



The effect of open-source software technologies in Health-tech Startups

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Noman Ahmad
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Abstract

Technology-driven startups, also referred to as health tech startups, are essential for providing cutting-edge solutions to numerous healthcare concerns in the rapidly evolving healthcare industry. These startups use technology to create solutions that boost, advance healthcare delivery, and improve healthcare systems. Open-source software technology has become an essential part of health tech startups' toolkits, providing various advantages and chances for innovation.

The research investigates how open-source technology improves product efficiency and identifies the challenges encountered by startups when introducing open-source software technologies in the startups. The semi-structured interviews were conducted with healthcare startups based in Oulu. Thematic data analysis was performed to analyse the collected data and identified common themes and sub-themes to the research objective.

The findings of the study show that startups improve product efficiency through open-source software like GIT, Linux, Android, Angular, and Unity. Startups gain access to cost-effective options, scalability, flexibility, and time-saving benefits. During the growth phase, the ability to customize the software to satisfy specific needs and leverage existing infrastructure greatly benefits startups. In addition, open-source software components accelerate the development process by reusing existing assets. However, the adoption of open-source technologies comes with challenges for startups. These obstacles include overcoming the learning curve associated with open-source software, managing frequent software updates and integration, navigating regulatory requirements, and addressing security concerns.

The thesis concludes that open-source software is important in improving the product efficiency of healthcare startups. By taking benefit of open-source software, such as flexibility, lower cost, and support from the community, healthcare startups can develop innovative solutions and improve the efficiency of their product. The challenges which startups might face include rapid changes, understanding open-source software, and regulatory issues.

Keywords

Startups, Health-tech Startups, Open-source software, Product efficiency

Supervisor

Nirnaya Tripathi, PhD (University Lecturer)

Foreword

I would like to sincerely thank my supervisor Dr. Nirnaya Tripathi who provided support to me through the process of my thesis and writing it. He gave me some valuable insights and suggestions after reviewing my work whenever I was struggling with some issue.

Lastly, I also want to thank my friends and family who supported me during the time of thesis.

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List of Terminologies

ADHD Attention Deficit Hyperactivity Disorder

AI Artificial Intelligence

CEO Chief Executive Officer

CTO Chief Technology Officer

EHR Electronic Health Record

EMR Electronic Medical Record

FOSS Free Open-Source Software

IOT Internet of Things

MRS Medical Record System

OS Operating System

RQ Research Question

SQL Structured Query Language

Contents

Abstract	2
Foreword	3
List of Terminologies	4
Contents.....	5
1. Introduction	6
2. Background	9
2.1 Startups	9
2.2 Health-tech Startups	9
2.3 Open-Source Software.....	10
2.4 Open-source software in Health-tech organizations.....	11
2.5 Product development in Startups	12
2.6 Use of Open-source software in product development	12
3. Methodology	14
3.1 Research Questions	15
3.2 Research Approach.....	15
3.3 Interview subject selection	15
3.4 Data collection.....	16
3.5 Data Analysis method.....	18
4. Findings	20
4.1 Participant and Startup information.....	20
4.2 Thematic Mapping of Findings	21
4.3 Product efficiency through the use of open-source software	22
4.3.1 Product development process	23
4.3.2 Open-source software characteristics.....	25
4.3.3 Open-source tools	28
4.3.4 Mentorship to Startups	30
4.4 Challenges while adopting open-source software	31
4.4.1 Rapid Changes	31
4.4.2 Open-source software knowledge	32
4.4.3 Regulation	34
5. Discussion	35
5.1 Answers to Research questions	35
5.1.1 Answer to RQ1: How can open-source technology help health-tech startups to increase product efficiency?.....	35
5.1.2 Answer to RQ2: What challenges do health-tech startups face when introducing open-source technologies in their organization?	36
5.2 Comparison with previous literature	37
5.3 Recommendations for Health-tech Startups	37
5.4 Study Limitations and further research suggestions.....	38
6. Conclusion.....	39
References	40
Appendix A. Interview Questions	44

1. Introduction

In recent years, it has been seen that software technology is getting more advanced day by day. Most companies want to get benefit from this technological advancement and introduce these technologies in their organization. With this advancement come significant concerns and risks. It is relatively easier for big or mature companies to deal with these hurdles, but startups need guidance due to limited technical expertise and resources in complex areas such as open-source software adoption. Researchers' and practitioners' deep knowledge and experience in open-source software can provide guidance to tackle the hurdles.

Open-source software technology is one of the technologies which has evolved a lot with time. The new organizations try to utilize those open-source software technologies in an effective way. Open-source software allows the software development team of any new startup to utilize the source code of a software application at no cost (Silva et al., 2023). The model of open-source software technology has changed the way software is developed because of open-source software's capability of providing reusability. Open-source technology became widely popular when it started to be utilized in business applications such as databases and servers. It all led to the development of the most famous open-source softwares, such as Apache and MySQL. Free Open-source software has provided a revolutionary way of increasing innovation by providing a powerful platform for low cost, better security, and customization (Silva et al., 2023). It is important to know for new entrepreneurs how they can utilize the open-source software technologies in their startups. This study focuses on the deployment of open-source software in the startups developing solutions for healthcare. The geographical focus is selected to Oulu area in Northern Finland due to practical research data gathering reasons.

Healthcare tech, in recent years, has become a rapidly important area of research and development because the advancement of healthcare infrastructure, such as health information systems, relies heavily on the findings of healthcare technology research. Technology integration can potentially improve the quality of care, innovative healthcare systems, and lower development costs. In the healthcare tech industry, open software can help in many important areas, such as electronic health records, clinical decision support, and other solutions. So, there is increased interest in investigating the intersection of healthcare and information technology. The healthcare industry is important in current society, and the need for the service is growing regularly. Healthcare startups try to utilize innovative open-source software technologies to meet the demand for healthcare services as a result of the advancement of technology. (Jha et al., 2008).

Some previous studies, such as Karpoka et al. (2014), discussed the benefits and adoption of free open-source software in the health care industry. The study views at several successful free, open-source software projects and products such as Apache server, Linux, MySQL, and Libre office and tells their possible use in the healthcare industry. This study also suggests that adopting open-source software in healthcare can produce good results in terms of cost saving, increased flexibility, and improved interoperability. Karpoka et al. (2014) study also shows that free, open-source software can improve collaboration between healthcare professionals. Moreover, the study by Syzdykova et al. (2019) also discusses the benefits of using open-source EHR systems, such as increasing the speed of accessing healthcare data, improving patient care, and also saving in cost. The study also discusses some challenges, such as technical expertise, limited support, and data security. However, the authors pointed out that more research is needed to assess these systems'

effectiveness and long-term viability in these low-resource settings (Syzdykova et al., 2019).

Syzdykova et al. (2019) also present a systematic review of open-source electronic health record systems specifically designed for use in low-resource settings. The study gives an overview of these open-source EHR systems' functionalities, features, and limitations, as well as their potential benefits and challenges. The study also discovered that OpenMRS and OpenEMR are the most commonly used open-source EHR systems in low-resource settings. It also shows that open-source software systems themselves are recognized as being customizable, easily adaptable, and scalable, making them ideal for the unique requirements of low-resource settings. (Syzdykova et al., 2019).

The use of open-source software in healthcare information systems is also covered in the study by Reynolds et al. (2011). The study shows that open standards and open-source software can improve the healthcare information system, such as a high degree of interoperability, cost reduction, and promoting innovation. According to Reynolds et al. (2011), possible advantages of implementing technologies in healthcare information systems are lower software development, enhanced data sharing between the system, and maintenance costs.

According to Nagy et al. (2010), open-source software offers cost-saving benefits, flexibility options, and the opportunity to compete with proprietary software dominance. While open-source software is becoming increasingly popular due to free use, there are still some issues while adoption in software companies (Nagy et al., 2010). Reynolds et al. (2011) also present the possible difficulties that can arise when open-source software is used in the healthcare industry, such as a lack of awareness or not understanding the open-source software correctly. The study discusses about security issues such as open-source software is not that secure as compared to closed proprietary software and it also suggests that healthcare organizations consider open-source software and standards when they select and implement information systems (Reynolds et al., 2011).

Oulu is the region where many startup companies have grown over the past few years. Technology advancements have had an important impact on startup development in the region of Oulu. Oulu is a city in the north of Finland. It is also known for its big focus on research & development, and innovation. Many startups are working on cutting-edge technologies such as IOT, 6G, and health-tech. According to (BusinessOulu, 2023), there are almost 320 startups registered currently, and out of 320 startups, there are almost 38 Healthtech startups in Oulu. Oulu is currently flourishing in the healthcare startup ecosystem, and a lot of healthcare startups in Oulu are taking advantage of open-source software technologies for the efficiency of their product.

The proper utilization of open-source software technologies in healthcare startups can allow them to improve their product efficiencies, such as customization, cost saving, and increased development speed. Startups usually struggle to invest so much money in highly paid software technologies or start everything from scratch. So, open-source software can play an important role in the healthcare startup industry. This research is to know how healthcare tech companies in Oulu region can benefit by using these open-source software technologies and the challenges they face while introducing those technologies into their organization. This research seeks to contribute to new startups in healthcare tech to know how they can benefit from using open-source software technologies in their organization by analyzing the use of open-source software technologies in the existing startups.

A qualitative research methodology was used to accomplish these goals, including semi-structured interviews with relevant participants related to health-tech startups and with thematic data analysis. The findings of this study provide knowledge about the effect of open-source softwares for increasing product efficiency and also challenges while adopting open-source software technologies in healthcare startups and provide helpful guidance for making the most of these open-source softwares.

This thesis has the following outline. Chapter 2 presents a literature review about concepts related to open-source software in healthcare startups. Research methodology, data collection, and analysis are presented in Chapter 3. The study's findings are presented in Chapter 4, which focuses on product efficiency through the use of open-source software and challenges while introducing open-source software in startups. The discussion about the answer to research questions is presented in Chapter 5, along with recommendations, comparison with previous literature, and further research suggestions for health-tech startups and researchers. The work is wrapped up in Chapter 6 with a conclusion.

