Co-creating with Stakeholders: Ideating eHealth Applications to Support Antibiotic Stewardship in Hospitals

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Abstract— **Inappropriate prescription of antibiotics can lead to complications with hospital infections and increased antimicrobial resistance. Antibiotic stewardship programs have been developed to influence antibiotic prescription behavior in hospitals at a multidisciplinary level. Infectionmanager.com is part of such a program. It is an online platform for stakeholders in the antibiotic therapy process that provides eHealth applications tailored to their roles and needs. This paper focuses on the process of stakeholder involvement to design an implementation strategy for our infectionmanager.com. We used business modeling tools in a focus group and in individual interviews. By analyzing the antibiotic therapy process with a value-driven dialogue with all stakeholders, we ideated possible eHealth technologies based on what stakeholders find valuable in their daily practices. We also conclude an implementation strategy as a basis for human-centered design to develop these eHealth technologies with end-users that can be used as a basis to sustainably implement the platform in its intended setting.**

eHealth technology; implementation; stakeholder co-creation; business modeling; antibiotic prescription.

I. INTRODUCTION

Increasingly antimicrobial resistance threatens the health and safety of patients and citizens and is, therefore, a major concern for public health authorities [1]. Hospital-acquired infections resistant to antibiotics yearly cause an estimated 4 million infections in Europe, resulting in around 37,000 deaths per year [2]. A change in prescription behavior is imperative since up to 50% of all prescribed antibiotics is reported inappropriately prescribed, avoidable or affects the effectiveness of these antibiotics [3]. Infection control experts have developed antibiotic stewardship programs (ASP) or antimicrobial stewardship interventions (AMS) to ensure prudent use of antibiotics for better patient outcomes, lower risk of adverse effects, promotion of cost-effectiveness and reduction of resistance levels [4].

As part of EurSafety Health-net project we co-created with relevant stakeholders, an online infection control platform called infectionmanager.com. Stakeholders are defined as all people or organizations that are influenced by or influence the eHealth technology used to reinforce antibiotic stewardship [5]. Its purpose is to provide a platform with several eHealth technologies that support ASP and implementation advice for all stakeholders involved with infection prevention and control and antibiotic therapy. We focus on a bottom-up approach, where stakeholders are actively involved to determine what eHealth technologies are deemed valuable for ASP.

Many eHealth technologies floundered because they failed to involve the intended users [6]. To be successful, implementation research for eHealth should start involving stakeholders [7]. They need to be involved ab initio in designing eHealth technology and participate in its implementation [6, 7]. Stakeholder interaction, stakeholder relationships and added value(s) offered through the eHealth technology need to be understood for determining a fitting implementation.

We had the following research objectives: 1) Understanding the antibiotic therapy process from stakeholder-perspective and identifying the stakeholders; 2) Understanding problems that stakeholders encounter in the antibiotic therapy process; 3) Identifying which improvements and opportunities stakeholders see in this process; 4) Ideating what eHealth applications are required; 5) Designing an implementation strategy for a platform with eHealth applications to support ASP.

Section II introduces the methods used to involve stakeholders in our business modeling research, using focus groups and interviews. In section III, we provide the business modeling results of our process and problem analysis (objectives 1 to 3) as well as ideated eHealth opportunities and implementation strategy inferred from values found in co-creation research with stakeholders (objectives 4 and 5) [8]. In sections IV and V, we discuss and conclude that stakeholder involvement and business modeling adds to the existing ASP guidelines, as it helps to understand problems with antibiotic therapy from a bottom-up perspective.

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II. METHODS

A. CeHRes Roadmap

Central to our research is the Center for eHealth research (CeHRes) roadmap. It supports researchers to develop, design and implement eHealth technologies using a holistic approach that combines human-centered design principles and business modeling principles [6]. In this paper, we focus primarily on its business modeling research activities. Our method of business modeling is all about determining what the added-value of the eHealth technology should be together with the stakeholders. Subsequently, this co-created added-value is the foundation for an implementation strategy for the technology. By arranging value-driven dialogues with stakeholders, researchers can discuss and understand value needs [8]. We define a value as any ideal or interest a stakeholder aspires with regard to an eHealth technology [9]. In this paper, we used business modeling tools that are part of the CeHRes roadmap, to co-create and ideate possible interventions based on value needs of stakeholders.

