

Unveiling Synergies Among University Partners in Developing a Dairy App in Uganda: An In-Depth Exploration of the Design Thinking Process from Ideation to Prototyping and Testing

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Abstract

A common goal drives university-community engagement: understanding local community challenges and collaboratively developing solutions. Recent studies highlight co-creation benefits, yet partner involvement is often insufficient, leading to ineffective outcomes. This research explores two key questions: (1) How can institutions engage partners to develop tools reflecting the preferences of diverse partners? (2) How do partners perceive the value of co-creating community engagement tools? This article examines a qualitative case study in which dairy farmers, university faculty, and software developers co-created an app, utilizing the three stages of the design thinking model: ideation, prototyping, and testing. Faculty and farmers first developed app content during the ideation stage, then created and pre-tested a usable “Beta¹” prototype app. The prototype was then iteratively tested in workshops with the farmers, gathering feedback on the app’s content and functionality, as well as the farmer’s perceived value of co-creating it. The final prototype, “Beta²”, reflects the dairy farmers’ preferred features. Findings also reveal five broad themes regarding co-creation: deeper connection to engagement outcomes, deeper connection to the institution, empowerment to share their knowledge, performing a service for themselves, and digital competency. The case contributes to the literature on partner engagement and co-creation in university-community engagement, demonstrating that involving diverse partners in the design thinking process results in more user-friendly tools responsive to partner needs. Future research should evaluate further use of the co-created app as a tool for knowledge-sharing and community engagement.

Introduction

University-community engagement is a cornerstone of many institutions’ overarching missions to drive positive societal transformation and enhance the welfare of local communities. Community engagement (CE) is a dynamic exchange of knowledge and resources characterized by co-creation—the collaboration between institutions and their partners to address shared challenges (Hodge et al., 2020; Ogunsanya & Govender, 2019). There has been a notable shift toward CE since the mid-twentieth century, as governments and politicians worldwide have encouraged universities to recognize the need for CE in generating social transformation (Fitzgerald et al., 2016; Mbah, 2019; Wanjiru & Xiaoguang, 2021). At its foundation, CE is based on developing relationships and collaboratively designing solutions to address shared challenges for mutual benefit (Armer et al., 2020; Gupton et al., 2014; Starke et al., 2017).

In the evolving and challenging landscape of CE, enthusiasm has increased for designing technologies to facilitate interaction between universities and communities (Bernardo et al.,

2012; Garfin, 2020). The prospect of digital tools, particularly those using smartphones, has captured the interest of many scientists, policymakers, and conservation professionals (Bartlett et al., 2015; Fordis et al., 2011; Javaid et al., 2022; Marshall & Taylor, 2005). The enthusiasm to use apps is enhanced by the increased affordability and adoption of smartphones (Gichamba & Lukandu, 2012; Kamboj et al., 2020) and improved internet connection (Di Gangi & Wasko, 2009; Eitzinger et al., 2019). Furthermore, the use of technology was heightened during the global COVID-19 pandemic as individuals and institutions shifted from their usual modes of face-to-face interaction to internet-based tools (Garfin, 2020).

Extant literature shows that digital tools, such as apps, promote active public participation in urban planning procedures (Delitheou et al., 2019; Ertiö, 2015) and marketing (Dube & Helkkula, 2015). In agribusiness and farming, apps can allow institutions to collect accurate and timely data for research (Alice et al., 2022; De Alwis et al., 2022; Daum et al., 2018; Eitzinger et al., 2019; Michels et al., 2019) by monitoring animal

health, reproduction management, and farm records (Kenny & Regan, 2021). This data can improve livestock production and productivity (Katamba & Mutebi, 2017). More importantly, apps empower users to create and share knowledge with other stakeholders (Dehnen-Schmutz et al., 2016; Gichamba & Lukandu, 2012). For institutions confronted with challenges in the traditional face-to-face interaction model, such as a budget shortage and time for physical engagement, apps could be a remedy.

However, a disparity often exists in the engagement of community partners, such as farmers, in creating technology tools (Armer et al., 2020; Harder et al., 2017). Partners' non-participation in developing engagement apps leads to suitability issues and a failure to meet users' needs (Al-kumaim et al., 2021; Llema & Vilela-Malabanan, 2019; Mirri et al., 2018). According to Hovis et al. (2021), empowering partners to engage in tools and knowledge development is critical to effective CE. Earlier researchers such as Filieri (2013) and Kumar et al. (2016) demonstrate that engaging partners in knowledge or tool development benefits the institution and reduces the risk of product failure. Bergold and Thomas (2012), Durugbo and Pawar (2014), and Mirri et al. (2018) also purport that developers should engage users in developing technology tools and prioritize deep empathy. In fact, successful innovation is achieved through empathy-based activities like co-creation that engage partners in designing solutions (Davis et al., 2016).

Multiple studies highlight co-creation as an innovative CE strategy that can enhance end users' participation in designing and developing products (Al-kumaim et al., 2021; Baelden & Van Audenhove, 2015; Herselman et al., 2010; Liang et al., 2023; Voorberg et al., 2015). In theory, co-creation blends the ideas of several collaborators or partners to create mutually beneficial outcomes (Davis et al., 2016). In practice, co-creation represents a systematic set of interactions among persons from various backgrounds, jointly identifying needs, and co-creating tools, services, and knowledge to address them. Morell and Hidalgo (2020), Shan et al. (2021), and Thomson et al. (2022) show that co-creation stimulates empathy, fosters mutually enriching partnerships, and bridges gaps in CE initiatives. Some research suggests that engaging partners in co-creating solutions could ensure that university CE interventions are contextually relevant and have a higher chance of success (Kenny & Regan, 2021; Mansson et al., 2020),

while partners are empowered to take ownership of their development processes.