2. Background

This section discusses the background of Startups, health-tech startups, and open-source software technologies, explaining some aspects of open-source software in health-tech organizations. The section 2.1 describes the background of the startups. Section 2.2 discusses about health-tech startups and the importance of technology in the healthcare industry. Section 2.3 represents the background of open-source software technology, also the challenges and adoption of open-source software. Section 2.4 discusses the knowledge of open-source software in health-tech companies. Section 2.5 represents the background of product development in startups, and Section 2.6 is about the use of open-source software in product development.

2.1 Startups

Krejčí et al. (2015) define “startups as a brand-new business with a cutting-edge technological and innovative business plan”. These businesses also have the potential for quick development and scalability. According to Spender et al. (2017), a startup is an organization, partnership, or short-term business created to find a scalable and repeatable business model. Ehsan (2021) introduces a revised definition of a startup that takes important factors like creativity, potential for development, and risk-taking into account. Product innovation is also considered one of the key difference makers between startups.

Entrepreneurship is viewed as a means to increase economic growth and generate wealth, and technology startups have gained popularity in this context. Startups usually bring unique products to the market and provide changes to conventional industries and boost economic growth. The success of startups highly depends on their ability to introduce radical innovations and maintaining a high level of product innovation for market competitiveness (Stahl et al., 2023).

Ehsan (2021) highlighted that further study on startups and open innovation is important. Studies that combine techniques, ideas, and theories from several disciplines are essential in longitudinal research to fully comprehend the role of startups in open innovation processes. Empirical research is needed to determine the extent to which new businesses employ open innovation tactics during their beginning phase.

2.2 Health-tech Startups

The health-tech startups sector has been growing rapidly in recent years. Usually, these startups are categorized and fueled by technological advances, improved healthcare services, and a growing interest in better healthcare outcomes with less cost. Health tech startups are taking advantage of emerging technologies, such as artificial intelligence, machine learning, and telemedicine, to create new solutions and revolutionize traditional healthcare models (Sreenivasan & Suresh, 2022). The Topol (2019) study shows that the capability of health-tech companies to use data and analytics for creating personalized and data-driven healthcare solutions is one of their main advantages.

Governments are in charge of providing everyone with a high-quality healthcare system at a fair price (Chakraborty et al., 2021). These health-tech companies are often started by entrepreneurs, healthcare professionals, or industry specialists who see an opportunity to enhance patient outcomes, increase efficiency, or improve care delivery. The delivery

of providing good quality healthcare services is quite challenging, and health-tech startups play a vital role in overcoming the challenges (Chakraborty et al., 2021).

A study conducted by Beaulieu et al. (2018) discusses that new health-tech startups also face competition from the big established companies, and sometimes the startups also use the services of those big giant companies. Further, Beaulieu et al. (2018) study shows that health-tech startups enable patients to manage their own health, but it comes with some risks and challenges.

2.3 Open-Source Software

The concept of open-source emerged in the late 1990s, but the idea of free software started in the 1980s (Gonzalez-Barahona, 2021). Over time, it has changed from being regarded as a fringe movement to being broadly embraced by people, businesses, and governments (Gonzalez-Barahona, 2021). According to Karpoka et al. (2014), open-source software allows users to use, share and change it and provides liberty to use the source code. Today there are many examples of free, open-source software products that are widely used, such as Android OS, Linux, and Apache servers. (Karpoka et al., 2014).

Open-source software is widely used nowadays in a lot of organizations as well as the research community. Many companies are developing software by reutilizing some open-source software libraries. Both users and makers of the software can participate in the development of open-source software through specialized processes, with consumers taking part in both new and existing products. The maker must make software-related choices, including licensing (Kapitsaki et al., 2022). Open-source software provides advantages in terms of its flexibility and potential for community engagement. Moreover, it gives the advantage of transparency because the code is available to the user for review and performing modification (Heron et al., 2013).

The Kapitsaki et al. (2022) study talks about the categorization of problems related to open-source software- such as the study giving important insights about the most common issues are faced by the development team and also shows an understanding of how important licensing and copyright are in the open software development. The study (Kapitsaki et al., 2022) analyzes twenty-six categories of problems related to open-source software development discussed on the open-source stack exchange site. The study results show that the most faced issue by development is with often understanding license and copyright and they are mostly discussed categories (Kapitsaki et al., 2022). Using open-source components in related software presents challenges, such as license problems, support and maintenance, community fragmentation, and legal issues (Butler et al., 2022).

The open-source software community has also been at the forefront of developing groundbreaking practices and thoughts around intellectual property licensing and the management of creative endeavors. Research on developer motivations and incentives, community dynamics, and the influence of open-source software can be proved productive on conventional software development models. (Von Krogh & Von Hippel, 2006)

Silva et al. (2023) discussed the factors which affect adopting open-source software, as the study shows that security, quality, usability, costs, effort, social influence, and performance are the important factors for utilizing free open-source software. Stol & Babar (2009) reviewed 63 empirical papers presented at four open-source software conferences, aiming to study empirical research in open-source software. They assessed

the quality of the studies and provided recommendations for improvement. The authors proposed four distinct categories for classifying empirical research in open-source software. The study (Butler et al., 2022) also highlights that organizations take the practical approach to assess open-source software components to use in products such as with larger organizations basing their decisions on frameworks or guidelines to inform their processes, whereas smaller enterprises reach conclusions through a group decision-making process, under the supervision of management.

2.4 Open-source software in Health-tech organizations

The use of open-source software in the healthcare industry is expanding quickly (Karpoka et al., 2014). The open-source software development model has played an impactful role over the years because it allows the developer community to contribute to development because of the free availability of the source code (Karpoka et al., 2014). In the healthcare industry, companies are adopting open-source software to ensure they can provide better patient care, innovation, low cost, and create value for the entire healthcare ecosystem involved (Santarsiero et al., 2023).

According to Alsaffar et al. (2017), electronic health record systems were first introduced at the start of the 1960s. In recent times, open-source electronic health records tools have been crucial in saving patient records and organizing data. The success of the open-source software system is dependent on elements like usability and functionality, which are often influenced by the objectives of the developer and subject-matter expertise. The study also provides insights into the developer's characteristics, background, and motives for working on open-source EHR projects. (Alsaffar et al., 2017).

The study by Shaikh et al. (2022) provides a qualitative analysis of open-source electronic health records. It discusses the adoption of open-source EHR systems in healthcare companies, highlighting the issues and challenges. The development of open-source EHR systems has benefits, including accessibility without financial restrictions, user-friendliness, and increased compatibility. Open-source software faces some difficulties, such as organization ownership, financial support for ongoing maintenance, usability issues, and limited resources in relation to the environment (Shaikh et al., 2022).

Butler et al. (2022) explained some issues that organizations face while adopting the open-source software components, such as

- Companies encounter difficulties in creating efficient work procedures for open-source software component evaluation. This also involves the assessment of the cost and hazards of adopting a component together with issues like functional needs and license compliance.
- There is pressure to keep improving software review methods due to the size and speed of software development in some firms.
- Some companies depend on developer-led techniques and other less conventional methods. Still, there are some companies that have built procedures for assessment of open-source software components that accommodate more complicated and nuanced assessments.

2.5 Product development in Startups

Product development is an important process for startups as they try to produce and promote new products. Startups frequently work in volatile and constantly changing contexts, challenging product development. (Blank, 2013)

Tripathi et al. (2019) discusses the different important stages of product development in startups, such as startup stabilization, growth, and maturity. Their study explicitly aimed toward the minimum viable product development in software startups. They carried out empirical research, including interviews with experts in the subject, and established a theoretical framework. The study provides insight into how software startups produce their minimum viable products and how the startup ecosystem affects this process. According to the findings of the study, there may be a need to distinguish between product idea validation and requirements validation in software startups. (Tripathi et al., 2019).

Several research publications have examined the relationship between Lean startup strategies and startup product development. For example, Lüthje and Franke (2017) investigated the impact of Lean startup practices on product development performance in early-stage startups. Customer validation and quick prototyping were favorably associated with product development performance in the study.

According to Kencanasari & Dhewanto (2022), one of the most important methods for startups to succeed in the competitive market is to consistently innovate and improve the new product development. Creating new products is thus a critical step in the growth and scaling of a firm. While many recognized frameworks for new product development exist, startups need to develop their own unique approaches that contribute to the wider theory and understanding of how to create successful digital products. (Kencanasari & Dhewanto, 2022)

Nguyen-Duc et al. (2017) discusses some challenges related to startup product development, that there is a mismatch between the iterative, evolutionary-oriented method used to build startup products and the effectuation-based approach used to develop startup businesses, particularly regarding software firms. The study shows that software startups frequently concentrate on locating regionally optimal solutions and give short-term feedback precedence over long-term plans. This method can result in difficulties with prototype planning, including ambiguity, the paradox of demonstration, and the requirement to iterate and reject prototypes continuously. (Nguyen-Duc et al., 2017)

2.6 Use of Open-source software in product development

The process of developing software has been extensively impacted by the adoption of open-source software (Fitzgerald, 2006). Researchers have discovered that open-source software can enhance the quality of the software, speed up software development, and foster developer collaboration (Fitzgerald, 2006). For example, Fitzgerald (2006) discovered that open-source software projects have better code quality and fewer bugs than proprietary software because of the vast number of engineers and contributors who examine and test the code. However, utilizing open-source software likewise presents some difficulties, including the need for efficient project management and governance and concerns related to intellectual property and security (Crowston et al., 2008).

The development of large software systems using free open-source software (FOSS) is popular as an alternative approach. Open-source software projects present new traits for project success that differ from the ones found in conventional industrial software projects, as well as new sorts and forms of software development techniques. (Scacchi et al., 2006).

