibiotics by gender.

Gender Differences in Metronidazole Prescription

A notable finding is that Metronidazole prescriptions are almost twice as high for females compared to males. This could be indicative of gender-specific health issues or infections that are more prevalent or more aggressively treated in females. Metronidazole is often used for bacterial infections, including those specific to female reproductive health, which might explain this discrepancy.

Implications for Healthcare Practices

The data reflects specific trends in antibiotic use, which could have implications for healthcare practices. The high use of certain antibiotics like Vancomycin and Levofloxacin may point to commonality in the types of infections encountered or may raise questions about antibiotic stewardship and resistance patterns. The significant gender difference in Metronidazole prescriptions could prompt further investigation into the reasons behind this trend, such as differences in disease prevalence, diagnostic practices, or prescribing behaviors between genders.

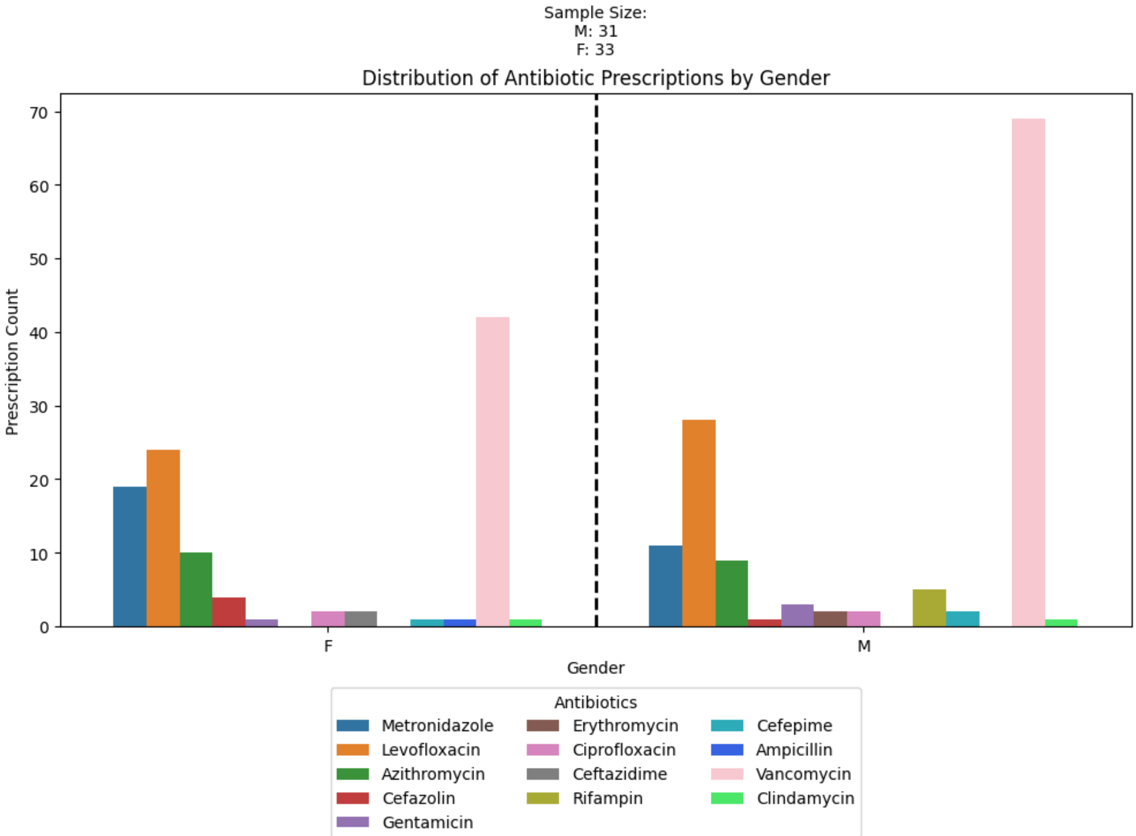

Figure 5.5: Distribution of antibiotics prescriptions by gender.

Figure 5.6: Disease Occurrence by Age Group.

In Figure 5.6 the heatmap visualizes how frequently each of the top 20 ICD-9 codes occurs in each age group. The color intensity represents the count of occurrences: darker or warmer colors indicate higher counts, and lighter colors represent lower counts or zero occurrences. The heatmap analysis distinctly shows that the age group of 60-69 exhibits the highest color intensity. This observation is crucial, as it implies that individuals in this age bracket have the highest frequency of the top 15 ICD-9 diagnoses compared to other age groups in the dataset. This elevated intensity signals a heightened prevalence or incidence of these health conditions among people aged 60 to 69.

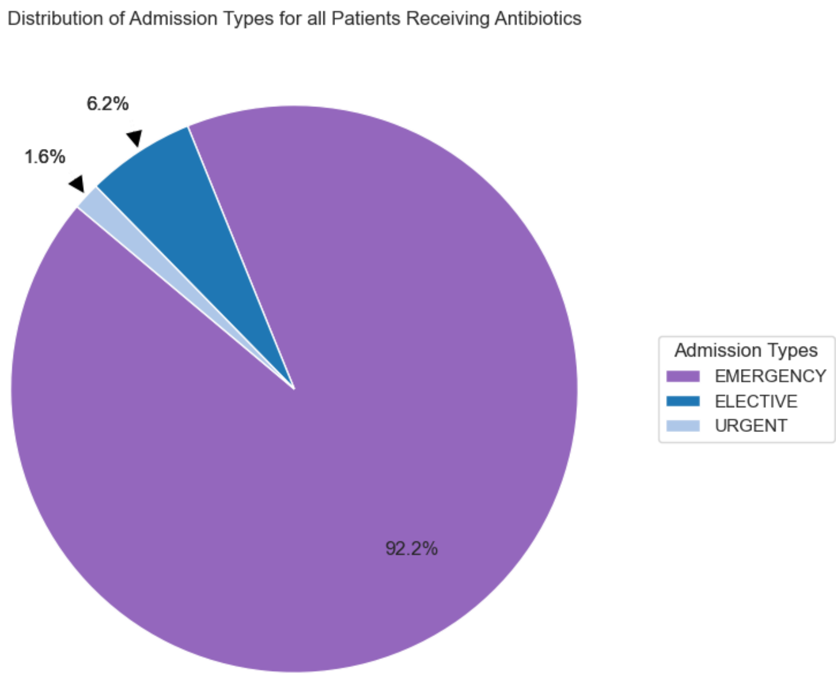

Figure 5.7: Distribution of admission types.

Figure 5.7 shows the distribution of admission types. There are three different types of admission, "Emergency", "elective" and "urgent".

- **Elective admission**: You have a known medical condition or complaint that requires further workup, treatment, or surgery.
- **Emergency admission**: This occurs through the emergency department. You may be admitted to a floor, a specialized unit (for example, the medical or surgical intensive care unit), or a holding (observation) unit.'
- **Urgent**: The patient requires immediate attention for the care and treatment of a physical or mental disorder.

As depicted from Figure 5.7, it is very clear that the biggest group of admissions that is recorded belongs to the "emergency" category.

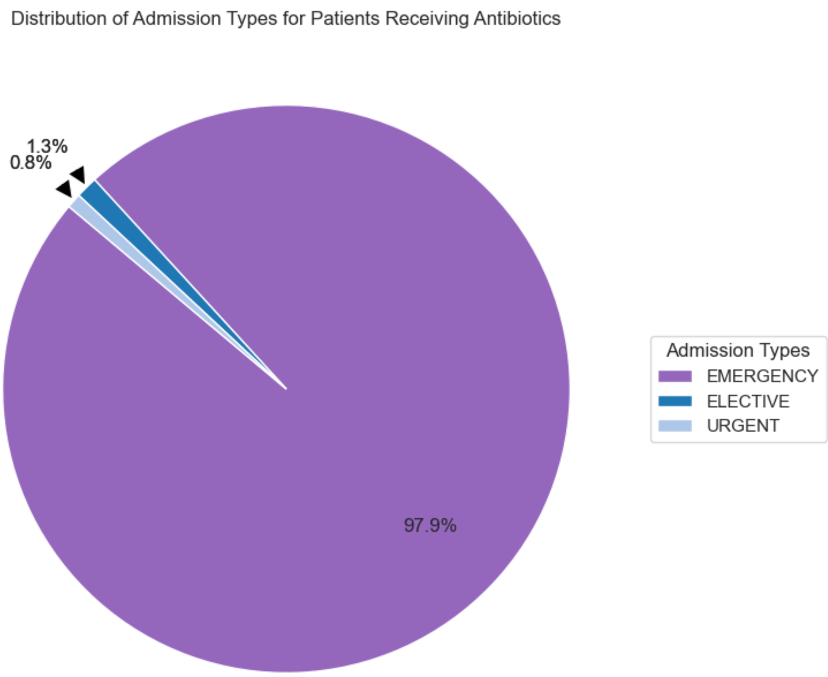

Figure 5.8: Distribution of admission types where patients have received antibiotics.

Figure 5.8 shows the distribution of admission types of cases where the patients has received any form of antibiotic treatment, which shows a similar image of the reality of a hospital as shown in Figure 5.7.