In short, a problem analysis (applied in the form of a focus group) was used to understand the antibiotic therapy process from a stakeholder's perspective and to understand which stakeholders are most influential in the antibiotic therapy process. This problem analysis was also used to analyze problems that stakeholders face in the antibiotic therapy process. These problems and bottlenecks were the starting point for value-driven dialogues. We used follow-up interviews to discuss improvements and opportunities and possible eHealth applications to support ASP and the value needs and to organize these needs in an implementation strategy.

B. Focus group with scenarios

We organized a focus group with stakeholders in a pilot hospital participating in the EurSafety Health-net project [10]. Based on a literature scan and expert recommendations, we selected healthcare professionals from the pulmonary ward: clinical microbiologist, clinical pharmacist (2x), chest physician (2x), residents (2x), nurse, ward manager, nurse manager and quality manager. We prepared a complex scenario, known as scenario-based testing [10], with a fictive patient to invoke discussion over the exact choice of antibiotic therapy. With the scenario, we discussed the roles of stakeholders, which communication and information needs are present and critical issues. The focus group was recorded and transcribed in Excel for analysis.

C. In-depth interviews

We organized semi-structured one-on-one interviews of one hour with a resident, a clinical microbiologist, a nurse manager and two ASP experts to further specify their views on the added-value of ASP with eHealth. As we focus on implementation, we addressed the following topics to discuss possible value needs: what should the added value of the interventions be? Who need ASP and how can they be involved? What is required in terms of infrastructure and resources? Who pay for ASP and what are its benefits? We discussed value needs and organized these in a possible business model for ASP with the interviewed stakeholders. The interviews were recorded and transcribed in Excel for analysis.

III. RESULTS

A. Understanding the antibiotic therapy process and identifying the stakeholders

The focus group concluded the primary stakeholders in every form of therapy are physician, patient and nurse. A physician prescribes medication and a nurse usually administers all medication. In the case of prescribing antibiotics, a clinical microbiologist may be consulted by a physician or resident for interpreting laboratory results or advice with non-routine antibiotic therapy. Clinical pharmacists check all prescribed medications, including antibiotics. They also occasionally give extra advice to physicians or nurses or provide background information on medication. Nurses use this information regularly when administering antibiotics. This list of key stakeholders is comparable with the ASP stakeholders suggested by experts in available literature [4, 11] Other stakeholders in the focus group stated they play a more facilitating role and do not directly influence antibiotic therapy. They, however, facilitate the other stakeholders in terms of organizational aspects, resources and support with protocols.

B. Understanding problems that stakeholders face in the antibiotic therapy process

We report the results of the problem analysis in three topics: communication, information/documentation and critical moments/bottlenecks in the process:

Communication: Stakeholders expressed two important moments of communication that are vital in antibiotic therapy: 1) Physicians need information from the clinical microbiologist or clinical pharmacist usually communicated over phone. Contact with a microbiologist or pharmacist should be 24/7 possible; 2) Nurses take daily care of patients and frequently need patient-specific instructions from a physician and occasionally need additional information concerning intravenous delivery from protocols, a physician or a resident (face-to-face), or a clinical pharmacist (phone). A common communication problem expressed by the focus group is that communication by phone that information gets 'lost in translation' as the clinical view is explained from the perspective of the physician.

Information/documentation: All stakeholders required information sources and documents. They reported information comes in mixed forms, either digitally in intranet information systems or hardcopy in folders or

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pocket cards. A few common complications were mentioned: 1) Finding the right information can be problematic due to multiple and different information sources and require research; 2) The patient information system is not directly accessible by the microbiologists thus they rely on patient information shared verbally by the physician; 3) Culture exchange and laboratory results on the cultures is prone to delays. The faster this information is available; the faster antibiotics can be adjusted.

Critical moments/bottlenecks: The most important critical moments regarding patients' health are reported to be in the therapy process itself (diagnostics, prescription, administration), in the communication of laboratory results (correctness and timeliness) and the physical responses of the patient on the therapy (timely adjustment of medication). Stakeholders also expressed critical issues apart from patient-related ones: 1) Antibiotics should be stocked; 2) (Too) many diverse information sources for protocols, information, etc.; 3) Delays in sending cultures and communication of laboratory results cause prolonged antibiotic therapy that may be unnecessary; 4) Laboratory results are sent to the physician/resident who requested them, which is not ideal when physicians/residents share the care of patients and the one who requested the results is not available or present. 5) There is a focus on efficiency; which means available resources, time and personnel are limited and a balance has to be found in improving quality with ASP and efficiency; 6) Communication per phone can have a negative effect on quality of antibiotic therapy if not all information is shared. The more informed the decision making for therapy is, the better.