The study (Spinellis et al., 2009) discussed the framework for improving the software development process in open-source projects. Spinellis et al. (2009) highlighted issues related to process management difficulties that open-source projects have and proposed a methodology that blends agile development techniques with the Capability Maturity Model Integration (CMMI) framework. The suggested model comes with a list of best practices and key performance indicators that may be used to gauge the software development process's level of maturity and pinpoint areas in need of improvement. The study also tells the benefits of implementing the suggested framework, including enhanced productivity, lower development costs, and higher-quality products. The report finishes by proposing potential lines of future research for improving and validating the proposed model (Spinellis et al., 2009).

3. Methodology

The three most common research methods are qualitative, quantitative and design science. Grosseohme (2014) defined the definition of qualitative research as that “it is arrangement, systematic collection, and analysis of textual data obtained from discourse or conversation is known as qualitative research”. On the other hand, quantitative research concentrates on gathering and examining numerical data in order to spot patterns, connections, and statistical associations (Creswell, 2014). A research methodology known as Design Science Research places a strong emphasis on the development and assessment of creative artifacts that solve actual issues (Hevner et al., 2004).

According to Sumathipala et al. (2011), Qualitative research methods can access the areas of inquiry topics that other research methods cannot because they seek to comprehend the intricate aspects of human behavior through the perspective of the participants in a real-life setting rather than in a controlled environment. The purpose of qualitative methods is to investigate a variety of phenomena, including feelings, ideas, human interactions, and other related processes (Sumathipala et al., 2011).

Qualitative research methods are one of the approaches to studying human beings because it allows a thorough and nuanced understanding of each individual's experiences and perspectives (Wallwey & Kajfez, 2023). Qualitative research should be ethical, well-documented, and use appropriate, rigorous methods. In qualitative research, the integrity of the research and its robustness are important. While studies involving measurable data necessitate replication, investigating personal or social experiences must capture everyone's distinct point of view. It is critical to present real-life experiences in a meaningful and representative way. (Hammarberg et al., 2016)

It is common practice in qualitative research to analyze and evaluate textual or numerical data, primarily gathered through spoken or textual methods, to find patterns that accurately characterize a given phenomenon, event, subject, or item (Chigbu, 2019). There are different types of qualitative research methods exist, such as focus groups, interviews, observation methods, action research, case study, and consensus methods (Sumathipala et al., 2011).

Quantitative methods have been extensively adopted because items that can be numbered or measured have more scientific credibility than things that cannot be measured or counted. However, quantitative study alone cannot adequately capture and address the extent of some cases, such as the impact or consequences in some scenarios. In such cases, qualitative approaches take a comprehensive approach, retaining the complexity of human behaviour by answering the "how" and "why" questions. (Lakshman et al., 2000).

In the case where factual data is needed to provide the answer to a research question, when general or probabilistic data about attitudes, opinions, beliefs, perspectives, or preferences is needed; then qualitative research methods are the better choice to utilize. Quantitative techniques can show, for instance, what proportion of the public supports assisted conception, how people are distributed by factors like marital status, age, and location, and variations from one poll to the next. (Hammarberg et al., 2016).

According to Borgstede & Scholz (2021), Quantitative research methods usually depend on the variable-based model and typically adopt a top-down generalization technique from an abstract population to specific cases. However, Case based models are preferred in Qualitative research methods, and it adopts a bottom-up generalization technique.

Design science research is another paradigm for solving a problem that aims to improve human knowledge through the creation of new modern artifacts. Design science research strives to increase technology and science knowledge bases through the development of new artifacts that help in solving the issues and making the better environment in which they are instantiated. (vom Brocke et al., 2020)

The qualitative research method is utilized in this research because it is suitable for identifying the perspectives and experiences of the participants related to health-tech startups. The semi-structured interviews are conducted with the participants to collect the data. Another reason for using the qualitative research method is that it is suitable for providing in-depth perspectives.

3.1 Research Questions

In this research, the author has focused on Healthtech startup companies based in Oulu. It is important to know about the effects of using open-source technologies in startups. The objective of the research is to determine how the open-source technological aspects affect product efficiency in startups and the challenges startups face while introducing open-source software technologies. To meet the objective, the identified research questions (RQs) are proposed in Table 1.

Table 1. Research Questions

RQ No.	Research Question
RQ1	How can open-source technology help health-tech startups to increase product efficiency?
RQ2	What challenges do health-tech startups face when introducing open-source technologies in their organization?

3.2 Research Approach

This study used semi-structured interviews and a qualitative research method to examine the experiences and perspectives of participants related to the use of open-source software technology in health-tech startups. Qualitative research is particularly suitable for investigating complex phenomena such as the adoption of new technologies in organizational contexts (Creswell, 2014). Participants for this research were chosen from startup companies related to healthcare with relevant knowledge and experience in this area. Semi-structured interviews were chosen as the method of collecting the data because they allowed for flexibility in the questioning and allowed the participants to elaborate on their responses (Sumathipala et al., 2011).

3.3 Interview subject selection

To select the interviewees for this study, purposive sampling is used to identify the use of open-source software technology in Oulu-based health-tech startups. The study's resources and the level of data saturation attained during the data collection process is used to determine the sample size. The elements, such as the stage of development and

the kind of health-tech services or products provided, are considered to ensure the cases chosen for the study represent the population of interest.

Startup CEOs, developers, and other decision-makers who know about adopting and using open-source technology are the subjects of the chosen interviewees. To get good, detailed data, it is ensured that the factors such as level of experience or role in the startup and familiarity with open-source software. The combination of purposive and snowball sampling methods is used to choose research participants.

Purposive sampling techniques are numerous, but criterion sampling is one of the most used in implementation studies or research. Combining sampling strategies, however, might be more in line with current advancements in quantitative methods and the objectives of implementation research. (Palinkas et al., 2013)

Snowball sampling is the qualitative research sampling technique mainly used when there are challenges to find subjects who have knowledge related to the research topic or the characteristics. In this method, the existing study subjects who have knowledge about the topic can give reference to the researcher and the sampling carried out until it reaches data saturation. The benefit of using the snowball method as compared to the random sampling method is that it helps to find the subjects which are not easily reachable by using random sampling. (Naderifar et al., 2017)

In the context of this research, purposive sampling is used as the researcher first identifies some health-tech startups in Oulu that are using open-source software technology. This is done using information from sources such as the business Oulu website (BusinessOulu, 2023). The initial set of startups is selected based on the use of open-source software in their company

Snowball sampling is used in the way that the already identified health-tech startups are asked to refer the other health-tech IT startups that meet the criteria of inclusion, such as the use of open-source software. The already identified startups are asked to give the contact information of other startups. So, reaching the startups or subjects with relevant information about open-source software becomes more convenient. This process continued until the desired sample size is reached.

Both sampling methods entailed identifying important players in each startup responsible for making decisions regarding the adoption and use of open-source technology and then requesting that they recommend additional potential subjects who satisfy the study's requirements.

3.4 Data collection

Purposive sampling, a non-random selection strategy that involves choosing people with specific qualities related to the research issue, was used to recruit participants (Palinkas et al., 2013). Participants in this study were selected who work in healthcare startups.

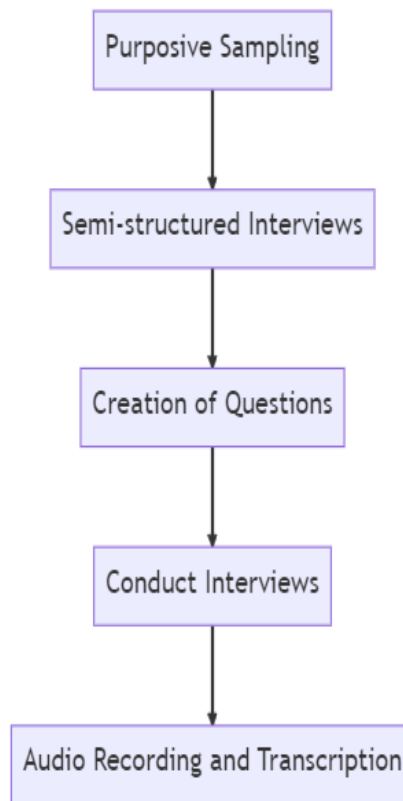


Figure 1. Data collection steps

Figure 1 shows that purposive sampling is used as selection strategy for the participants and the main method for collecting the data was semi-structured interviews. Semi-structured interviews were selected because they permit a flexible and tailored approach to data collection that can produce rich and detailed data (Jamshed, 2014). A versatile method for collecting data, semi-structured interviews help in a detailed study of participants' experiences and opinions (Jamshed, 2014). A series of open-ended questions created based on the study topics were used during the interviews.

The objectives of the interview questions (see Appendix A) were to collect data on participants' viewpoints and experiences with open-source technology use in health-tech startups. The interviews were carried out in startups companies remotely utilizing video conferencing software such as Teams. The interview questions were designed according to our research questions requirement. The interview questions were categorized into three parts. In the first part warmup questions in which participants and startups information is asked. The second part of the interview was main questions related to the research questions, and the third part was wrap-up questions. A few questions evolved during the interviews for example questions about the integration of open-source software with the existing system and about the benefits provided by open-source software. For analysis, every interview was audio recorded and transcribed. The consent was also asked to record the audio, and the findings' summary was sent to the participants for consent.

Data were collected up until the point of data saturation (Guest et al., 2006). The data is collected from the 6 participants from six different startups because the research was specifically based on the startups which are utilizing open-source software.