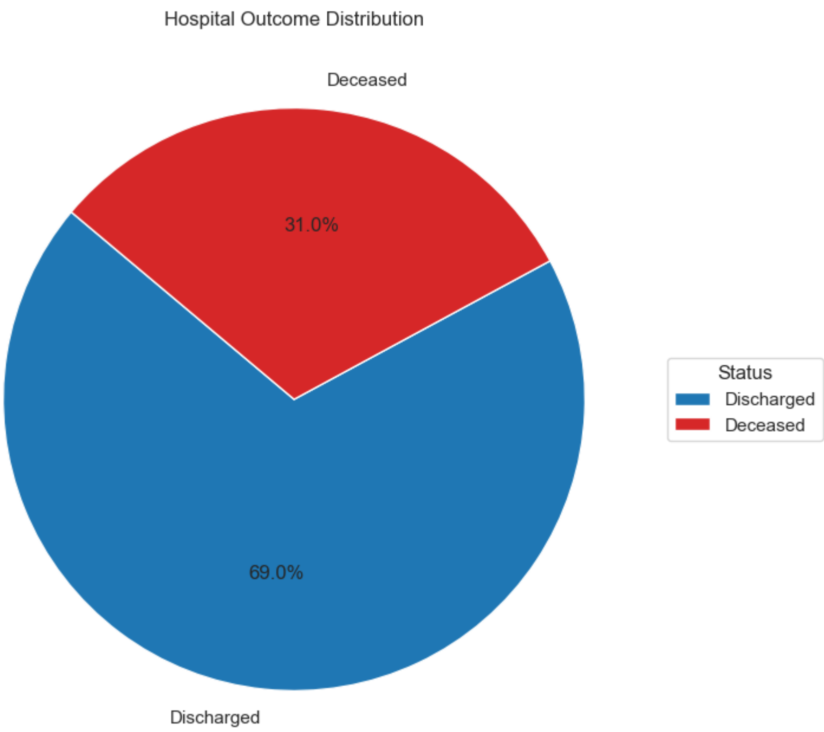

Figure 5.9: Hospital Outcome of Patients.

The chart depicted in Figure 5.9, titled "Hospital Outcome Distribution," visually represents the distribution of patient outcomes in a hospital setting, as categorized into two groups: “Discharged” and “Deceased.” The data is based on the ‘hospital_expire_flag‘ in the admissions dataset of MIMIC-III repository.

Exploring factors that contribute to higher discharge rates might be beneficial to decrease the number of mortality rates in a hospital. The fact that a majority (61%) of patients were discharged suggests a positive outcome for most patients derived from this dataset. This could be indicative of effective treatment protocols, efficient healthcare delivery, or the nature of cases admitted to the hospital. However, The 31% mortality rate, while lower than the discharge rate, is still notable. It is essential to explore the reasons behind this for further research, looking at factors such as the severity of illnesses treated, the patient demographics (age, pre-existing conditions), or the quality of care should be considered.

Chapter 6

Prototype Development

This chapter presents the development tools used to design and create the prototype. It offers an in-depth exploration of the various iterations and methodologies implemented throughout the prototyping process, highlighting how each contributed to the evolution and refinement of the artifact.

6.1 Integrated Technologies and Tools

Notion

Notion is an all-in-one productivity and collaboration software that provides a flexible and customizable workspace for individuals, teams, and organizations [51]. It combines a variety of features, such as note-taking, document editing, project management, knowledge management, task tracking, and more into a single platform.

The reason for using Notion is due to its use of boards, which made it a good choice for tracking and documenting the iteration progress. As illustrated in Figure 6.1) the prototype development was organized through three main stages to keep track of the progress. In addition, it acted as motivation to move forward during the development, while keeping track of what features were not fully implemented and gave a reminder of what status the cards were classified as, such as "current", "done", "overdue" and "upcoming".

Git and Github

The choice of GitHub and Git for the artifact's creation was influenced by several key factors as well as personal experience using it.

GitHub, as a secure and reliable platform for hosting Git repositories, offers centralized storage for our codebase, facilitating easy collaboration. Git's version control system efficiently tracks and manages code changes, simplifying code reviews and merges. GitHub's collaborative features, like issue tracking, pull requests, and code reviews makes it easy to track different version of the working project [21].

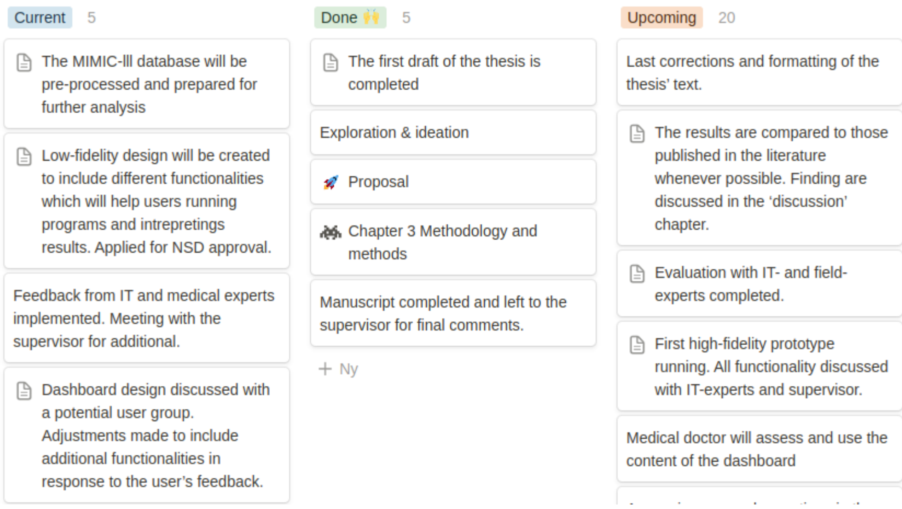

Figure 6.1: Board of project tasks.

React.js for Building JavaScript App

The reason for using React.js for the development of the prototype was due to personal experience and how it employs a component-based architecture, allowing to break down the user interface into reusable and modular components [56]. This approach promotes code reusability and maintainability, making it a good choice for building complex web applications. Additionally, it uses an unidirectional data flow, which helps in managing the state of an application to ensure that data changes are predictable and debugging becomes more manageable [57].

Figma and Illustrator for Sketches, UX and Logo Design

Figma is a web-based design and prototyping tool known for its collaborative features, making it suitable for creating user interfaces and interactive prototypes. It allows multiple team members to work on the same project simultaneously in real-time, which is particularly advantageous for remote teams [15]. On the other hand, Adobe Illustrator is vector graphics editing software used primarily for creating and editing detailed illustrations, logos, icons, and other scalable vector-based graphics [2].

The decision to use Figma and Adobe Illustrator for designing the user interface of the prototype stems from a combination of practical experience and the specific advantages offered by these design tools.

Figma's cloud-based platform facilitated project progression when working remotely, while personal experience with Adobe Illustrator made it the preferred choice when the circumstances allowed.

Vercel for Project Deployment

Vercel is a platform that allows developers to deploy applications, built on the Next.js framework, known for its efficiency and speed, ensuring that applications can handle high traffic levels without performance issues [13]. One of the reasons behind choosing Vercel, is because it is optimized for React applications, leading to quicker page loads and enhanced performance when hosted there [72]. Additionally, one of the main of Vercel is its easy integration with Github that allows developers to deploy applications quickly and easily [68].

6.2 Overview of the Iteration Process

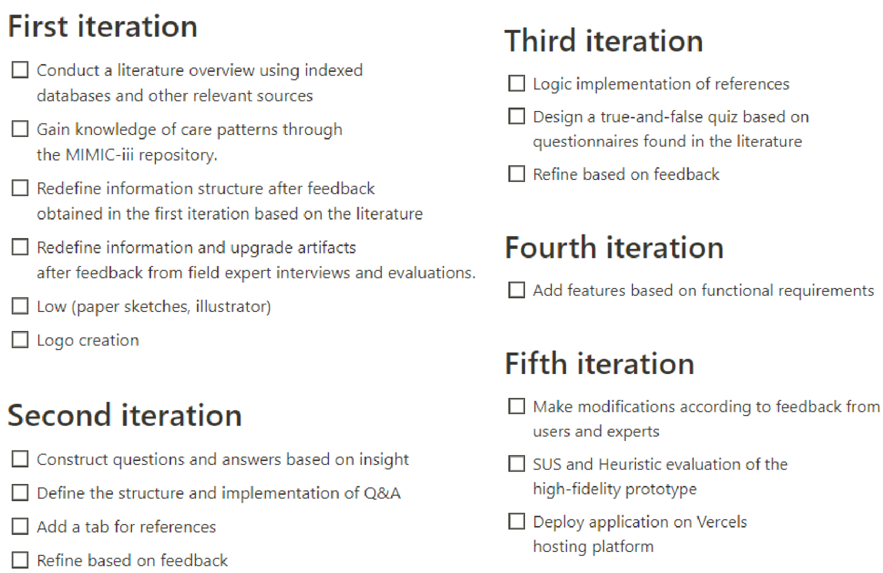

Figure 6.2: Overview of the iteration process.

6.3 First Iteration

This stage of the project focused on analyzing care patterns in antibiotic treatments using the MIMIC-III database, as well as insights from the literature review. MIMIC-III is a real-world clinical database that mirrors the actual conditions doctors face in treating various diseases with different antibiotics. These antibiotics vary in type, duration, and administration methods (both intravenous and oral). The research on this revealed that a significant number of patients were admitted urgently, as described in Chapter 4, Figures 5.7 and 5.8.

Data analysis has suggested that physicians must apply medical knowledge quickly and understand different circumstances and patient situations. Given that there are many kinds of antibiotics, it is important that clinical knowledge is always updated and available when needed. It is equally important to understand the resistance to microbiological treatment and what causes it. Such information is of interest to the patient, who can benefit from knowing what kind of treatment they have been given and what it means to receive antibiotics frequently.

Review of online resources, shows that certain websites are specifically dedicated to stewardship [32, 1, 20], encompassing clinical, societal, and legal aspects. These stewardship reports are extensive, addressing more than just medical concerns and are accessible internationally.