C. *Identifying which improvements and opportunities stakeholders see in this process*

Stakeholders mentioned the following improvements and opportunities how the antibiotic therapy process can be improved: 1) A bed-side audit consisting of a physician and microbiologist would improve clinical assessment for appropriate antibiotic therapy (apps #4, #5, #6, see D). Clinical pharmacists would also benefit from joining this bed-side audit to assist with prescription details. A bed-side audit is not needed at every prescription, yet with complex treatments it might be beneficial to visit the patient as a team; 2) Looking for uniformity in protocols and provided information can also be beneficial for antibiotic therapy (apps #1, #2, #3, see D). In fact, a resident stated many available protocols could be replaced with a solid uniform one; 3) Education to disseminate new protocols, changes in protocols or generally news regarding antibiotics could improve knowledge and awareness of ASP (app #7, see D).

Two desired improvements were also mentioned that are outside the scope of an antibiotic stewardship program as they are hospital-wide issues that would be beyond our ability to change: 1) Improvement in timely logistics with the microbiology laboratory, by adequately sending cultures to the laboratory and getting timely results might be needed; 2) Current IT systems require better data connectivity and information sharing.

D. *Ideating what eHealth applications are required*

Based on the antibiotic therapy process and problem analysis, we ideated the following eHealth opportunities for the infectionmanager.com with stakeholders, available guidelines and literature and expert opinions. The following paragraphs provide an overview of opportunities for eHealth applications based on what stakeholders deem helpful in the antibiotic therapy process translated into a short, general description of each eHealth application.

1) *App #1: Antibiotic prescription information*

An important step is the start of this therapy, known as empiric therapy. For common infections or antibiotics, the physician can rely on his/her experience, yet for certain infections or antibiotics, extra information is needed to verify the right antibiotic, dose and duration. Physicians and residents usually use an antibiotic formulary that contains most of this information. Additionally, there are national guidelines and local guidelines and protocols that can be used as well. An antibiotic prescription information application can bring all these sources of information together in one place so that physicians have to search less. Another strong point of this application is that it can fulfill the need for uniformity in protocols and information if content of the application has a consistent presentation.

2) *App #2: Antibiotic prescription decision support*

In the pilot hospital, another intervention was recently implemented called 'Surviving sepsis'. This is a little pocket card to help physicians and residents signal life-threatening infections by scoring a few parameters in a checklist. A possibility for an ASP application is to replicate this pocket card with an antibiotic prescription decision support that can make this checklist go more in-depth towards, e.g., suggesting possible infections and possible therapies. This application can be an expansion of the antibiotic prescription information application.

3) *App #3: Antibiotic administration information*

Nurses administer antibiotics to patients. With common antibiotics, the delivery is done on experience, yet for uncommon antibiotics, information is needed regarding the delivery. For example, the exact flow rate of an intravenous antibiotic or if an antibiotic has to be given before or after dinner. Nurses - and occasionally also physicians and residents - check an information system of the pharmacy or national guidelines and local guidelines and protocols. Digital sources can be accessed via the Computer-on-Wheels but some protocols are available as printed copies. The antibiotic delivery/administration information application can bring all these sources of information together in one place. That way nurses, physicians and residents do not have to search in multiple sources. Also,

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this application can fulfill the need for uniformity in protocols and information, if content of the application has a consistent presentation.

4) App #4: Information patient care transfer

The care of patients is transferred between multiple disciplines: Physicians transfer the care to nurses or physicians can transfer among each other or to residents. An opportunity for an application can be to provide an infection-specific or antibiotic-specific checklist of important therapy details that need to be shared during transfer. A nurse gave as an example that he sometimes had to verify with the attending physician or resident when to stop therapy or that therapy was continued longer than officially stated in protocols.

5) App #5: Facilitating the team/audit

A possible ASP application is a bed-side assistance application to quickly access information: 1) Patient information (primary parameters (age/weight), history, allergies); 2) Antibiotic medication information (antibiotic formulary, guidelines); 3) Laboratory results.

This bed-side assistance application can be useful for microbiologists, infectious disease physicians, pharmacists and physicians (depending on the ASP team formation) to obtain information while doing audit rounds. Providing antibiotic medication information is easiest to manage as the technology and content will have much in common with the information applications described above. Patient information and laboratory results, however, require connectivity with existing IT systems or some manual preparation beforehand.