3.5 Data Analysis method

The technique of thematic analysis is utilized to analyse, identify and report patterns within the data. The thematic analysis approach flexibly trims the data and integrates with other approaches. The use of thematic analysis has some benefits, such as many different research problems and topics that may be addressed using this type of data analysis. (Castleberry & Nolen, 2018)

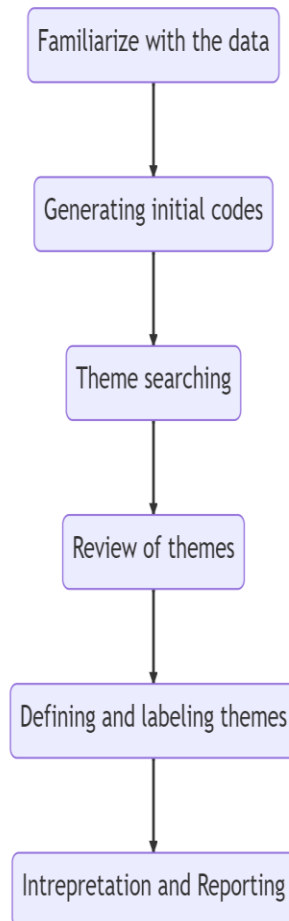


Figure 2. Thematic analysis steps as mentioned in Braun & Clarke (2006)

Figure 2 presents the data analysis steps which were introduced by Braun & Clarke (2006). Firstly, the data is familiarized, and spotting the patterns and themes that emerge from the data, a researcher must read and reread the transcripts several times. The second step involves the coding of data, which is performed, and it involves producing a set of codes that express the data's meaning. To find patterns and themes in the data, codes are labelled so that they reflect various characteristics of the data. (Braun & Clarke, 2006)

The third step involves identifying the themes by combining the codes related to comparable concepts or ideas to form prospective themes. The fourth step is review and theme improvement process which is performed such as reading the transcripts again to be sure that it still appropriately reflects the data. (Braun & Clarke, 2006)

The fifth step involves defining and labelling the themes, it involves labelling and defining the themes to ensure that they accurately represent the underlying patterns, characteristics, or meanings. Each theme is also given a name that accurately represents its content. The reason to perform this step is to analyse each theme and subtheme

carefully. The last step is reporting the finding, giving a clear and well-organized presentation of the themes and the data that supports evidence. (Braun & Clarke, 2006). In the study, data analysis is started by transcription of audio from the interviews. The interview transcripts are used step by step to find patterns, themes, and important insights. The goal of the analysis was to document the experiences related to product efficiency, viewpoints, and challenges associated with using open-source software in health-tech startups. The data is classified and arranged using codes. Text passages that indicated related thoughts or concepts were given codes. To find repeating themes and patterns, a detailed reading of the transcripts is performed.

The developed themes are identified after further analysis of the coded data. The iterative process of analysing and improving the codes led to the emergence of themes. Each theme highlighted a key component of the research study, such as product efficiency through the use of open-source software and the difficulties of implementing open-source software in healthcare startups. After discovering themes, themes are examined and interpreted to offer valuable information. In order to find connections and patterns in the data, it is made sure that themes and sub-themes are related to one another. It is made sure that the conclusions are rigorous and valid.

To support the determined themes, relevant quotes from the interview transcripts were included in a concise and well-organized summary of the data analysis's conclusions. The findings were presented in a thorough manner that addressed the goals and questions of the study.

4. Findings

This section discusses the findings found through data analysis from qualitative data. Section 4.1 defines about the background of the participants. Section 4.2 provides the summary of the findings through thematic mapping of the qualitative data.

4.1 Participant and Startup information

A total of 6 startups participated in the research, and the interviewees were CEO, CTO and Product and software development manager of healthcare startup companies. The participants were utilizing the open-source software in their startups and had relevant knowledge about the open-source software. The interviews were conducted online remotely on teams and the time duration for interviews were 45 minutes.

Table 2. Participant and Startup Info

Participant No.	Role	Health-tech startup description
Participant 1	CEO	This health tech startup develops a Preventive care system focusing on oral health. Startup offer organizations a way with their preventive care system to ramp up the preventive care
Participant 2	CTO	Solution for healthcare professionals, mainly for nurses, to be able to. Working at point of care situations with patients, mostly in hospitals, and like a mobile interface to the patient electronic health records system.
Participant 3	Product development manager	Warehouse management, logistics management and ordering program for healthcare. There are clients who use the system for medicine and some clients uses for healthcare and products related to healthcare. There is another segment which is for lab laboratory stuff.
Participant 4	Software development manager	Handheld fundus camera for taking retinal pictures of the eye
Participant 5	CEO	Neurological rehabilitation for speech and language therapy and neuropsychology. Now their focus is mainly on building and developing a product for the evaluation of executive functions which is one of the key components of attention deficit hyperactivity disorder (ADHD). They have designed product for ADHD evaluation. It's currently used in virtual reality, but

		they have started the clinical trial for Web version also.
Participant 6	CTO	Health-related mobile and web apps. Patient management systems and the latest healthcare product is an IoT product that is an IOT device that is placed to human ear, and it stimulates some nerves there and the mobile application where you can see how it's going.

4.2 Thematic Mapping of Findings

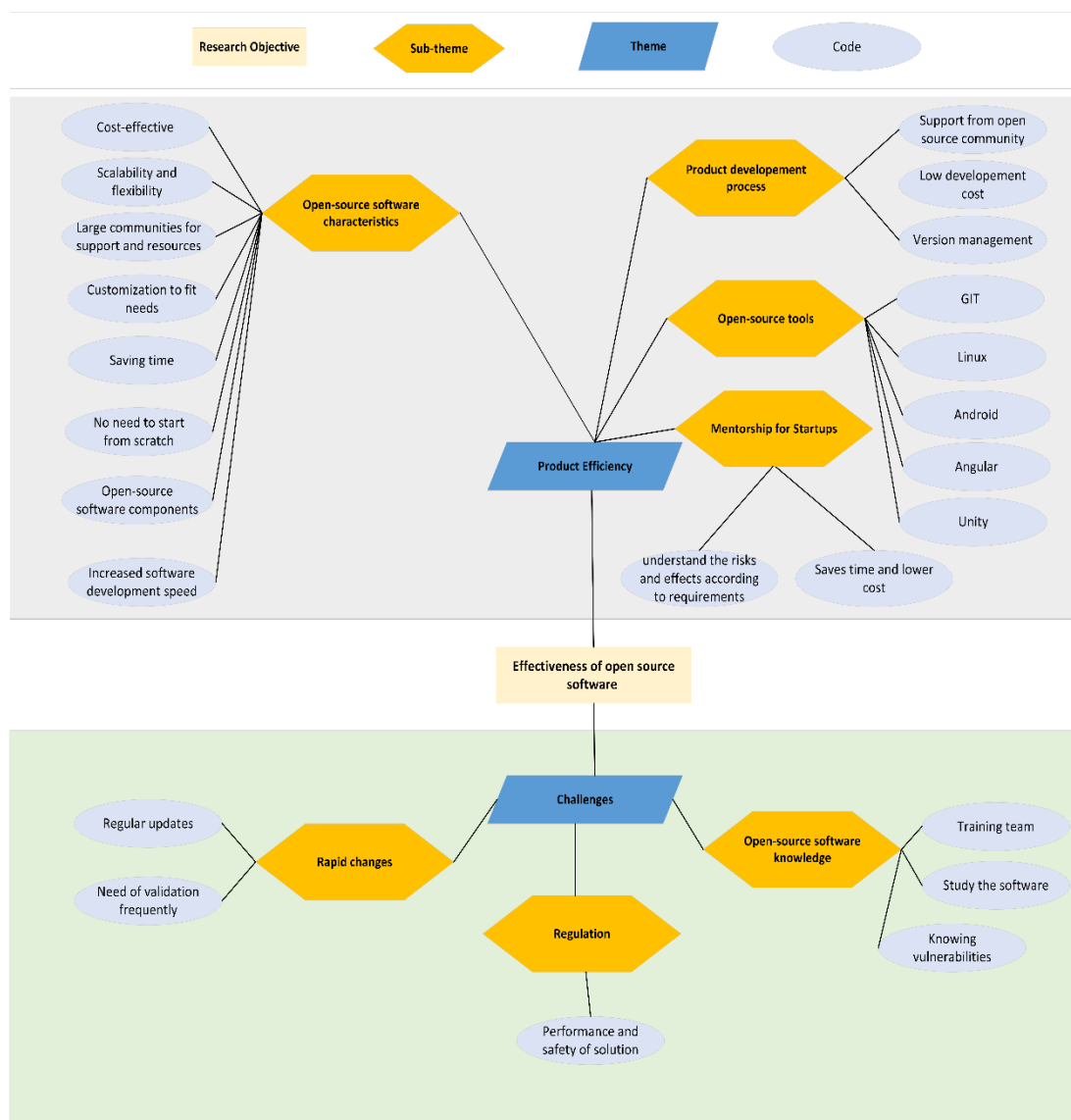


Figure 3. Thematic Map of findings

Figure 3 shows the graphical representation of the research findings through the use of a thematic map of findings. The thematic map features twenty-four codes and seven sub-

themes with two main themes. The first theme is about product efficiency through open-source software, represented by the grey background. The second theme is about the Challenges of startup companies while adopting open-source software, represented in the light green background.

4.3 Product efficiency through the use of open-source software

Table 3. Product efficiency through use of open-source software

Subtheme	Main factors
Product development process	Support from open-source community Low development cost Version management
Open-source software characteristic	Cost effective. Scalability and flexibility Large communities for support and resources Customization to fit needs. Saving time No need to start from scratch. Open-source software components Increased software development speed
Open-source Tools	GIT Linux Android Angular Unity
Mentorship for startups	Understand the risks and effects according to requirements. Saves time and lower cost

The product efficiency theme involves four sub-themes and codes found from the data collected through the participants through semi-structured interviews. It includes a total of eighteen codes which were showing the product efficiency and it involves the data from the interviews which have same patterns (see Table 3).

Following four sub-themes which are found in the product efficiency theme such as 1) product development process, 2) open-source software characteristics 3) open-source tools 4) mentorship for startups.

4.3.1 Product development process

The discussion with participants indicated that the impact of open-source software technology on the product development process improves the effectiveness of the final product in a number of ways. Most of the participants discussed about the fast pace of development because of support from open-source community and time saving due to proper version management of the product and also reduced expenses which directly improves the product efficiency.