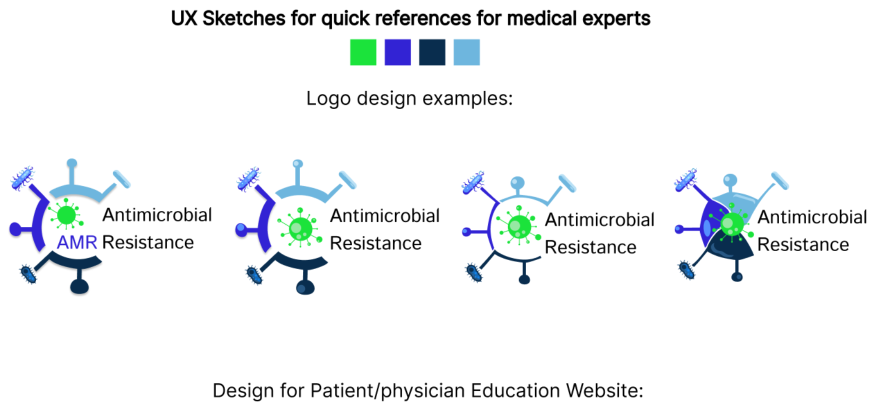

Figure 6.3: Development of Logo Design

There are also various online questionnaires designed to assess knowledge about antibiotics, targeting both the general public (such as those by the World Health Organization) [69] and medical professionals [5]. These initiatives serve to both educate the public and maintain professional engagement with ongoing developments in antibiotic treatments.

When creating a platform that consolidates important information on antibiotics, it's crucial to consider all these aspects. This platform aims to serve both patients and professionals, facilitating engagement with the material presented. Research indicates that general knowledge about antibiotics is lacking [65, 25, 5]. Additionally, there's a need for physicians to continuously update their knowledge in various situations and through different methods [5].

Hence, our objective in developing this tool was not to encompass every detail of knowledge, but rather to make this information readily accessible within a hospital or regional context, where both professionals and patients seek information.

Figure 6.3 displays the progression of our medical logo design, which went through four iterations to reach its final state. The logo tries to effectively capture the concept of AR. At its heart is a stylized depiction of an antibiotic-resistant bacterium, signifying the challenge we're tackling. This bacterium is vibrantly illustrated using a palette of four colors, adding dimension and energy to the design. A circular border surrounds the bacterium, essential to communicating our core message. From this circle, six lines extend, each representing a different facet of our mission and activities. Along these lines, various images, such as bacteria and pills, are placed, highlighting the critical nature of AR. The color palette is deliberately chosen to enhance the symbolism; the deep green represents growth in medical knowledge, the rich purple adds depth and complexity to the design and the two shades of blue, one vibrant and the other subdued, symbolize trust in sharing medical expertise and encourage collaboration and communication within the medical community and the general public.

Figure 6.4: Front page sketch

6.4 Second Iteration

Following the initial iteration, we determined that the information should feature sections tailored for physicians and patients, a questionnaire or quiz section, and references to key websites that consistently update their content with the latest clinical research, societal, and legal information. Figure 6.5 presents the initial design and application of our logo. Crafted using primarily four colors and their variations, the logo aims to facilitate quick recognition of the platform through repeated visits. The chosen colors are subdued, and the accompanying text is in black and white, a common color scheme found in most of the websites we reviewed.

As shown in Figure 6.6 displays the responses to the questions on the question-

Figure 6.5: The header navigation

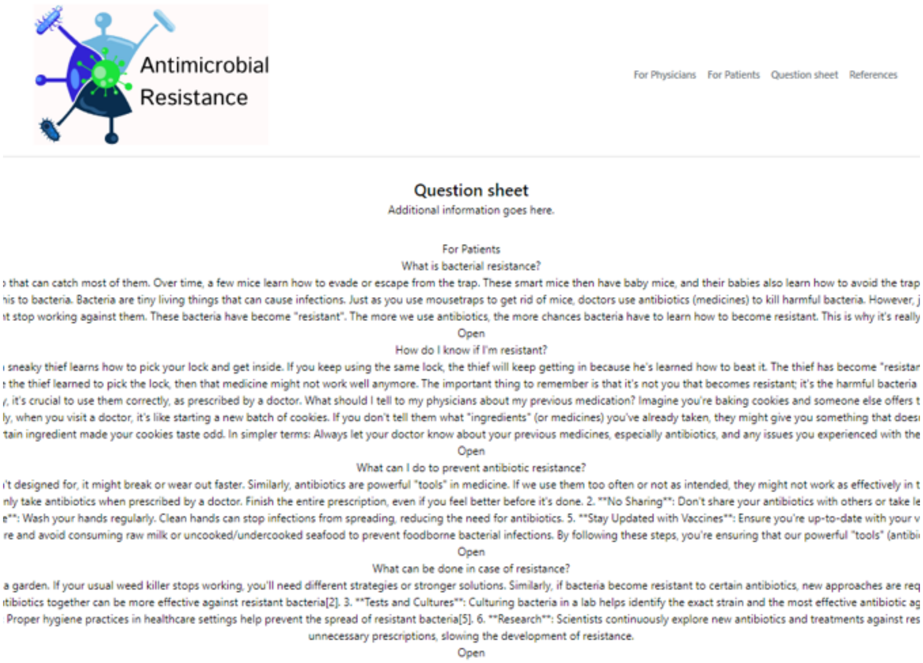

Figure 6.6: A set of questions and answers in the "for patients" tab

naire. The answers are compactly arranged to fit one set of questions per page, ensuring transparency throughout a session. While the text is clearly visible on the screen, it does present a large amount of information at once. Consequently, we have acknowledged that this format might be somewhat cumbersome to digest.

As shown in Figure 6.6 the answers are densely written to keep one set of questions on one page and, ensuring transparency throughout a session. On the screen, the text is normally visible, but there is a lot of information presented together. Therefore, we have considered that this way of presenting it might be somewhat cumbersome to digest.

Figure 6.6 illustrates a method of presenting information to patients. In this example, users encounter a series of questions and must click a button to view the answers, encouraging them to ponder the correct response. These questions are crafted based on literature and are simplified, incorporating the most pertinent information and analogies for easy understanding. The goal is to make the content as clear and approachable as possible for the general public. Following these questions, users can take a quiz to assess their knowledge. This quiz is in a True or False format, with statements derived from the "for patients" section. After each response, a brief, straightforward explanation is provided, along with references to the source of the information.

This flexible structure enables the addition of new questions and the organization of various types of questions to address different topics, such as diseases, antibiotics, or other relevant subjects.

6.5 Third Iteration

The quiz designed for medical professionals is more challenging, encompassing a wide range of topics from general knowledge to the latest research findings. The responses provided are concise and informative, supplemented with links to medical references where further detailed publications can be accessed for in-depth study. To illustrate the effectiveness of this approach, we have incorporated a quiz originally used in an Australian hospital [5], comprising 20 questions with answers that often suggest additional scientific literature for further reading. Quizzes are particularly valuable in clinical settings for both assessing and enhancing the knowledge of medical staff. Research has shown that experienced medical educators often develop questions to gauge and improve the understanding of healthcare professionals. Such a method could be beneficial for our information platform too, as it allows for quick creation and dissemination of quizzes, tailored to the needs and educational goals identified by senior medical staff. These shorter quizzes can be efficiently generated and added to the quiz section of the platform.

Following a cognitive walkthrough, we realized that the volume of information presented might be too much for users. A solution was found in a revised layout. Figure 6.7 demonstrates this new design, featuring four questions with buttons underneath to reveal the answers. This update has made the site more user-friendly and the key content more prominent by highlighting the selected questions. Now, any visitor to the site can quickly choose to delve deeper into the questions or move on to the next one, facilitating a smoother and more engaging user experience.

How the answers are presented to users

When presented with medical information, it is important that the patients are presented with information that might ease the medical aspects to it. As shown in Chapter 5, Section 4.1.3, one communication method that could help patients comprehend information is through analogies. In our research, examples of such are implemented in every answer to the questions in the "For patients" tab. One example of this is shown below for the questions:

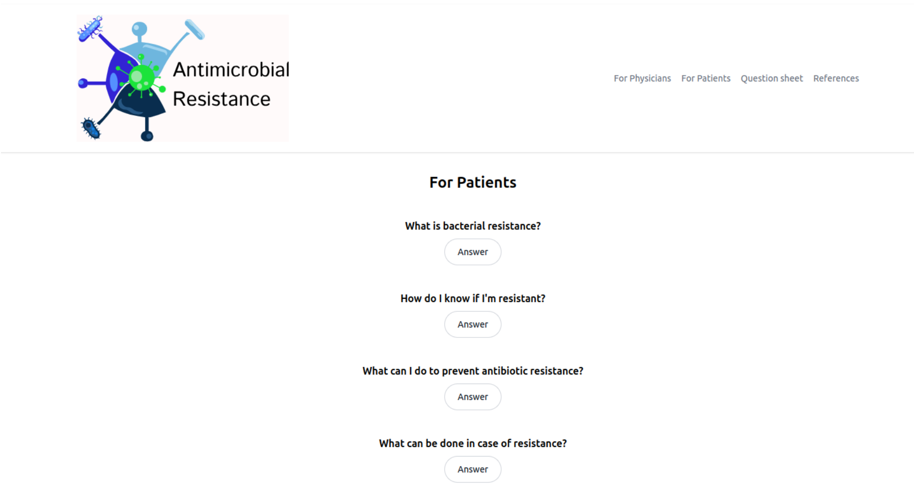

Figure 6.7: The updated version (Figure 6.6) of the questions and answers in the "for patients" tab.

"How do bacteria develop resistance?"

Imagine you have a lock on your front door to keep out unwanted guests. One day, a sneaky thief learns how to pick your lock and get inside. If you keep using the same lock, the thief will keep getting in because he's learned how to beat it. The thief has become "resistant" to your lock. Similarly, when you get sick, the medicine is like a lock that keeps out the "thieves" (harmful bacteria). But if the bacteria learn how to beat the medicine, just like the thief learned to pick the lock, then that medicine might not work well anymore.

The important thing to remember is that it's not you that becomes resistant; it's the harmful bacteria inside you. When a medicine doesn't work as well as it used to, it might mean the bacteria have figured out how to "pick the lock."To help our "locks" (medicines) work effectively, it's crucial to use them correctly, as prescribed by a doctor.