6) App #6: Alerts/notifications

Within the antibiotic therapy process there are a few critical moments where an alert or notification application can be helpful: 1) In the reviewing process, done by clinical pharmacists, an alert or messaging system for important messages per receipt can be used to notify physicians to re-evaluate therapy or to provide patient-specific information such as conflicting medications. This can be combined with a restriction-approval strategy as suggested as a possible ASP strategy in IDSA/SHEA guidelines for implementing antibiotic stewardship programs in hospitals [11]; 2) When laboratory results are available for a certain patient, the currently attending physician or resident can be notified in addition to sending results directly to the physician or resident who requested them; 3) When an antibiotic is prescribed and administered, after a certain time a re-evaluation is in order. This is described as a day-3 bundle that after two or three days the effectiveness of antibiotic therapy can be assessed [12]. At that point, the prescribed antibiotic can be continued, adjusted or even stopped. An eHealth opportunity here is to give an alert or notification when the re-evaluation should take place or co-create an application providing a daily list of antibiotic therapies to re-evaluate.

7) App #7: E-Learning

In the focus group, it became apparent that education is important. Also in ASP guidelines, education is an important supplementary strategy in implementing ASP interventions [11]. For every educational element of ASP there is an eHealth possibility to provide that education using E-Learning applications. The following educational activities were deemed interesting when implementing ASP applications: 1) All personnel needs to be informed about the importance of ASP in general to gain awareness and understanding; 2) All personnel needs to be informed why a team is performing audits; 3) Physicians, residents, nurses, microbiologists, infectious disease physicians and pharmacists should stay up-to-date with new information, guidelines, protocols, etc.; 4) Training in using other eHealth applications implemented for ASP.

E. Ideating an implementation strategy for a platform with ASP applications

In the follow-up interviews, we discussed with stakeholders and two ASP experts what the expected-added value of the platform and eHealth applications should be. All stakeholders unanimously agreed that the most important benefit from optimized antibiotic therapy will be a reduction in length-of-stay. The length-of-stay of patients will reduce when they have optimal therapy, can go home sooner with oral antibiotics, and have less risk of complications with infections. This has beneficial consequences for the quality of care as well as less antibiotic use and thus less antibiotic costs.

All stakeholders also agreed that hospital management needs to be convinced that ASP and subsequently using the infectionmanager.com platform and its eHealth applications is beneficial. There is supportive evidence in literature of already existing ASPs that they are beneficial [13], however, the role of technology in ASP is rather limited. Using eHealth applications as part of an ASP in the hospital may lead to improvements when integrated with ASP initiatives within the hospital. Proving the beneficial effects of individual parts of a program is difficult as results are always reported over a program consisting of multiple interventions. Therefore, the platform can be implemented as part of (starting) ASP initiatives, but requires these existing ASP initiatives as a prerequisite. It can be part of a program and the team can choose which eHealth applications they want to embed in the ASP in their hospital. Nonetheless, the platform can also improve its own value by providing information how to set ASP initiatives up using the platform and its eHealth applications to facilitate teams with the introduction of the eHealth applications in their program.

Based on the above, the strongest business case for the hospital management is that this reduced length-of-stay that

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will reduce costs and improve patient safety. One interviewee said the hospital management needs to understand that "investing at the beginning will pay off at the end". The investment mostly requires FTEs and resources for stakeholders to prepare and perform ASP activities. Also for the platform and eHealth applications, minimal costs are necessary for general maintenance. The revenue is in cost reductions: all costs related to length-of-stay can be reduced but also when speedier interventions in antibiotic therapy can be made, complications can also be reduced and thus reduce costs and negative effects for the patient.

IV. DISCUSSION

We involved stakeholders in our research to ideate eHealth applications and a possible implementation strategy for improving the antibiotic therapy process in hospitals. Stakeholders expressed complications mostly with information sharing and, related, communication. With a focus group and interviews, we had value-driven dialogues with stakeholders to assess opportunities for eHealth. In this article, we conclude seven applications that are worthwhile to implement to support antibiotic therapy processes in a hospital. In sum, these applications mostly need to provide therapy or patient specific information to assure optimal therapy.

With a growing body of literature of expert recommendations on antibiotic stewardship [3, 4, 11, 14], the available ideas for interventions for ASP are expanding. Nonetheless, these expert recommendations still need to be implemented locally in every hospital. Despite guidelines, these local implementations are still diverse and Patel et al pose that little guidance is offered on the practical aspects of implementing ASPs and that e.g., non-academic hospitals in the US need to overcome implementation issues by accounting for unique characteristics of their institutions [15]. The strong point of our bottom-up focus is that by combining value-driven dialogues with available guidelines, we assessed which interventions are required and supported by the stakeholders themselves. The stakeholders, therefore, added a local relevance to the possible eHealth technologies.