In the impact of open-source software technology on product development process three main codes were identified such as support from open-source community, low development cost, version management.

Support from open-source community is mentioned by most of the Participants in the research. Participant 1 discuss about the large open-source community support, such as they get *“a lot of help through those communities and already information about open-source software’s on the Internet because there are different kinds of tutorials to help which provides flexibility to use open-source software and modify them according to our own use”*.

Participant 1's remark emphasizes the value of open-source communities in providing developers with assistance and resources. These communities are made up of people who are passionate about software development and are eager to share their knowledge and expertise with others.

The open-source community offers help in a variety of ways. As Participant 1 mentioned, there are various tutorials accessible on the internet to help developers use and alter open-source software. These tutorials are frequently written by experienced developers who have already gone through the software installation process and can provide helpful insights and advice.

While discussing efficiency, Participant 5 also talked about the open-source community that *“we have the open-source community that has already done these things and they are already made tools that you don't have to design it by yourself”*. Participant 5 further mentioned about Unity software *“as the open-source community in Unity has helped us a lot”*.

The comments of Participant 5 emphasize the value of the open-source community in providing existing tools that can save developers time and effort. This is especially important when designing software and tools that may already exist in the open-source community. Developers can avoid reinventing the wheel by accessing these tools and instead focus their efforts on adapting or building upon existing solutions.

Participant 5 particularly references Unity software and the open-source community within it in this example. Participant 5 discussed that the key part of their product is virtual reality simulation to evaluate ADHD symptoms same as the game. Unity is a prominent game creation engine that offers a variety of tools and resources to help developers create high-quality games. The Unity open-source community is a group of developers who give

code, tools, and knowledge to the community, making it easier for new developers to build upon their work.

Participants 1 and 5 comment shows that by facilitating chances for knowledge sharing, reusability, collaboration for innovation, and continual development, the open-source community's support increases product efficiency. It also shows that startups can speed up their development process by lessening effort duplication and accessing resources and experience from the open-source community.

Low development cost of open-source software technology is impactful on product development process, which is discussed by most of the participants. Participant 1 talked about the cost effectiveness by using open-source software and he stated that *“the cost effectiveness and open-source software are flexible and scalable which are the like the most important things when developing”*.

Participant 1's statement regarding open-source software's cost-effectiveness and flexibility underlines some of the primary benefits that developers can receive from utilizing such software in their projects. Open-source software is frequently accessible for free or at a low cost, which can greatly lower the financial burden of software development, especially for small and medium-sized organizations.

Furthermore, according to participant 1 statement, open-source software provides a great degree of flexibility because users can alter and personalize the software to meet their own needs. This enables software developers to tailor the software to individual use cases and needs, resulting in more efficient and effective solutions.

While talking about the cost, Participant 2 said, *“The cost benefit is quite obvious. We are Deploying our solution on premise style. So the full deployment stack, the platform doesn't require any like licenses costs at the moment at this scale. So especially if you're startup and then depends on of course how you deploy, but if you can keep the footprint fairly low then then this is a good choice.”* Participant 3 also mentioned while talking about open-source software impact *“Surely they are cost efficient.”* Both Participants 2 and 3 underline the importance of low cost of open-source software. Participant 2 emphasizes that using open-source software to deploy their solution provides apparent financial benefits, particularly for startups. They emphasize that using open-source software eliminates the need for costly licenses, which can be a substantial cost for organizations, for the deployment stack and platform. Participant 3 concurs that open-source software is inexpensive.

The comments by Participant 6 also show that open-source software provides low cost in product development, as Participant 6 mentioned, *“Definitely it saves in cost so you don't have to buy some, uh expensive libraries to use it”*. Participant 6 statement tells that open-source libraries also help to save startups some money by employing open-source software instead of spending money on pricey proprietary libraries or tools. One of the main factors in the widespread adoption of open-source software across numerous industries is its ability to reduce costs.

According to participants' comments, open-source software can be a realistic and cost-effective choice for startups, particularly those with limited resources or in the early phases of development. Startups that use open-source software can save money on licensing and invest more in other aspects of their company. As Participant 2 mentioned, using open-source software allows them to deploy their solution in a more customizable and scalable manner.

The participants' comments show cost saving through open-source software is also linked with product efficiency because cost savings allow companies to more wisely deploy their resources, spend money on product improvements, and provide high-quality services while still being competitively priced. The cost-saving from open-source software improves product efficiency by optimizing resource usage and encouraging sustainable growth for companies.

Version management is one of the factors which Participants talked about the impact of open-source software in version management as Participant 5 mentioned that *“we are using in GIT in our product development process and that is basically the source code, version management software and that's an open-source tool that we utilize.”*

Participant 5 furthermore added, *“GIT is like a core of the version management and understanding of source code And I would say that it has quite significant impact. For the product development as a team it is important to know the version and how they are and it's also on the regulation side that we can prove the changes that we have made and what versions we have and then to the change control and change history.”*

Participant 3 also talked about GIT as open-source software: *“we use GIT pull to take the code to myself and I am I have been a programmer, so I still read code.”* And further added that *“we actually quite recently switched to GIT and I've been hearing good things about that it is much easier to handle the code with it”*.

Participant 5 statement tells the importance of version management and the role of open-source software in it. The usage of GIT as a source code version control solution has aided the Participant 5 team in tracking changes and maintaining a history of the version, which is critical for product development and regulatory compliance. The team gets access to a mature and extensively used tool that has been developed and tested by a huge community of developers by using open-source software like GIT. This not only saves time and effort, but also ensures the tool's dependability and stability. Version management is very important in software development since it allows teams to keep track of changes, cooperate effectively, and avoid mistakes. Participant 3 highlighted the advantages of adopting GIT, particularly in terms of code management convenience. As a programmer, Participant 3 finds GIT makes it easier to read and work with code. The positive things they've heard about GIT also influenced their decision.

Overall, participants' statements show the importance of version management due to open-source software in improving product efficiency. The open-source software helped the startups in improving the efficiency of the product by saving time through version management because the teams in startups can collaborate and keep track of changes that happens in the product.

4.3.2 Open-source software characteristics

The subtheme of open-source software characteristics for startups is identified because the participants talked about the benefits through which they improved the product efficiency by utilizing open-source software in startups. It is found from discussion that lower expenses, time saving, open-source software components, increased development speed, scalability and customized solutions, and community support, all of those factors improve the overall effectiveness of their products. Most of the participants talked about utilizing the advantages of open-source software, startups can better match their product

offers with consumer needs, accelerate the process of development, and lower the costs which boosts product efficiency and competitiveness.

Following are the codes which were identified in the sub-theme of open-source software characteristics such as saving time, cost effectiveness, scalability and flexibility, large communities for support, customization to fit needs, open-source software components, increased development speed and no need to startup from scratch.

Time saving, some of the participants talked about time saving through use of open-source software in the same pattern such as participant 5 mentioned that “*use of open-source software saved us time and without them we needed to start from scratch which consumes time*”. Participant 1 also talked about time saving that “*open-source software provides benefit of faster time to market*”. The benefits of utilizing open-source software for time savings are highlighted by participants 1 and 5. The benefit of faster time to market is especially mentioned by Participant 1, which means that startups can release their products to the market more quickly by employing existing open-source software rather than developing everything from scratch. Since they may concentrate on creating their distinctive features and functionality rather than spending time on developing fundamental infrastructure, this might be especially advantageous for startups or small businesses with limited resources.

In order to avoid having to start from scratch, Participant 5 further reinforces this idea by pointing out that utilizing open-source software saves time. Instead, programmers can expand upon already developed software and alter it to suit their unique requirements. When it comes to product development, where time-to-market can be a crucial success factor, this strategy can be especially beneficial. Startups can save time and money and launch products faster by utilizing open-source software.

Scalability and flexibility in open-source software are also discussed by participants such as Participant 1 said that “*Open-source software’s are flexible and scalable which are the like the most important things when developing.*” Participant 1 further added that “*flexibility and scalability and possibility to customize everything gives us benefit.*”

The benefit of employing open-source software for flexibility and scalability is highlighted in participant 1's statement. Scalability refers to the program's capacity to grow or shrink in response to shifting demand, whereas flexibility in this context refers to the ability to adapt and alter the software to satisfy particular needs.

Participant 4 statement proves that open-source software provides customization because their startup builds proprietary service software based on open-source software and tools such as he mentioned, “*we're using a lot of open-source libraries and open-source tools to build our proprietary service software.*” Overall, the participants' statements show that open-source software provides flexibility to customize your software and it also provides scalability. Developers can easily adapt open-source software to meet their unique needs thanks to the extensive customization options it offers. With open-source software, developers can alter the code, add new features, or delete undesirable functionality. This degree of personalization enables programmers to produce distinctive solutions that cater to their particular startup requirements, thus enhancing their competitive advantage.

Cost also enhances productivity and efficiency, which is discussed by many participants in the same pattern mentioned above in low development cost in more detail such as participant 2 said that “*cost effectiveness is obvious*”. Participant 2 also gave information about the benefits of using open-source software and he stated that “*open-source software*

reduces the cost for deployments". Participant 5 also said that *"open-source software provides cost savings"*. Open-source software also helps in cost saving and participant 6 statements proves that *"Definitely it saves in cost so you don't have to buy some, uh expensive libraries to use it"*. Participant 6 statement tells that startups can avoid buying some expensive libraries by utilizing open-source tools and libraries which have almost no cost. The cost effectiveness of using open-source software is an important benefit, and it is acknowledged by most of the participants in the study. By taking advantage of open-source software, startups can save deployment costs while also gaining some customization and flexibility that arrives with open-source software.