Figure 6.8 showcases a curated selection of prestigious websites that comprehensively cover antibiotic treatments and resistance. The aim of our platform is to expedite data searching by providing a vast array of relevant sources. Users are encouraged to delve deeper into each reference, which often links to additional websites and various reports. Many of these sites also refer to medical references for more detailed research insights. This section of the platform is exemplified with two references, one from Australia and another from Norway. It's common for national resources to be accessible globally, allowing for a comparison of different clinical approaches to antibiotic treatment. Notably, Norway is recognized for its judicious use of antibiotics, providing a valuable perspective for professionals in systems with higher antibiotic usage [18, 24]. In Figure 6.9,

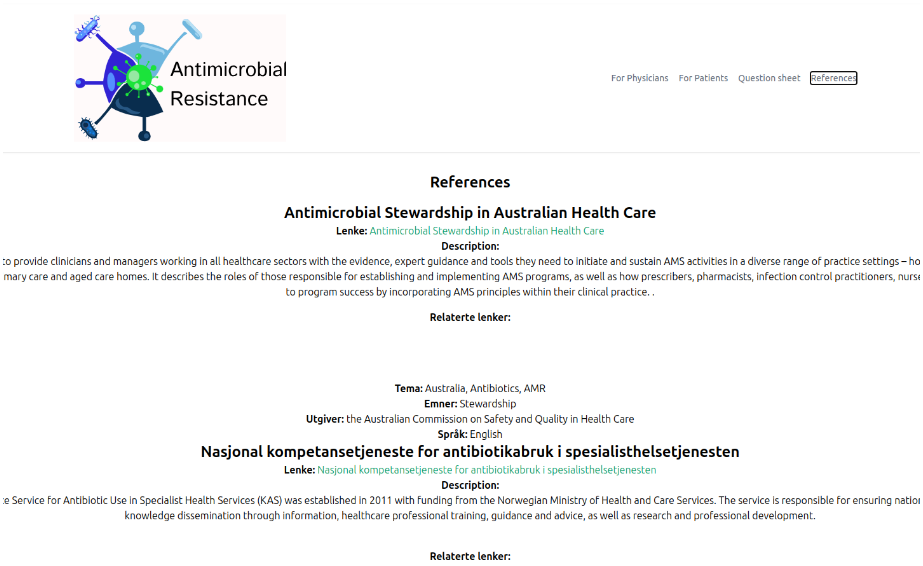

Figure 6.8: The "References" tab.

the quiz section tailored for patients was designed to spark interest by allowing them to test their knowledge with simple and straightforward true or false questions. Upon selecting an answer, users receive immediate feedback with facts related to the question, along with confirmation of whether their answer was correct or not 9.5. We deliberately chose a limited number of questions to maintain focus on the most crucial topics that the general public should be knowledgeable about.

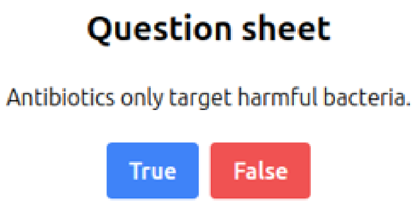

Figure 6.9: The quiz for patients to test their knowledge about important facts.

6.6 Fourth Iteraton

In this iteration, we focused on determining the most effective way to present information to physicians, ensuring it is easily accessible, informative, and regularly updated. We found that a format of questions and answers, similar to that used in conferences, was most effective for engaging physicians and disseminating new knowledge, especially given the frequent updates in antibiotic treatment. Recognizing that physicians often have limited time with patients, providing a quick reference tool can be extremely beneficial.

Figure 6.10 shows a layout with four questions. Physicians can read the

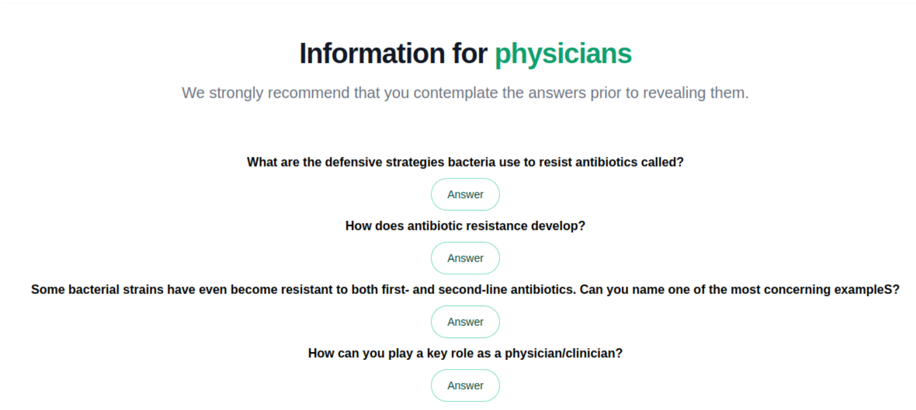

Figure 6.10: Four questions for physicians

full question and then click a button to reveal the answer. This design allows for the inclusion of more questions and the flexibility to categorize different types of questions. It's crucial to keep this page updated by staying abreast of ongoing research and scientific articles. The complexity of the questions can be tailored to accommodate physicians at various stages of their careers, from general practitioners who need regular updates to specialists who require more in-depth information.

In Figure 6.11 the quiz is designed to be taken by both patients and physicians. The level and amount of information as well as questions is adjusted accordingly. Even though it is not expected that patients are experts in antibiotic treatment, raising awareness of using antibiotics is important to mitigate the risks of misunderstanding the usage of antibiotics for all kinds of antibiotic-related treatments. Research in Australia has shown that patients often show that they have limited knowledge of antibiotics [5]. Current design of the site includes just a few questions that can be further investigated by clicking on the reference in the explanation section after the user has pressed their answer

Most of the questions for physicians are coming from professional medical sources created for physicians and a quiz presented at a conference [9]. This illustrates that knowledge is being updated frequently, and there is a need to make physicians aware and even read further following the links attached in the explanation. The current sample of ten questions can be extended with new questions and updated with new publications.

Both sets of questions can be answered by everyone who uses the platform. However, we have made two distinct sets (green for patients and blue for physicians) due to the level of medical knowledge that physicians have and that the public is not expected to have but could find useful and interesting to read.

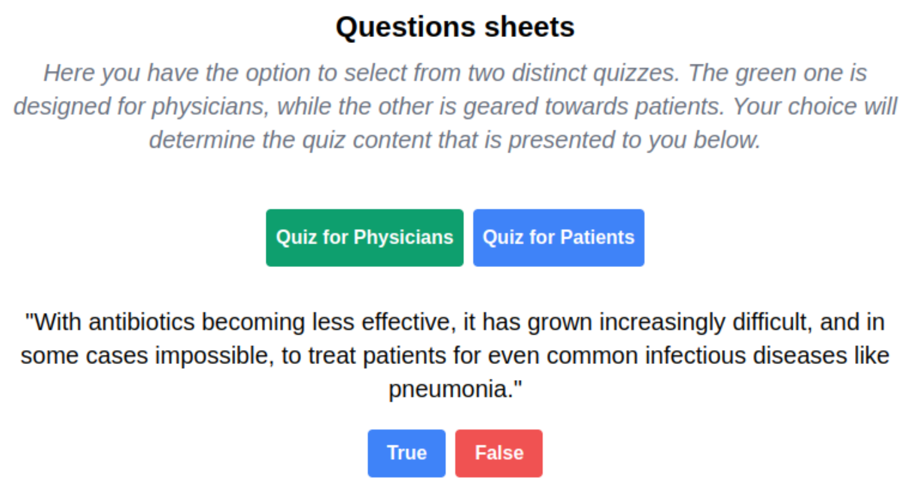

Figure 6.11: Quiz page for physicians and patients to test their knowledge about antibiotics.

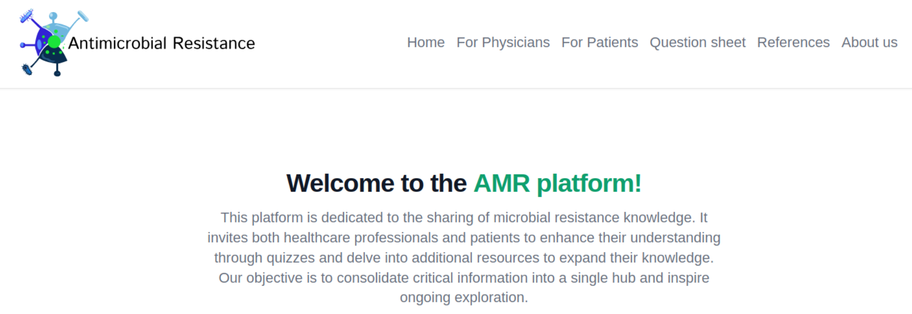

Figure 6.12: The home page of the website.

Here two practical web tabs added, one describing the mission of the platform and the other providing basic information about the creators and how to contact them as shown in 6.13.