ASPs can be very comprehensive programs and contain multiple interventions for basically any process where antibiotics are involved. We decided to focus on primary care processes in the hospital and specifically the antibiotic therapy process as a first focus to implement possible interventions for ASP as one of the key pillars of antibiotic stewardship is a more optimal prescription of antibiotics.

When we looked in a review for the use of eHealth in ASP in literature, we noticed eHealth technology is rarely mentioned or used. Some ASPs make use of existing software systems like electronic prescribing, electronic patient records, but few technological tools specifically designed for ASP were present. eHealth is attributed to helping efficiency and thus, can be helpful to optimize efforts and resources for ASP. Especially as manpower and (financial) resources are most attributed barriers that hinder ASP implementation.

The first step in our ASP research was to prepare a plan of action for possibilities to implement eHealth applications in ASP. By putting the antibiotic therapy process central, we identified stakeholders that fit the local, Dutch context and daily processes in the piloting ward. Also, the seven possible eHealth applications to support ASP were ideated based on this process. These ideated applications are input for further research and development to design eHealth applications that fit the needs of end-users and that fits the overall goals of an ASP. Further research is also needed in the conditions necessary to implement ASP and further analysis and co-creation with stakeholders is necessary to determine a fitting implementation strategy for ASP.

Currently, there are three information applications in development. An antibiotic delivery/administration information application for nurses (app #3) finished its pilot with nurses at the pulmonary ward and is implemented in other participating hospitals [16]. Residents saw this application and asked whether they could have a spin-off information application. We also developed a similar information application called the antimicrobial therapy information application (app #1), containing German antibiotic therapy information tested in three German hospitals. Preparatory research for an antibiotic prescription decision support application (app #2) is in progress. The research and development of the other remaining possible ASP applications are still to be planned.

eHealth applications available via infectionmanager.com need to be part of a larger, more comprehensive ASP. Commonly these ASPs require an ASP team, surveillance of antibiotic use and infections, local guidelines, education and audits) [4, 11]. An implementation strategy for the infectionmanager.com therefore has to align with starting ASP initiatives. Helpful would be to add implementation advice inside the infectionmanager.com how to embed eHealth applications to support starting ASP initiatives. We are also working on an additional implementation tool to help to implement these apps in a wholesome ASP.

Limitations in this research are that we held a focus group in one ward in one hospital, who offered to participate in our research. Although some problems may be local and hospital-specific, we decided to provide generic tools that focus on the structure of presenting information and knowledge. The content of these eHealth applications can be hospital-specific and altered as hospital professionals see fit. Later, we also expanded our research to multiple hospitals to implement the applications elsewhere as there was interest in trying the applications in other ASPs. Based on this expansion we can test whether the structures are robust and how the content changes.

When we started our ASP research, very few hospitals were active with ASP. That was also the main reason why we collaborated with the pulmonary ward as they offered to be part of our pilot. Later when interest in ASP arose at

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other hospitals, mainly due to new guidelines in The Netherlands, we got more interest in our eHealth applications as well.

In future research, we will expand our research to other hospitals and research the necessary components for ASP to help hospitals with their implementation of ASP and the eHealth applications available via infectionmanager.com. For designing these applications, we used the ideas of the ideated eHealth technologies and we use the principles of the CeHRes roadmap, human-centered design for requirements engineering and designing the technology for end-users and business modeling for stakeholder-based value-creation to embed the eHealth applications in ASP [6-9].

V. CONCLUSION

This example case of infectionmanager.com demonstrates the use of business modeling methods to assess possible eHealth technologies for ASP. We argue for more awareness among researchers who design and develop technologies targeted for healthcare that they should not only focus on designing great eHealth technology but also focus on the implementation of these technologies. This infectionmanager.com example case demonstrated that analyzing the implementation of technology early on the in any eHealth technology development process contributes to the understanding of what the added-value of this technology should be. In terms of our example case, it adds up to the available expert guidelines (that also hardly deal with eHealth) for antibiotic stewardship. There is a role for eHealth in ASP when one looks at the opportunities how technology can improve processes. These applications are worthwhile to develop for ASP and a basis for an implementation strategy for eHealth applications within ASP.

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