The participants talked about utilizing existing components and solution in the product. Participant 1 and Participant 2 both acknowledge the same benefit of utilizing existing solutions and components instead of reinventing them. Participant 1 stated that *"Open-source software are cost effective and flexible. Moreover, there are large communities and a large information available on the internet, including a wide range of tutorials, rendering them highly adaptable and modifications can also be made according to use."* Participant 2 mentioned that *"we speed up the development by using existing components instead of writing our own code. We have hundreds of different open-source components in the solution and for runtime the platform also uses open-source components. So, they are performing various functions within our solution."* Moreover, participant 2 said that *"there is no point in reinventing the wheel"*. Participant 1 highlights the affordability and adaptability of open-source software.

Participant 1 statement highlights the affordability and adaptability of open-source software. This aligns with the idea that using open-source software instead of proprietary solutions might help firms save money. Open-source software is also adaptable, making it simple to modify it to meet certain requirements. Participant 2 highlights the acceleration in the development process that can be attained by employing pre-existing open-source components as opposed to creating new code from the beginning. Participant 2 statement also shows the enhanced effectiveness achieved through the utilization of pre-existing solutions and components.

The common theme in participant 1, participant 2 and participant 3 statements is the acknowledgment of the advantages of open-source software in terms of cost-effectiveness. Both Participants 2 and 3 recognized the benefits of employing pre-existing components and solutions instead of creating from the start, which is in line with the concept of capitalizing on the efforts already made by the open-source community.

Participants 4 and 5 reasons were also similar to the other participants in terms of utilizing the open-source libraries and tools which already exist and can be customized such as Participant 4 gave the reason for utilizing open-source software as *"Well, open-source software's are an essential part of our product. The whole system is based on Linux, which is an open-source. To build the whole operating system and on top of that we're using a lot of open-source libraries and open-source tools to build our Proprietary software."* Participant 5 described the reason as *"the key component of our product is simulation part in virtual reality and that is basically the same as game. So, for developing that kind of a simulation, there are a lot of components like gaming industry they use which are open-source, so for that we utilize unity and a lot of open-source components from that."*

Participant 4 statement shows how important open-source software is to their startup because their whole system is based on Linux, and they are using a lot of open-source libraries instead of starting the work from scratch. On the other hand, Participant 5

statement also says that they are using open-source components from Unity which is open-source software.

The statement from participant 6 emphasizes the widespread use of open-source products and recognizes their importance in the development process. Participant 6 said, *"we have used a lot of open-source Software. While developing web applications, we usually use open-source frameworks and multiple open-source packages that are used inside those apps"*. This statement also shows that developers can use open-source frameworks as a base to build their web apps.

Overall, it shows that all participants talked in same pattern in terms of the open-source software characteristics in their startups which are directly related to product efficiency. Those advantages include cost-effectiveness, saving time, increased development speed, scalability, and flexibility, enabling startups to optimize resource allocation, customization to fit needs solutions, and increased development speed due to existing solutions.

4.3.3 Open-source tools

The subtheme Tools is identified because each participant from different startups discussed open-source software and tools which helped them achieve the product efficiency. Most participants repeatedly talked about these specific open-source tools, such as Linux, GIT, Angular, and Android Studio. Participant 1 said that *"we are using open-source technologies such as Angular 2+, ionic, JavaScript, and Google Technologies. The company also uses Android platform which is open-source to run their virtual kiosk."* Participant 6 also talked about utilizing Angular in their startup, as *"For web applications we use mostly we develop Progressive web applications with Angular"*.

The use of open-source tools like Angular 2+, Ionic, JavaScript, and Google Technologies is mentioned by Participant 1. Their software development is built on top of these technologies. Ionic is an open-source framework for creating mobile applications, whereas Angular is a well-liked open-source framework for creating web applications, and Participants 2 and 6 both talked about the use of Angular in their respective startups. The open-source scripting language JavaScript enables dynamic and interactive functionality. They can improve their development process by utilizing Google Technologies, which frequently offers open-source tools and libraries. Additionally, Participant 1 discusses using the open-source Android platform to host their virtual kiosk. Participant 1's startup takes advantage of community support, frequent updates, and a wealth of resources by utilizing open-source technology in their product development.

Participant 2, Participant 3, and Participant 4 mentioned about use of Linux in their startups such as Participant 2 mentioned, *"There's no point in reinventing the wheel so for that our technology stack runs on Open-source best product like Linux operating systems. Docker Community edition and also We are using plenty of open-source components within our solution to perform various functions."* The Linux operating system is one of the important open-source software items highlighted by Participant 2. Their startup uses Linux because of its reputation, and startup gained benefit from using Linux because it is an established and well-supported operating system. Their solution has a strong basis due to the large open-source community's contributions to the growth and advancement of Linux.

Participant 3 talked about Linux, GIT, and use of other open-source software in their startup as he states *“First of all we are using Linux which is open-source and google web toolkit and also eclipse. But using eclipse is not mandatory because some of our coders use other platforms to write the code. Java is the main programming language which our company uses. We also use Android studio and GIT for version control and MySQL.”*. Participant 4 mentioned that *“we're using Linux as our main development environment, so we using Yocto, which is open-source to build the image, the software image the Linux distributes and that we use in our product. Uh, we use Jenkins to build automation and then give us build reports”*.

Participant 3 and Participant 4 talked about use of Linux operating system in their startup. According to participant 3, GIT which is open-source tool has helped their startup in version control which shows importance of tracking changes and managing code. Participant 3 startup also utilized services of MySQL. Moreover, Participant 4 mentioned that their startup is utilizing Yocto which is open-source tool by the Linux. Yocto intends to offer a collection of procedures and tools that make it easier to create Linux distributions designed especially for embedded and Internet of Things software. Participant 4 further talked about utilizing Jenkins which is a free and open-source Java-based DevOps platform for continuous integration. Participant 4 startup utilizes Jenkins to build automation and getting the reports of the build.

Participant 5 talked about the GIT and mentioned that the *“tool which we are using in our product development is GIT and that is basically the source code, version management software and that's an open-source tool.”* Further added that *“GIT is like a core of The version management and understanding of source code And I would say that it has quite significant impact for the product development as a team. We are also utilizing open-source tool Unity in our product”*.

Participant 5 discussed GIT in a similar way to participant 3. Participant 5 highlighted their perspective on GIT as a tool used in their product development process. Participant 5 describes GIT as a version management utility for source code. This indicates that GIT is being used to monitor source code modifications throughout the product development lifecycle. Open-source nature of GIT helps startups to access the source and modify them according to their needs. Participant 5 also mentioned about use of Unity as open-source tool and further told that Unity open-source community helped them a lot.

All the statements by participants show that open-source tools play important role in the product development process of startups, and they specifically mentioned about GIT that helped them a lot in version management. Almost three participants repeatedly mentioned about utilizing Linux which is open-source. It shows that startups in healthcare got benefit by using these certain tools. Overall, participants' comments indicate that the adoption of some specific open-source tools has an impact on making the product efficiency such as GIT, Linux, Android, and Angular because these tools encourage quicker development, effective teamwork due to proper version management, stability, availability of a helpful community, and cost savings due to their open nature. Startups use these technologies to improve team cooperation, streamline their development processes, and allocate resources wisely, all of which will result in more effective product development and delivery.

4.3.4 Mentorship to Startups

The participants provided guidance for the startups, and it also shows that how much startups can get help from that guidance and instructions to improve product efficiency in the new startups. Participant 1 talked about the guidance as *“Challenges are different for different Startups. So, I think using open-source software takes some additional work on learning curve in the beginning of the company, but when those challenges have been overcome and it can be a positive thing overall.”* According to participant 1 statement, challenges may vary for different startups when it comes to use of open-source software. Participant 1 also underlines the importance for startups to be ready for some additional work in terms of the learning curve associated with open-source software. The statement also suggests that the advantages of utilizing open-source software outweigh its initial difficulties and steep learning curve. The overall result may favor the startup once these obstacles are addressed and overcome.

Participant 2 and Participant 3 also provided guidance for the startups such as participant 2 told that *“My advice would be to go ahead. Why not? It's an easy step to begin, and you'll quickly catch up with the process. If you encounter any requirements or needs in the future that may require you modify the process, you can refactor and redesign accordingly. I advise you to just go forward if you think about starting with low expenses and keeping efficiency then it is the best course of action.”*. On the other hand, participant 3 said, *“Of course, money is important in some scenarios when you are at startup level. It's better to use open-source software if you want low cost but if there is a better product out there and you can afford it, I will use that because it would be efficient to develop with best possible tools”*.

Both participants 2 and 3 viewpoints were slightly different, but they shared a common theme of considering efficiency and cost-effectiveness when making decisions. Participant 2 supports the utilization of open-source software by startups, emphasizing its user-friendly nature and agility in accommodating changes. The importance is placed on the adaptability to restructure and reconfigure the process in response to any forthcoming demands or necessities. According to the perspective of Participant 2, starting with minimal expense while ensuring optimal performance is a favourable strategy. Participant 3 acknowledges the value of money, especially in the beginning phase of the startup. Participant 3 advised utilizing open-source software because it is inexpensive, however, participant 3 mentioned that if some product offers better services and reasonable price, it would be more effective to create using the best tools.

When recommending the utilization of open-source software, both participants take the financial element and cost-effectiveness into account. They acknowledge that startups often have limited resources and advise using open-source software as it might be a sensible and economical option.

Participant 4 and Participant 5 both talked in the same pattern about understanding the open-source software first before utilizing them such as participant 4 said when asked about guidance to other startups, *“Go for it. Do your homework before utilizing open-source software for your product but there will be less surprises on the way if you utilize carefully”*. Participant 5 also mentioned, *“I would encourage startups to use open-source software and understand how they work?”*. Participant 4 and Participant 5 statements show that learning about the open-source software before using it in the product is important. This supports the idea that careful research and assessment should be carried out to make sure that the selected open-source software complies with the demands and compatibility criteria of the startups. According to both Participant 4 and Participant 5

statements, startups can mitigate potential surprises or difficulties by conducting thorough research before using or integrating open-source software into their product development process.