Summary remarks of the Iteration Process

The content developed in this iteration was deemed sufficient for the purpose of serving as a quick reference. That was also estimated to be complete in terms of facts, links to the relevant websites, and raising awareness. In contrast to very detailed web resources such as government sites, this platform was intended to help different kinds of users gather information quickly and in the simplest possible fashion. The lean structure of the site, using just a few fresh colors, was designed to keep focus and make the retrieval of information straightforward. This iteration has included some improvements and functions compared to previous iterations. For example, the layout of the reference page has been changed to include a 'show more' button for the purpose of adding more white space so

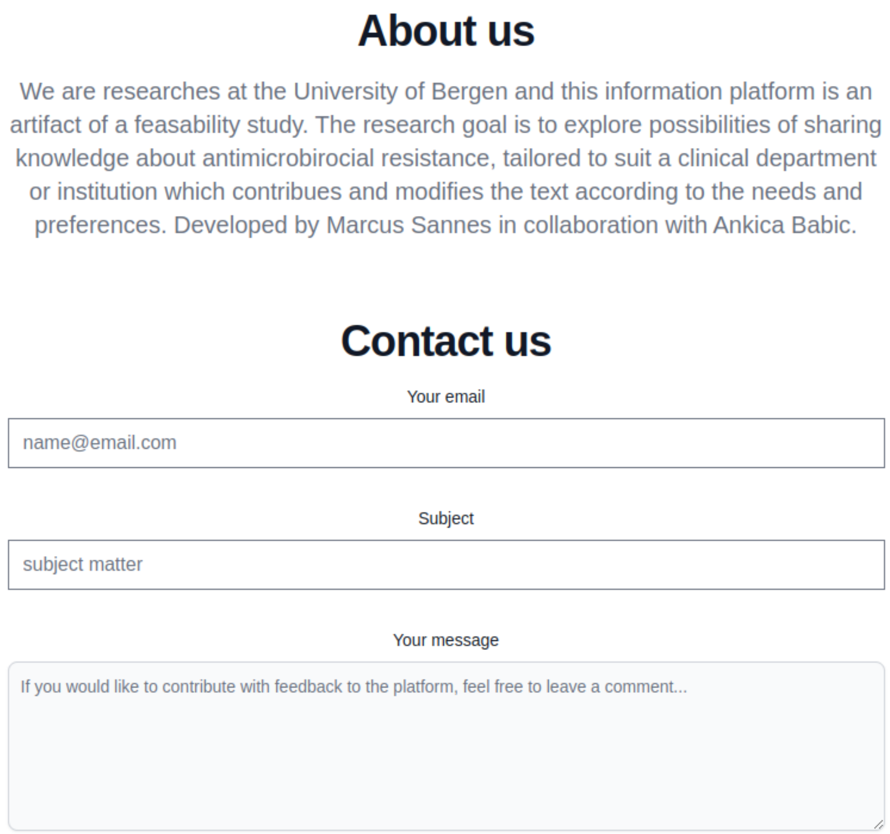

Figure 6.13: A simple "about us" page where potential users can contact the owner(s) of the platform

that the content is easier to read and scroll through. The structure of the tags is also more inline and compact, so it is easier to see the start and endpoint of each reference presented.

Chapter 7

Patterns of Antimicrobial Resistance

According to the literature there are several patterns of resistance which were obtained applying machine learning techniques in the MIMIC-III database 4.1 related work. The extracted knowledge is focused on medical diagnoses, such as sepsis [7, 41] or treatment of emergency cases at the general hospitals [14] as applied in a general hospital in Greece.

Research has identified various important patterns and two key elements that must be considered from patient data, as highlighted in the studies [41, 7]. These elements are Treatments (i) and Confounders (ii). **Firstly**, in Intensive Care Units (I), the challenge of managing infections resistant to multiple drugs is notably greater than in other hospital sections. Promptly identifying the infecting organism and determining its drug response is crucial for effective treatment, thereby enhancing the probability of positive patient outcomes [41, 7]. Thus, the analysis of various antibiotic treatments during ICU stays becomes imperative. **Secondly**, the role of (ii) Confounders, which includes a range of patient-specific factors such as vital signs, lab results, and demographic information like age and gender, is critical. These factors can significantly impact the efficacy of treatments and the course of the disease. Through thorough analysis of how these variables interact with treatment plans, a more personalized and effective care strategies can be applied.

Integrating Medical Insights through IT Systems for Enhanced Knowledge Sharing and Decision Support

Medical experts can evaluate and apply insights from literature, which is not easily found online or in digital formats. Therefore, IT systems are essential for spreading this knowledge. Simple guidance on medical tools can boost awareness and aid in decision-making. Although it's tough to merge different types of knowledge, a user-friendly IT platform can make them available, manageable by a single entity or a larger healthcare group.

Chapter 8

Artifact

This research has resulted in an artifact that combines different source of content directed at clinicians and public which can be accessed at www.teemo.no [66]. Its first mission is to inform and provide quick access to references of relevance for antibiotic-based treatment and resistance to it. It may support clinical decision-making, but this is not the primary goal. By being simple and providing possibilities to test the knowledge it attempts to make learning and interaction easy and engaging. The maintenance of the artifact is easy in the sense that tools are available for a straightforward implementation and the medical content can be moderated by physicians or interest organizations. By involving the most credible and practicing resource makes such a platform attractive for users to interact with. In spite of being a simple IT tool, it can include even further analysis should any database be available for public exploration. The medical content is to be evaluated and updated continuously which can be done as a part of antibiotic stewardship that is already dedicated to closely following the literature and medical practices.

There is also a question as to where this platform should be placed. It could be done as an institutional information system or it could come as a part of a professional healthcare system. In its nature, it is easy to employ in various settings and implement missing functionalities. The current conceptual model is based on the informative part in the form of quizzes and further references to relevant medical literature. But, it can be expanded to include more information, such as educational material in the form of case studies or further information to patients with the potential to highlight risks of antibiotic overuse and prevent disease development.

The Artifact in its current form is very simple which follows an outlay in many other dedicated websites. The design of existing information systems tends to be very lean and simple, with few figures or animations. However, additional media material (figures and presentation of bacterial development) could be added to the prototype providing that there is enough interest.

Chapter 9

Evaluation

This chapter focuses on the evaluation of the artifact, designed to enhance the overall UX of the artifact. The evaluation includes ten users, as well as four IT usability expert, who were encouraged to provide feedback and use the SUS questionnaire after having performed the 9 usability tasks created in this research.

9.1 Fifth iteration

In the fifth design iteration, the focus was to implement the suggestions provided throughout usability testing. Both users and IT experts evaluated the prototype through the means of SUS (Section 2.2.3) and heuristics (Section 2.2.4 as shown in Chapter 2. Additionally, the prototype was deployed on Vercel and can be accessed at www.teemo.no [66].

9.1.1 User Experience Feedback Group

In order to obtain diverse and comprehensive feedback on the prototype, a usability group comprised of various backgrounds participated in the evaluation. The purpose of such a design was to collect detailed feedback, specifically targeting the functionality and design aspects of the prototype from a distinct perspective.

According to Sharp et al., usability testing is not just a beneficial practice but a crucial and foundational process in the realm of Human-Computer Interaction (HCI) [63].

The group consisted of ten participants who could represent the target group and act as real potential users. This sample size was chosen to provide a focused baseline for evaluating novel designs and to detect usability issues effectively.
While a larger sample might offer a broader range of feedback, a carefully selected group of ten evaluators can still yield valuable insights into the prototype's usability and user experience [35].

I think that I would like to use this system frequently.	I found the system unnecessarily complex.	I thought the system was easy to use.	I think that I would need the support of a technical person to be able to use this system.	I found the various functions in this system were well integrated.
3	3	4	2	3
2	2	5	4	4
3	3	2	4	2
2	1	5	1	4
1	4	2	1	4
3	4	3	2	3
2	3	4	1	3
3	2	4	2	4
2	1	5	1	4
3	3	4	1	4

Table 9.1: Results from the users' SUS: First five questions

9.1.2 Usability Testing with Users

Ten users participated in the usability testing. The testing was conducted both in person and remotely over Zoom. This approach was designed to facilitate a comfortable environment where users could freely express their opinions and explore the content at their own pace.

A set of nine different tasks were defined for the users to complete. It was emphasized that questions during the testing phase would not be answered, and users were instructed to move on to the next task if they were unable to complete a given task to minimize bias as much as possible.

9.1.3 SUS Evaluation with Users

After solving the nine tasks the users completed the SUS evaluation form. Table 10.1 displays each user's score, which was rated using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The scoring process, detailed in Section 3.2.3, was facilitated by a custom macro in Google Sheets. The underlying logic of this macro is shown below.

```
function sus(...answers) {
  let soma = 0;
  for (let indice = 0; indice < answers.length; indice++) {
    if (indice % 2 === 0) {
      soma += answers[indice] - 1;
    } else {
      soma += 5 - answers[indice];
    }
  }
  return (soma * 2.5);
}
```

Listing 9.1: Raw automated SUS calculation [23]

The average score of the SUS evaluation was 62,5. According to Bangor et al. (2009), this score is considered to be good [6].

I thought there was too much inconsistency in this system.	I would imagine that most people would learn to use this system very quickly.	I found the system very cumbersome to use.	I felt very confident using the system.	I needed to learn a lot of things before I could get going with this system.	Raw automated SUS calculation
3	4	2	4	2	65
4	3	3	3	1	57,5
4	2	4	3	3	35
3	4	2	2	4	65
3	5	1	5	5	57,5
2	3	3	3	3	52,5
3	4	2	4	2	65
3	4	3	5	2	70
1	5	2	5	1	87,5
2	4	3	5	2	72,5
		Average raw automated sus calculation	62,75		

Table 9.2: Results from the users' SUS: Last five questions

9.1.4 Usability Testing with IT Usability Experts

Usability testing was done with four experts with background and knowledge on how to evaluate prototypes. Every expert who participated in the usability testing have a relevant background in IT - the majority of the participants have all completed a degree in information science. In Table 9.3 an overview of the experts with their background is shown. The table is based on the answers the experts gave in the interview guide (Appendix 11.2)

Based on the prototype all four experts were asked to complete the nine ques-

Experts	Background
Expert 1	Master's degree in information science, focusing on medical technology. Currently working with quality assurance of data.
Expert 2	Master's degree in information science, focusing on recommender systems. Currently working as a full stack developer.
Expert 3	Master's degree in information science, focusing on logics. Currently working as a full stack developer.
Expert 4	Bachelor in Cybersecurity and Hacking. Currently working with IT security.