The discussion with participants showed that startups can improve their product efficiency by following certain guidelines such as avoid utilizing open-source software directly instead of doing proper homework before utilizing open-source software. It also shows that the process of utilizing open-source software is a learning curve which will take some additional time but it's worth it in the end for the startups because they get a lot of benefits such as cost reduction, time saving etc. Most of the participants encouraged the utilization of open-source software and talked about understanding the open-source before it's used to make your product efficient.

4.4 Challenges while adopting open-source software

Table 4. Challenges while adopting open-source software

Subtheme	Main factors
Rapid Changes	Regular Updates Need of Validation Frequently
Open-source software knowledge	Training team Study the software. Knowing vulnerabilities
Regulations	Performance and safety of solution

The challenges during adopting open-source software theme include 3 sub themes and six codes identified from the data through the participants by semi-structured interviews. It involves challenges which are found from the data through the interviews which have same patterns (see Table 4).

The challenges are categorized into three sub-themes: rapid changes, understanding the open-source software, and regulatory challenges.

4.4.1 Rapid Changes

Rapid changes are one of the obstacles that is discussed by three participants in the same manner. Participants 6, 3, and 5 identified a shared obstacle that is commonly encountered in open-source software frameworks, namely, the high frequency of updates. The participants talked about the challenge of maintaining pace with swift updates and the resultant effects on their application development process and validation.

Participant 3 discussed the regular update challenge which startups can face while adopting open-source software as *he states* "Study the software carefully is important that it doesn't come with so many updates because that would be a problem later. So yeah, regular updates are like a concern if there are like regular updates, then you have do

some changes again.”. Participant 3 statement shows the significance of learning about the software to avoid facing too many updates' issues. Participant 3 said regular updates could pose issues in the later stages. This shows that frequent updates can add complexities and call for modifications, which can be time consuming.

Participant 6 also raised a concern regarding regular updates because regular updates require rapid changes in the software. Participant 6 talked about the frequent updates as he described *“Open-source Software frameworks are updated almost every year and we face that when everything is updated really fast and It's hard to keep up with all the updates coming so we need to like freeze the development to a certain point”*. Participant 6 also added that one challenge is validating applications. Participant 6 statement highlights that how frequently open-source software frameworks are updated, almost annually, and how this rapid rate of revisions complicates their development process. It forces them to freeze their development at a certain point since it becomes tough to do rapid changes due to the steady stream of updates. Freezing the development can maintain a dependable and consistent codebase that is in line with the selected framework version. Additionally, Participant 6 also mentions the difficulty of validating applications. The validation procedure becomes more difficult because of the frequent updates. Application functionality, compliance, and performance standards are among the criteria that must be met in order for the applications to be validated. However, continuous updates can make the validation efforts more difficult because every new version might bring about modifications that need to be carefully tested and verified.

Participant 5 also talked about open-source software updates in a similar manner to participants 3 and 6, such as Participant 5 mentioned that *“Open-source technologies often update quite frequently. It becomes difficult for us to validate those tools frequently.”* It shows that some open-source technologies quite often update and suggests that it is challenging for open-source technologies to keep up with the required validation processes, which might affect the dependability and stability of their applications, given the rapid pace at which they undergo upgrades.

It indicates from participants 3,5 and 6 comments that maintaining these regular upgrades of open-source software can be difficult for startups. The requirement to track updates and incorporate them into the development process takes a lot of time and effort. While adopting open-source software, startups must look out for these challenges such as regular upgrades, halting development to preserve stability, validate applications and performing rapid changes due to all these regular updates.

4.4.2 Open-source software knowledge

Open-source software knowledge is one of the factors while adopting open-source software in the startups which participants talked about frequently. Most of the participants talked about training the team, studying the software and knowing about vulnerabilities that are the challenges in adopting open-source software.

Participant 1 mentioned that *“while adopting open-source software technologies not everyone in the team knows about that open-source software and it comes with the learning curve and it slows down the development process”*. He further discussed another challenge: *“open-source technologies may not always integrate seamlessly. With existing proprieties of software which can create technical issues and delays because adopting new technologies requires that organization to learn about the software and invest in specialized expertise”*. The statement by Participant 1 indicates that adopting open-

source software comes with a learning curve that could possibly hold down development. In comparison to proprietary software, open-source solutions frequently have different structures, workflows, and paradigms. This means that team members who are not familiar with open-source software may need additional time and resources to learn how to use and collaborate effectively with these technologies. Secondly, Participant 1 discussed that there might be technical difficulties and delays when integrating open-source technologies with currently used proprietary applications. Open-source and proprietary software may not always work together seamlessly since different groups and organizations produce open-source technologies. To address these issues, the startups must spend some money on specialist knowledge and train staff members, so they have the knowledge and abilities to negotiate and overcome integration hurdles.

Participant 4 also talked about the challenge of teaching about the open-source software in the startups in almost same pattern as Participant 1. Participant 4 said that *“I was the only one with actual experience with open software’s inside our startup, so getting everybody else in the startup to adopt the ideas about the open-source software has been the hardest part.”*. Adopting open-source software often needs a change in a startups culture because it means accepting new ideas, tools, and ways of developing software. Participant 4's experience as the only person who had used open-source software before shows how hard it is to get others on board and help them understand and accept its benefits. Participant 4 statement also shows that there can be a reluctance to new technologies and ideas, especially if team members are used to working with proprietary software and haven't had much experience with open-source solutions.

The importance of understanding the vulnerabilities of open-source software components prior to their integration into a startups development process is discussed by both Participant 2 and Participant 3.

Participant 2 talked about understanding the open-source software components and its vulnerabilities is important before utilizing Participant 2 stated that *“of course you have to remember the life cycle of the open-source software components and you have to consider different aspects of the third party components? Does it get updated and also knowing about vulnerabilities?”*. Whereas Participant 3 also mentioned that *“Study the software carefully that it doesn't come with so many updates”*

Participant 2 talks about how important it is to think about the life cycle of open-source software components and evaluate the different parts of third-party software components. This means checking to see if the parts get regular updates and knowing how vulnerable they are. This knowledge helps reduce the risks that could come from too many software updates or security flaws. This keeps the software stack safe and up to date. Similarly, Participant 3 statements show that it's important to read software carefully to avoid problems caused by frequent changes. Open-source software often changes quickly, with new versions and fixes coming out often. Even though these changes can add useful features, they can also make things hard for startups because managing and integrating frequent updates into the development process may take more time and resources. The importance of understanding about open-source softwares before utilizing can also be seen by Participant 5 statement, *“understand how they work before using open-source software”*.

All the comments by the participants tell that understanding the open-source software before utilizing it in the startups takes some work to do, and it's a learning curve process. It also shows that startups have to do some homework before adopting open-source software to avoid vulnerabilities which is a challenging task.

4.4.3 Regulation

The regulatory challenges are also an important factor to be taken care of while adopting open-source software technologies, especially when developing healthcare solutions. Participant 5 and Participant 6 highlighted the importance of security and performance when adopting open-source software in the startup.

Participant 5 talked about performance and safety in a way that “*The regulations that We had to think each time when we use an open-source technology that does it actually affect the safety or performance of our solution? And can it be? Can it be like a part of our system or is it just like a script that we implement that doesn't need to be updated, or that it's just modified to our code*”. The statement by Participant 5 shows that regulations can be quite helpful in addressing the issues of performance and safety. There may be specific criteria or guidelines that must be followed to guarantee the safety and effectiveness of the solution, depending on the sector and regulatory requirements. These regulations might include security protocols, ways to protect data, and the following standards for your startup. It also shows that it's important to think about whether open-source technologies are built into the system or just used as scripts that don't need to be changed or updated often. The statement provided by Participant 5 also indicates the importance of understanding the dynamic nature of open-source technologies by mentioning the need for updates and revisions.

Participant 6 also talked about safety that “*the cyber security is currently threat because there's is more and more Artificial intelligence. Like going on so that open-source software's have to be more safer.*”. The comments made by Participant 6 highlight the growing significance of cybersecurity in the context of open-source software, particularly in light of the expanding use of artificial intelligence (AI) technology. Participant 6 emphasizes the necessity of open-source software to strengthen security measures as AI develops and becomes more widespread. Participant 6 statement also shows that cybersecurity is made more difficult and complex by the introduction of AI into numerous systems and applications. By offering frameworks, libraries, and tools that make it possible to apply AI algorithms and models, open-source software plays a vital part in the development of artificial intelligence. However, the open nature and accessibility of open-source software can also create potential vulnerabilities while adopting in the startups.

5. Discussion

In this chapter, both the research questions and the findings about those research questions are addressed. The chapter also provides comparison, recommendations, limitation and further research suggestions. Section 5.1 describes the answer to the research questions. Section 5.2 shows the comparison with the previous literature. Section 5.3 discusses recommendations for health-tech startups. The section 5.4 is about study limitations and further research suggestions.

5.1 Answers to Research questions

5.1.1 Answer to RQ1: How can open-source technology help health-tech startups to increase product efficiency?

Our results showed from the deep dive in the data about open-sources software use at startup and their benefits, which outweighs the challenges. Due to low cost or even free available software's help startups in their growing period and can provide a backbone for the start up. The discussion in interviews shows that scalability and flexibility provided by open-source software's helps them to alter and even increase the operations without the hassle. The open-source software provides startups option to customize the software according to their use. Interviews also indicate that open-source software saves time for startups because they don't need to start from scratch. The large open-source community also provides help to startups in a variety of ways because there are several tutorials accessible on the internet to help developers use and alter open-source software. There is a big impact of open-source software technology on product development process of startups. Interviews discussion also suggests that open-source software like GIT helps in version management and code management. It helps to track changes and maintaining a history of the version, which is critical for product development for the startups.

From discussion in the interviews, it shows that some specific open-sources softwares or tools play an important role in the product efficiency for the startups such as GIT, Linux, Android, Angular and Unity. Interview data shows that many startups rely on Linux, which is open-source operating system software. GIT is another important tool which helps startups alot in tracking code changes and managing the version. The Angular is also open-source framework for web applications which startups are taking advantage of. The result from the data also shows that some startups had similar reasons to use open-source software for product efficiency. Startups don't need to start everything from the scratch because they can leverage from existing infrastructure which is provided by open-source software libraries or frameworks. According to the interview discussion, open-source software components is also one of the reasons which startups provided about utilizing them for product efficiency. The open-source software components provide acceleration in the development process of the startups that can be attained by employing pre-existing components as opposed to creating new code from the beginning.

The participants provided guidance for the new startups for improving product efficiency in the discussion. Most participants in the interview recommended the use of open-source software's in startups because startups usually have limited resources in the beginning and open-source software can be a realistic and cost-effective choice for startups, particularly those with limited resources or in the early phases of development.

Furthermore, according to interview discussion, it is important for startups to understand the risks and effects which come with utilizing open-source software. It is mandatory to do some homework about the open-source software before utilising it.

5.1.2 Answer to RQ2: What challenges do health-tech startups face when introducing open-source technologies in their organization?

The results show that startups face several challenges while adopting open-source software. The discussion tells that one of the challenges which startups face is about understanding the open-source software. The results indicate that introducing open-source software in the startup comes with a learning curve that can hold down the development process. According to the results from the data, Open-source software usually has a different structure, workflow, and paradigms as compared to proprietary software. So, the team members in the startups who are not familiar with open-source software usually require additional time and resource to learn how to use and collaborate successfully with open-source software technologies.

Another challenge that startups face is rapid changes due to regular updates of the open-source software. Open-source software often changes rapidly, with new updates and fixes coming out often. Even though these changes can add useful features, they can also make things hard for startups because managing and integrating frequent updates into the development process may take more time and resources. The requirement to track updates and incorporate them into the development process takes time and effort. Results also show that rapid changes in open-source software sometimes force startups to freeze their development at a certain point when it becomes tough to do rapid changes due to the steady stream of updates. Regular updates can also make validation process difficult. Application functionality, compliance, and performance standards are among the criteria that must be met in order for the applications to be validated. However, regular updates in open-source software can make the validation efforts more difficult because every new version might bring about modifications that need to be carefully tested and verified.

Startups also face regulatory hurdles related to performance and safety such as discussion with participants shows that proper regulations can provide help in addressing the issues of performance and safety. There may be particular criteria or guidelines that must be followed to ensure the safety and effectiveness of the solution, depending on the sector and regulatory requirements. These regulations involve security protocols, ways to protect data, and following standards for your startup. The result from discussion also indicates that it's necessary to think about whether open-source software technologies are built into the system or just used as scripts that don't need to be changed or updated more often.

Moreover, results also show the increasing significance of cybersecurity from the perspective of open-source software, particularly considering the increased utilization of artificial intelligence technology. The discussion with participants shows that it can be a challenge while adopting open-source software because now open-source software is necessary to increase security measures as AI develops and becomes more widespread. Open-source software is essential to the advancement of artificial intelligence because it provides frameworks, libraries, and tools that enable the use of AI algorithms and models. Open-source software's accessibility and open nature, however, can also lead to can also create potential vulnerabilities while adopting in the startups. Overall, results show that there are some hurdles while adopting open-source software in startups, but if startups

were able to manage those challenges, they can get a lot of benefits by utilizing open-source software.

5.2 Comparison with previous literature

The results of the current study on the use of open-source software in healthcare startups' development are consistent with past research in a number of significant areas. Important insights and parallels between the results and preceding literature are revealed by comparison, as will be addressed below:

In prior studies such as Karpoka et al. (2014) and Santarsiero et al. (2023), it was noted that open-source software was becoming more and more common in the healthcare sector. The results of the current study support this development, highlighting the use of open-source software in healthcare startups to encourage innovation, lower costs, and provide value to the healthcare ecosystem.

Karpoka et al. (2014) study also shows that open-source software allows users to use, share and change it and provides liberty to use the source code. Today there are many examples of free, open-source software products that are widely used, such as Android OS, Linux, and Apache servers (Karpoka et al., 2014). Our results also show that startups are getting benefit of the open nature of open-source softwares, and also open-source software such as Linux and Android provide benefits to the startups. The study results also show some new aspects, such as that open-source software impacts the product development process, and some specific open-source software, such as GIT, provided help to so many startups in version management and tracking code changes.

5.3 Recommendations for Health-tech Startups

Based on the results, the recommendations for the startups are that they should start accepting open-source software to increase the efficiency of their products. Startups should consider using open-source software such as GIT, Linux, Android, Angular and Unity. Open-source software offers affordable options, scalability, flexibility, and time-saving benefits. Startups can take advantage of configurable software, make use of existing infrastructure, and quicken their development process by utilizing these technologies.

Moreover, startups should start investing in training and education about open-source software for their team members because understanding the architecture, workflow, and paradigms of open-source software is essential for successful implementation. Startups can reduce the learning curve challenge associated with adopting open-source technologies by providing the proper training and assistance.

The startups should learn about how often open-source software updates which they want to integrate in their system because if the open-source software is changing rapidly, then it can be trouble for startups to perform rapid changes in their system where they are utilizing that open-source software. Startups should also carefully consider and adhere to any regulatory obligations relating to the use of open-source software and taking into account performance and safety rules, and security procedures. Startups should carry out a thorough risk analysis prior to deploying open-source software. This entails knowledge about the vulnerabilities and difficulties linked to the use of open-source technologies.

To get advice and support, startups should actively interact with the open-source community. There are many resources, courses, forums, and professional opinions available because to the enormous open-source community. Startups may overcome obstacles, pick up best practices, and accelerate their growth by utilizing the expertise and experiences of the community.

5.4 Study Limitations and further research suggestions

Focusing the study onto healthtech startups in the Oulu area meant a quite small sample size of six startups, limiting the generalizability of the findings, though they were well in line with the prior research. The study added more to the use of open-source in healthtech startups. Furthermore, it was taken into account that results are valid and provide value to the startups.

The focus of the study was to examine how open-source software technologies affect product efficiency and how healthcare startups in the Oulu region deal with obstacles while introducing open-source software. While the answers to these study questions give valuable insights, there may be more elements and considerations involved in the adoption of open-source software by healthcare startups that were not explored. The effects on creativity, teamwork, and competitive advantage are only a few more potential areas for investigation in the future.

For the future, a comparison of the outcomes and experiences of healthcare startups adopting open-source software with those startups utilizing proprietary software or other technology solutions would allow for a better understanding of the specific benefits and hurdles which come along with open-source software adoption and can be considered. Further study could also concentrate on assessing the security precautions while utilizing open-source software in healthcare startups more specifically.

According to past literature, Shaikh et al. (2022) and Butler et al. (2022) adoption challenges with open-source software are similar to those found in the current study. Both sources draw attention to difficulties like the steep learning curve and unfamiliarity with open-source software, handling frequent upgrades, following rules, and dealing with security issues. Our results highlight the need for startups to comprehend the dangers and consequences of using open-source software and to carry out adequate analysis and planning before implementation. The unique challenge which was not much discussed in previous literature was understanding the open-source software because startups have to provide training to the team about the use of open-source software, which consumes time and resource.

6. Conclusion

A conclusion which is drawn from research findings is that open-source software technologies have a major impact on the growth of healthcare startups in the Oulu region. The results show that open-source technology contributes to product efficiency by providing startups with advantages such as cost-effective solutions, scalability, flexibility, and time savings. By offering solid frameworks, version control, code tracking, and the capacity to use existing infrastructure, the use of open-source software, such as GIT, Linux, Android, Angular, and Unity, plays a critical role in increasing product efficiency. Open-source technology adoption in startups is not without its difficulties, though.

However, the study identifies several challenges that startups have while implementing open-source software. The challenges include learning curve which comes with adopting open-source software because it is additional work which consumes time and resources. These challenges also include handling frequent updates due to startups' need to perform rapid changes. Startups also need to understand a lot about the open-source components before integrating them into the products. Startups also deal with issues related to performance and security.

Despite these challenges, the results highlight that using open-source software has advantages for healthcare startups that outweigh its disadvantages. The research participants offer insightful advice, advising open-source software usage as a practical and economical option, particularly for startups with limited resources or in the early phases of development. It is also highlighted that before implementing open-source software, startups should do an in-depth study and comprehend the dangers involved.

The results confirm the idea that open-source software solutions have a favorable influence on the growth of healthcare startups by enhancing product efficiency. Startups can improve their operations, foster innovation, and contribute to the overall expansion of the healthcare ecosystem in the Oulu region by skillfully resolving the issues and taking advantage of the advantages of open-source software.

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Appendix A. Interview Questions

Question No.	Question
1	What is your role in this startup?
2	How long have you been working with this startup?
3	What kind of experience do you have
4	What is your product?
5	Why your startup is using open-source software technology?
6	Can you describe the open-source technologies that your startup uses in healthcare?
7	What product development process do you have?
8	How has the effectiveness of your product development process been impacted by the use of open-source technology?
9	What specific features of open-source technology have contributed to the increased efficiency of your product?
10	Can you provide examples of how open-source technology has helped your startup to achieve its goals in the healthcare industry?
11	What creative or competitive advantages has open-source technology given your startup in the healthcare sector?
12	Can you describe any challenges your startup has faced in adopting open-source technologies in healthcare?
13	What unique challenges have you faced with implementing open-source technology?
14	While implementing open-source technology in healthcare, have you encountered any legal or regulatory obstacles? And if so, how did you respond to them?
15	Have you experienced any resistance or reluctance from stakeholders (e.g. investors, employees, customers) to the use of open-source technology? How did you overcome this?
16	Have you experienced any difficulties with integrating open-source software within the existing system?
17	What guidance would you offer to other startups who are thinking about adopting open-source technology in the healthcare industry
18	Is use of open-source software providing benefit to your startup?
19	Any related challenges while adopting open-source software technology that we missed but you would like to reflect on? Are those major concerns or minor threats?