Table 9.3: Overview of the IT usability experts

tions from the Google forms (Appendix 11.2). They were also asked to perform a SUS evaluation 9.2, Nielsen's heuristics 9.3 and answer questions from the interview guide (Appendix 11.2)

I think that I would like to use this system frequently.	I found the system unnecessarily complex.	I thought the system was easy to use.	I think that I would need the support of a technical person to be able to use this system.	I found the various functions in this system were well integrated.
3	2	4	1	4
2	1	5	1	5
2	2	3	1	3
3	1	4	1	4

Figure 9.1: Results from the IT experts' SUS: first five questions

I thought there was too much inconsistency in this system.	I would imagine that most people would learn to use this system very quickly.	I found the system very cumbersome to use.	I felt very confident using the system.	I needed to learn a lot of things before I could get going with this system.	Raw automated SUS calculation
2	4	2	4	2	75
2	4	1	5	1	87,5
1	5	1	4	1	77,5
3	4	2	4	1	77,5
		Average raw automated sus calculation	79,375		

Figure 9.2: Results from the IT experts' SUS: last five questions and the SUS score

9.1.5 SUS Evaluation with IT Usability Experts

The four IT usability experts did a SUS evaluation after the nine tasks were done and they had gotten some familiarization with the system. The SUS scores were based on the Likert scale (Section 2.4), from strongly disagree (1) to strongly agree (5). After the experts had given their scores, calculation as described in Section 2.2.3 was done. The results of the scores can be seen in Table9.2.

The average score of the SUS evaluation with the experts were higher than the scores with the users. The average was 79,37 witch according to Bangor et al., (2009) is considered scores above acceptable and reaching between good and excellent [6].

9.1.6 Heuristics with IT Usability Experts

In Table 2.2.4 Section 2.2.4 Nielsen's heuristics are described, and based on Figure 2.3 75% of issues can be uncovered with three to four participants. In this evaluation with gathered four participants. The experts were asked to give their input based on these heuristics. The grading was based on the Likert scale (Section 2.2.5), strongly disagree (1) to strongly agree (5). After the experts had given their input and score, the scores were calculated as described in Section 2.2.4. The results of the score are based on average values and are shown in Table 9.3.

Visibility of system status

The experts found that the visibility of the system status was clearly communicated to them and that they easily found the information. They also indicated that most of the time they knew what was going on in the system. However, three experts initially clicked on the wrong tab during the first task "Find the quiz for patients", which they found somewhat confusing.

Heuristics	Expert 1	Expert 2	Expert 3	Expert 4
Visability of the System	4	5	4	4
Match between system and the real world	5	5	4	4
User control and freedom	4	4	4	3
Consistency and standards	3	3	4	4
Error prevention	4	4	4	4
Recognition rather than recall	4	5	4	4
Flexibility and efficiency of use	4	5	4	4
Aesthetic and minimalist design	4	5	4	4
Help users recognize, diagnose, and recover from errors	3	4	4	4
Help and documentation	4	5	5	4
Results	3.9	4.5	4.1	3.9

Figure 9.3: Results of Nielsen's heuristics from IT usability experts

Match between system and the real world

The experts found the system's wording in the quizzes, answers, and the general language of the system to be understandable and easy to read, despite the presence of medical terminology. One expert stated, "The answers are precise; however, the text should be split into more lines. Add some whitespace to make it easier to read".

User control and freedom

Although there was no specific task to perform a quiz, the experts could interact freely with the system and take a quiz. However, they noted that the method to return to the previous question was not entirely clear

Consistency and standards

Additionally, three experts experienced confusion during Task 1 when attempting to locate the patient quiz. One of the experts stated, "A bit confusing as to whether or not it's under "for patients" or "question sheets" ".

Recognition rather than recall

Experts said that they did not have to memorize steps or information to navigate. However, one expert noted that elderly users might struggle to recall where to find the quizzes.

Flexibility and efficiency of use

The evaluators liked that they could go directly to the patient and physician sites without an additional step. An expert expressed enthusiasm for this feature, noting that it saves users time.

Aesthetic and minimalist

The input from all experts was that the system was very clean and had a nice use of color. However, an expert noted that the tabs were too tightly spaced, making it somewhat difficult to distinguish between them. Help and documentation Experts found it easy to perform quizzes and read the information for both patients and physicians. One suggestion was to implement a chatbot and a search function in the future, to further simplify navigation and assistance within the system.

Help and documentation

Experts found it easy to perform quizzes and read the information for both patients and physicians. One suggestion was to implement a chatbot and a search function in the future, to further simplify navigation and assistance within the system.

Concluding remarks

A comprehensive evaluation with users and experts was done to get feedback on the status of the system regarding user-friendliness and usability. The input from users and experts is helpful for future work on the system, and a possible next design iteration. New features could be added and some updates on the user experience. For example, change the names of some tabs and reduce whitespace.

9.1.7 Redefining after Feedback from Experts

A lot of useful information was gathered through usability testing. Some of the changes were modifications to the logo in the header, as the SVG file had minor bugs as shown in Figure 9.6. A "Show more" option was implemented in the references tab to make it more structurally pleasing, as can be seen in Figure 9.4. All these modifications resulted in a cleaner, high-fidelity prototype. Furthermore, an additional feature to the quiz was added, after the user pressed their answers, a pop-up appeared that included both an explanation and explanatory

Figure 9.4: "Show more" in reference tab

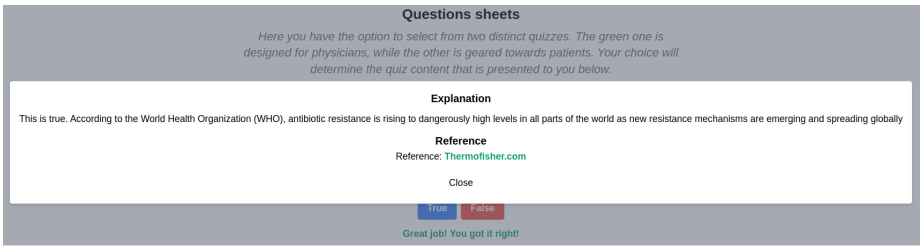

Figure 9.5: Explanation with references after answering the true or false quiz.

references as shown in Figure 9.5.

Color adjustments were made in the "For physicians" and "For patients" tabs as illustrated in Figure 9.7. Minor adjustments were made to the information presented when clicking "Answer" as shown in Figure 9.8.

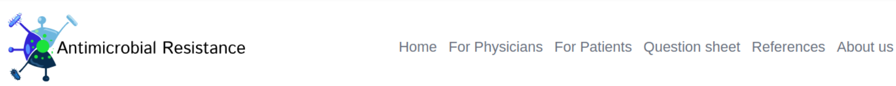

Figure 9.6: Adjustments made to the header

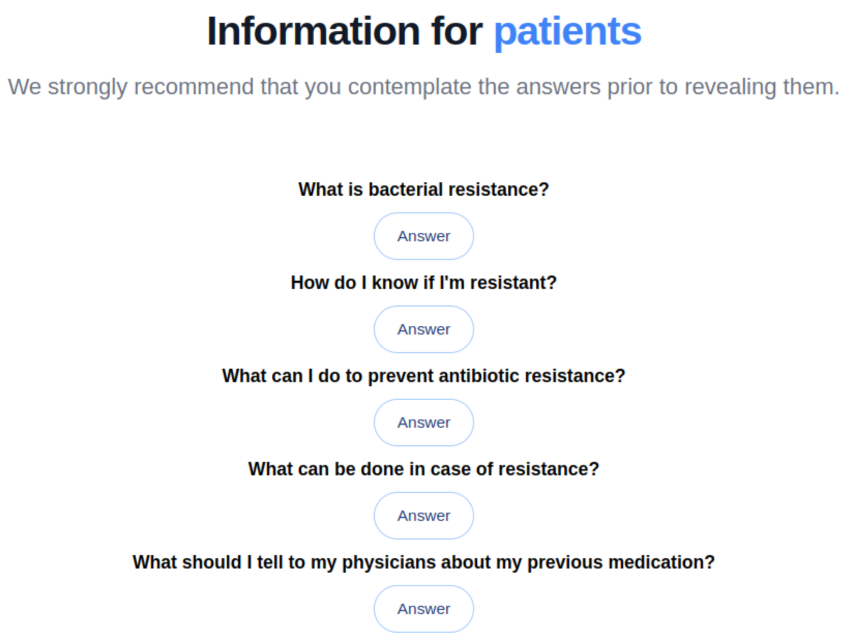

Figure 9.7: Color adjustments on "For physicians" tab.

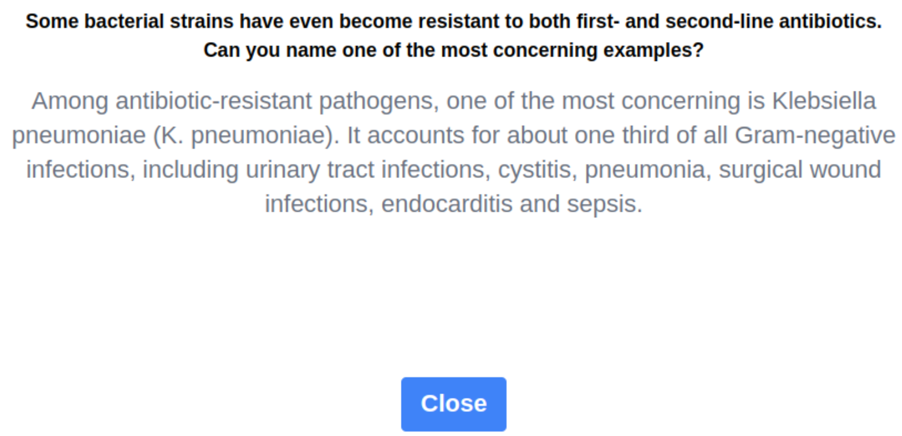

Figure 9.8: Text adjustments to the answer(s) provided

Chapter 10

Discussion

Antibiotic medicine is one of the most utilized treatment options in various fields of medicine, seen in elective and emergent patients of all ages starting from children to the eldest. Most of us will receive some or the other form of antibiotic treatment during our lifetimes even though there is a risk that we could become resistant to it if we are taking it often. Therefore, medicine has been exploring how to understand both the benefits and consequences of using antibiotics. The clear consequence of efficient or lacking antibiotic treatment is often described by the number of deaths which is more observed in some parts of the world due to the limited medication supply. However, prescribing it often also has consequences for patients. One of which is resistance that in some situations can lead also to poor patients' outcome. Part of the strategy is therefore to understand patterns of antibiotics usage and advise optimal and efficient medical treatment. For this purpose, the data is studied in different setups and a number of recommendations and guidelines are provided by healthcare authorities such as hospitals, councils and even governments.

Antibiotic-based treatment is a changing and growing field which physicians and other healthcare providers are required to follow either through their own hospital resources (consensus practice), governmental sites, dedicated healthcare bodies such as centers for disease prevention and monitoring. Even patients are becoming interested in topics relating to microbial-resistance and applications of guidelines (spreading awareness). For example, it might be advisable to avoid using antibiotics for some indications and preserve prescriptions for more severe illnesses in order to minimize the risk of becoming microbial-resistant. Studies have shown that there are many questions that patients could not answer regarding antibiotic treatment even though they generally are aware of its efficiency (Section 4.1.2). As a part of the preparation for this research, we have experienced how intensive and big research fields are concerned with antibiotic-based treatment and resistance to it. We had to focus on defining just a few research questions that could be answered based on the data and information we have found in the scientific literature, websites and MIMIC-III database dedicated to the antibiotic treatment.

10.1 Answering Research Questions

- **RQ 1:** What are the patterns of antibiotic treatment in general hospital based onMIMIC-III database? This question was answered by performing several procedures of data visualization tools to understand what kind of treatment, patients, admissions, and outcomes are registered in a standard everyday clinical routine. The database contains just a sample of the whole patient record system, but it is complete with respect to all kinds of clinical data recorded and kept during a patient stay. We have learned that the majority of patients are submitted as emergency cases, with only 6,2 elective cases. It would seem that on average, men receive more antibiotics with three most commonly prescribed antibiotic medications. Patients of all age groups are represented in the database with the age 60-69 having 20 recorded different diseases. The distribution of antibiotics suggests that older groups are prescribed more antibiotics, from the age of 60 up to 80 the frequency is only rising. Such information patterns suggest how valuable antibiotics are in treatment of emergency cases and how its usage is only growing with the age and covers all sorts of diagnoses, which is a posing a challenge to physicians on how to best manage treatment with antibiotics (5).

- **RQ 2:** What kind of information systems are available to support physicians with treatment?

  There is a huge amount of information in many forms that is not always easily available or understandable, especially in the cases of emergency when quick and practical advice could be most appreciated. One could start with the scientific publications that are many and often detailed and deal with focused research topics at the time. On the other side almost, each country has its own dedicated official website where lots of information is presented including legal, general recommendation, practical recommendations, and detailed information about the authorities themselves. There is even World Health Organization (WHO) to provide its own information system on antibiotics which includes some content dedicated to patients.

  There are also expert systems intended for learning and often providing as a part of the antibiotic stewardship. Several information patterns can also be identified, one of epidemiological dimension where effects of antibiotic treatment, and lack of it, are studied in terms of patient survival and impact on the society as a whole (Section 4.1.2). The next pattern is defined based on the clinical indication, such as sepsis (Section 4.1.4). There are also whole medical centers dedicated to either disease prevention or particularly to antibiotic treatment Antibiotikasensteret for Primærmedisin (ASP) [1]. Several hospitals have also created something which could be classified as an information platform whose purpose is to inform and provide the most essential and quick information. Such information systems have appeal especially as a support tool that could help users to receive information without going through vast number of websites, scientific publications, guidelines, and other topics. There are also examples of decision support systems capable of extracting information from the records or offering e-learning functionality [38] and tools dedicated to adverse events [4], all based on the same platform. The high-fidelity artifact resulting from this study could be modularly extended to include such functionality.

- **RQ 3:** How to design a user-friendly interface for physicians and other users to acquire and utilize information and treatment with antibiotics? This part follows the idea that is easy to utilize information that is also obtained smoothly and quickly. It does not mean that more elaborate competent and complex information cannot be considered easy to utilize. But then to be user-friendly, such information needs to be easily accessible and understandable. For example, the idea of an information platform that offers several important contents that are easy to review and approach, is one of the solutions to consider. An information platform should offer references where more detailed, complex knowledge can be found and studied further. The content can be presented in many ways to be appealing to users, but for utilizing quiz, questions and answers cuts the way to the important questions that deserve concrete and practical answers. This is typically appreciated by those who need information very quickly and to the point.

  Analysis of the websites and implemented guidelines suggest a very lean presentation of information with simple graphics and an easily readable amount of text. A practical information for such a design choice is probably that its saves time and keeps the ascension on the most relevant facts. The typical and biggest user groups are medical professionals that already have lots of medical training but are as well very occupied with routine work and not necessarily practicing only specialized fields as infections or antibiotics-based treatment. So, novelty and important information lifted to them in a simple way has a practical value and can be utilized very quickly (Section 6).

  Another group of users that are emerging is patients and the current content typically dedicated to them seems to be basic. A typical form is quiz with questions that can be answered with true or false

  with an explanation provided to raise awareness and inform about the main facts and issues relating to the antibiotic treatment. It needs to be explored how rich and simple design and interaction should be, when it comes to a broad range of public users. It is not excluded that adding interesting graphics, animations would have an appeal and help to better understanding of antibiotics. Research needs to be done with different user groups to create user-friendly functionality as has been seen in several other medical domains [67, 34, 31].

Chapter 11

Conclusion and Future Work

11.1 Conclusion

The artifact of this research was a most practical platform dedicated to antibiotics, open to all, ranging from novices to experienced individuals. The design and content are inspired by other professional sites used by medical doctors whose understanding of the background information is very high. Therefore, the artifact presents newer topics in the form of questions and answers, and offers a quiz section to test knowledge. In both cases, references are provided as part of the explanation and for further reading. There is also a dedicated section named 'References,' which is not limited to literature but includes other official websites and references as well. In this case, it can include materials such as reports or any other relevant readings not indexed in international databases. For example, a hospital might provide relevant documents, instructions, or particular guidelines for a certain period.

The artifact is currently designed as an independent platform, but it could easily be integrated into a larger information system, such as a hospital, university, or dedicated center, as a web-based system.This means that the owners of the system can modify the content, keep it updated, and maintain it as part of their own maintenance routine.

11.2 Future work

future work should combine the efforts of the front-end and the back-end to make a complete system for a wider audience such as patients, researchers and physicians. The platform is flexible enough that procedures for data-mining could be added if the owner of the platform has a database and want to share it. For example, there are quality registrars collecting data for decades, and they share results based on it. This can be extended to offering some data mining routines where users could obtain information for given periods, selecting indications of antibiotics given.

Two future directions could include developing an E-learning capacity and retrieval from various sources using a user-friendly interface.

Granting full access to the MIMIC-III would further benefit research and could elevate the role of providing an information system for spreading awareness, as well as further developing guidelines that might improve the usage of antibiotic treatment in order to keep resistance at a controlled level, thus maintaining its purpose and efficiency in treating diseases.

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A Appendix

A.1 Approval from SIKT

Sikt

Meldeskjema / Patterns of Antibiotic Treatment and Adverse Reactions: Towards a Use... / Vurdering

Vurdering av behandling av personopplysninger

Referansenummer	Vurderingstype	Dato
195722	Standard	27.11.2023

Tittel
Patterns of Antibiotic Treatment and Adverse Reactions: Towards a User-Friendly information platform Design

Behandlingsansvarlig institusjon
Universitetet i Bergen / Det samfunnsvitenskapelige fakultet / Institutt for informasjons- og medievitenskap

Prosjektansvarlig
Ankica Babic

Student
Marcus Sannes Thormodsen

Prosjektperiode
20.11.2023 - 31.12.2023

Kategorier personopplysninger
Alminnelige

Lovlig grunnlag
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Behandlingen av personopplysningene er lovlig så fremt den gjennomføres som oppgitt i meldeskjemaet. Det lovlige grunnlaget gjelder til 31.12.2023.

Meldeskjema

Kommentar
OM VURDERINGEN
Sikt har en avtale med institusjonen du forsker eller studerer ved. Denne avtalen innebærer at vi skal gi deg råd slik at behandlingen av personopplysninger i prosjektet ditt er lovlig etter personvernregelverket.

FØLG DIN INSTITUSJONS RETNINGSLINJER
Vi har vurdert at du har lovlig grunnlag til å behandle personopplysningene, men husk at det er institusjonen du er ansatt/student ved som avgjør hvilke databehandlere du kan bruke og hvordan du må lagre og sikre data i ditt prosjekt. Husk å bruke leverandører som din institusjon har avtale med (f.eks. ved skylagring, nettspørreskjema, videosamtale el.).

Personverntjenester legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til oss ved å oppdatere meldeskjemaet. Se våre nettsider om hvilke endringer du må melde: https://sikt.no/melde-endringar-i-meldeskjema

OPPFØLGING AV PROSJEKTET
Vi vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

B Appendix

B.1 Consent Form

Vil du delta i forskningsprosjektet?

"Patterns of Antibiotic Treatment and Adverse Reactions: Towards a User-Friendly information platform Design"?

Dette er en henvendelse til deg angående muligheten til å delta i et forskningsprosjekt med formål om å utvikle en nettbasert løsning for reseptutskriving av antibiotika. I dette skrivet vil jeg gi deg informasjon om prosjektmålene og hva din deltakelse vil bety for deg.

Formål

Hensikten med dette prosjektet er å skape en funksjonell prototype/en plattform for både helsepersonell og pasienter, med mål om å øke bevisstheten og fremheve viktig informasjon om antibiotikaresistens.

Et av hovedmålene jeg ønsker å utforske, er brukervennligheten til plattformen, samt om den presenterte informasjonen er godt nok strukturert og lett forståelig for brukerne.

Hvem er ansvarlig for forskningsprosjektet?

Universitetet i Bergen er ansvarlig for prosjektet.

Hva innebærer det for deg a delta?

Hvis du velger å delta i prosjektet, betyr det at du vil bli bedt om å gjennomføre et personlig intervju. Dette intervjuet vil ta omtrent 20-40 minutter av din tid. Under intervjuet vil du bli stilt spørsmål om dine meninger og erfaringer av å bruke systemet. Jeg søker tilbakemeldinger fra eksperter innen feltet for å kunne forbedre prototypen. Den primære metoden jeg vil benytte meg av er personlige intervjuer. I tillegg kan det også være aktuelt å gjennomføre brukertesting under nøye observasjon.

Det er frivillig a delta

Deltakelse i prosjektet er frivillig. Hvis du velger a delta kan du nar som heist trekke samtykket tilbake uten a oppgi noen grunn. Alie dine personopplysninger vii da bli slettet. Det vii ikke ha noen negative konsekvenser for deg hvis du ikke vii delta eller senere velger a trekke deg.

Det er ingen avhengighetsforhold for deg som deltaker.

Ditt personvern - hvordan vi oppbevarer og bruker dine opplysninger

Jeg vil kun bruke de opplysningene om deg som er beskrevet i dette skrivet. Alle opplysningene vil bli behandlet konfidensielt og i samsvar med personvernlovgivningen.

Som utgangspunkt vil deltakerne ikke kunne identifiseres i publikasjonene mine. Imidlertid kan deltakeren bli kreditert etter deres ønske. Hvis dette blir aktuelt, kan opplysninger som navn og yrke bli inkludert i publikasjonen etter samtykke fra deltakeren.

Hva skjer med opplysningene dine nar vi avslutter forskningsprosjektet?

Opplysningene vil bli anonymisert når prosjektet avsluttes eller oppgaven er godkjent, som planlagt i desember 2023. Ved prosjektslutt vil alle personopplysninger bli anonymisert, og all form for opptak (lyd, video) vil bli slettet.

Dine rettigheter:
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- Innsyn i hvilke personopplysninger som er registrert om deg, og rett til å få utlevert en kopi av opplysningene.
- Rett til å få korrigert feilaktige personopplysninger om deg.
- Rett til å få slettet personopplysninger om deg.
- Rett til å sende inn klage til Datatilsynet angående behandlingen av dine personopplysninger.

Hva gir oss rett til på behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke. På oppdrag fra Universitetet i Bergen har Sikt - kunnskapssektorens tjenesteleverandør vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?

Hvis du har spørsmål angående studien eller ønsker å utøve dine rettigheter, kan du kontakte:

- Prosjektveileder Ankica Babic og/eller Marcus Sannes Thormodsen (student) ved Universitetet i Bergen.
  - Ankica Babic - Du kan nå henne via e-post (Ankica.Babic@uib.no) eller telefon: +47 55 58 91 39.
  - Marcus Sannes Thormodsen - Du kan nå ham via e-post (dib009@student.uib.no).

Hvis du har spørsmal knyttet til Sikt sin vurdering av prosjektet, kan du ta kontakt pa e-post:
personverntjenester@sikt.no, eller på telefon: **73 98 40 40.**

Med vennlig hilsen

Ankica Babic (Forsker/veileder)

Marcus Sannes Thormodsen (Student)

....

Samtykkeerklæring

"Jeg har mottatt og forstått informasjonen om prosjektet "Patterns of Antibiotic Treatment and Adverse Reactions: Towards a User-Friendly information platform Design" og har fått anledning til å stille spørsmål. Jeg samtykker til følgende:

Jeg har mottatt og forstått informasjonen om prosjektet "Patterns of Antibiotic Treatment and Adverse Reactions: Towards a User-Friendly information platform Design" og har fått anledning til å stille spørsmål.

√ Jeg samtykker til å delta i personlig intervju.

√ Jeg samtykker til å delta i brukertesting (observasjonsstudie).

√ Jeg samtykker til at Marcus Sannes Thormodsen kan gi opplysninger om meg til prosjektet.

√ Jeg samtykker til at opplysninger om meg publiseres slik at jeg kan gjenkjennes gjennom navn, yrke, kjønn og alder.

√ Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet.

....

(Signert av prosjektdeltaker, dato)

B.2 Interview Form

Intervjuguide

Format: ansikt til ansikt eller digitalt intervju.

Svarregistrering: Lydopptaker, notater

Hensikten med intervjuet er å etablere en generell bakgrunn hos deltakerne. faglig og ellers. Deretter vil intervjuet fokusere mer på informasjonssystemer brukt i dagliglivet og etter hvert spisses inn mot teknologier brukt rundt antibiotika.

Intervju

Varighet rundt 30-60 minutter.

Deltakerne informeres om hva prosjektet går ut på og hva jeg ønsker med intervjuet. Deltakernes teknologiske kompetanse og deres kunnskap rundt antibiotika og tilhørende informasjonssystemer kartlegges.

Personalia

- Hvor gammel er du?
- Hva jobber du med?
  - Stilling / stillingsbeskrivelse?
- Hva er din høyeste utdanning?

Spørsmål:

- Hvilken erfaring har du med teknologi?
  - Vil du si at du er datakyndig?
- Hvilke teknologier bruker du på daglig basis?
- Kan du fortelle kort om en vanlig dag for deg med fokus på teknologier du bruker?

- Hvordan vil du beskrive din kompetanse i forhold til antibiotikabehandling?
- Har du kjennskap til informasjonssystemer som har fokus på antibiotika? Apper eller nettsider du bruker? Ikke-digitale løsninger?

- Hvordan finner du informasjon om antibiotika når du skal oppfriske kunnskap eller er i tvil om behandling?
- Er det vanlig å bruke digitale løsninger for å bestemme antibiotikabehandling?
  - Hvordan brukes de eventuelt?
  - Hvor sofistikerte er de?

    - Hva mangler de eller hva er vanskelig eller dårlig ved dem og hva er bra?

- Hvor fornøyd er du med nåværende løsninger for enten råd om eller læring om antibiotikabehandling?

- Hvilke funksjoner ville du helst hatt i en plattform for antibiotikabehandling?
- Hvor ofte tror du at du ville brukt en slik plattform om den var tilgjengelig?

- Har du noe mer du ønsker å tilføye som ikke har blitt nevnt eller spurt om?

Spørsmål etter visning av artefakt

Til medisinske eksperter:

- Hva synes du om løsningen som er blitt presentert?
- Har du noen forslag til endringer eller tilføyelser til artefakten?
- Hva synes du om det medisinske innholdet i artefakten?

Til IT-eksperter:

- Hva synes du om funksjonaliteten til artefakten som er blitt presentert?
- Hva synes du om designet?
- Har du noen ytterligere kommentarer til ditt SUS-skjema?
- Har du noen ytterligere kommentarer til ditt Nielsen-skjema?

B.3 User Experience Feedback Test

Prototype Usability and User Experience Feedback test

This survey is designed to gather feedback on the usability and user experience of a functional prototype. Participants will be asked to navigate through various features of the prototype, such as locating quizzes, finding specific references, and evaluating the clarity of information presented. The survey includes questions on the accessibility of content, the effectiveness of the design and color scheme, and the interactive elements like feedback mechanisms. Each question is optional, allowing participants to skip any as they choose. Your insights will be invaluable in enhancing the functionality and user experience of our prototype. Thank you for your participation!

1. Find the quiz for patients.

____

2. Find a Norwegian reference about microbial resistance.

____

3. In tab "for patients" - read the answer of question four. Was the explanation clear?

____

4. In what form is the information presented in the tab "for physicians"?

____

5. Is it possible to give feedback regarding the information presented on the platform?

   Markér bare én oval.

   - Yes
   - No

6. The quiz is giving no feedback to the questions, true or false?

   Markér bare én oval.

   - True
   - False

7. What is the purpose of using blue and green color?

   ____

8. Can you locate information on how to prevent antibiotic resistance.

   ____
   ____
   ____
   ____
   ____

B.4 System Usability Scale

System Usability Scale

The System Usability Scale (SUS) is a simple, ten-item scale giving a global view of subjective assessments of usability. It covers a range of aspects of system usability, including the effectiveness, efficiency, and satisfaction with which users can achieve their goals. Here are the general SUS questions, typically answered on a scale from Strongly Disagree to Strongly Agree

1. I think that I would like to use this system frequently.

Markér bare én oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

2. I found the system unnecessarily complex.

Markér bare én oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

3. I thought the system was easy to use.

Markér bare én oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

4. I think that I would need the support of a technical person to be able to use this system.

Markér bare én oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

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

Markér bare én oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

6. I thought there was too much inconsistency in this system.

Markér bare én oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

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

Markér bare én oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

8. I found the system very cumbersome to use.

Markér bare én oval.

	1	2	3	4	5	
Stro						Strongly agree

9. I felt very confident using the system.

Markér bare én oval.

	1	2	3	4	5	
Stro						Strongly agree

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

Markér bare én oval.

	1	2	3	4	5	
Stro						Strongly agree

C Appendix

Github repositories of MIMIC-III and the prototype

The codebase to the prototype

https://github.com/checkmatemarcus/AMR-Platform

The Codebase to the analysis of MIMIC-III data

https://github.com/checkmatemarcus/mimic-iii-data-analysis