Central to CE and co-creation is positioning communities or partners as active collaborators in creating knowledge and tools. The "design thinking" approach presents an opportunity to facilitate these goals. Design thinking engages partners in generating ideas and prototyping solutions by collaboratively designing and re-designing innovations to ensure mutual benefit and facilitating genuine discussion between all partners (Kummitha, 2019; Retna, 2016). The iterative, experiential principles of design thinking can offer a stimulating and engaging experience in CE activities (Davis et al., 2016) and could be instrumental in ensuring relevance in university CE projects.

Co-creation approaches such as design thinking can help support CE in creating technology-driven solutions (Davis et al., 2016). Moreover, partner engagement in design thinking provides a flexible channel for actively co-creating new technology tools that fit their needs (Mansson et al., 2020). Hodge et al. (2020), and Sickler and Gale (2021) state that co-creation with target users improves services and stakeholder relationships. Recently, researchers and practitioners have acknowledged that collaborating with target users to develop tools results in adopting more suitable and simple tools (Jackson et al., 2020; Kenny & Regan, 2021; Mansson et al., 2020). Researchers assert that providing partners with opportunities to contribute to apps' design and development ensures the contextualization of their needs (Pemsel et al. 2010; Prebensen et al. 2013; Trischler et al. 2019). More importantly, the synergy of varied perspectives enhances the creative process and ensures that technology solutions are more applicable and responsive to community challenges.

Study Context: Developing the App with University Partners

Engaging university-community partners in developing digital tools is increasingly recommended in scholarly literature (Drain et al., 2017). Yet, there is a noticeable gap in research that explores how tools are designed through the collaborative efforts of university-community partnerships. Addressing this gap, our study presents an empirical design thinking case study in which dairy farmers and multiple university partners collaborated to create a dairy farming app. The project involved faculty members of Mountains of the Moon University (MMU) in Uganda, a software design and development

team from Belgium, and dairy farmers in the Rwenzori region of Uganda. Mountains of the Moon University considers CE vital to its purpose. Since its inception in 2005, MMU has formed partnerships with the local community and Belgian collaborators to address social concerns and promote the welfare of people in the Rwenzori region. The university prioritized engagement activities with dairy farming due to its significant potential to create jobs and income for community stakeholders. In keeping with its commitment to CE, MMU built a Dairy Development Center and provided extensive training to dairy farmers, equipping them with the necessary skills and knowledge to enhance dairy farming.

However, recent cohort research by Alice et al. (2021) uncovered a plethora of practical challenges encountered during faculty members' engagements with dairy farmers. Among these were limited budgets for CE, insufficient information flow between the institution and dairy farmers, and inadequate follow-up of engagement activities. Dairy farmers also continued to face challenges such as ticks attacking dairy animals, while a lack of data hindered efforts to address such challenges, leading to the purchase of ineffective drugs and repeated treatments without satisfactory results. Furthermore, despite the university's efforts to train dairy farmers on the importance of record-keeping, it remained a common practice for farm records to be manually stored in notebooks or on paper sheets, posing challenges with data retrieval. For instance, farmers often struggle to provide information regarding medications administered to animals, animal calving dates, and other health events. As Manteaw et al. (2021) highlighted, inadequate record-keeping practices hinder effective farm management and growth. Moreover, proper record-keeping is essential for researching and developing effective animal treatment and drug strategies for tick management and other issues. Developing appropriate solutions to such challenges becomes much more difficult without accurate records.

Considering these challenges, an app could be a CE tool that benefits dairy farmers and the university. Dairy farmers can conveniently and efficiently input and store digital records of their farming activities, and the collected data can be closely monitored to facilitate decision-making and improve farm-management practices. Meanwhile, the information gathered through the app could support institutional research endeavours and enable timely feedback to be disseminated to

farmers through the university. Faculty members, for example, can gather data on prevalent animal diseases, identify patterns, and offer tailored advice based on insights gathered from the app. Additionally, an app has the potential to alleviate time and budget constraints posed by face-to-face interactions. Using a technological tool and understanding its influence on partner engagement presents an opportunity for the university to improve collaboration and enhance the impact of its CE activities.

While research emphasizes the benefits of using technology to enhance and facilitate CE, the processes and effects of university-community partners co-creating these tools are rarely studied. Traditionally, institutions focus on developing tools or knowledge for communities, with methodologies involving partners or communities in co-creation and design thinking initiatives largely unexplored (Cherrington et al., 2019). Furthermore, it is critical to understand how CE partners view the value of their engagement in co-creating tools or knowledge. Several studies focus on this—namely Drain et al. (2017) and Sara and Jones (2018)—yet they primarily examine design thinking and co-creation approaches without considering the viewpoints of partners engaged in the process. These gaps pose challenges for researchers and practitioners seeking to establish synergistic relationships and co-create mutually beneficial tools. Against this background, the current research makes a crucial contribution by addressing two practical questions that are crucial for advancing successful university CE:

- How can universities develop a community engagement tool that reflects the preferences of diverse partners?
- How do university partners perceive the value of co-creating community engagement tools?

This paper seeks to answer these questions through the aforementioned CE case study involving the development of a dairy farming app. In section 2, we present the methodology used, including the design thinking process. In section 3, we present the findings. Section 4 discusses findings, significance, implications, limitations, and future research. In section 5, we conclude with the lessons learned.

Methodology

Qualitative Case Study

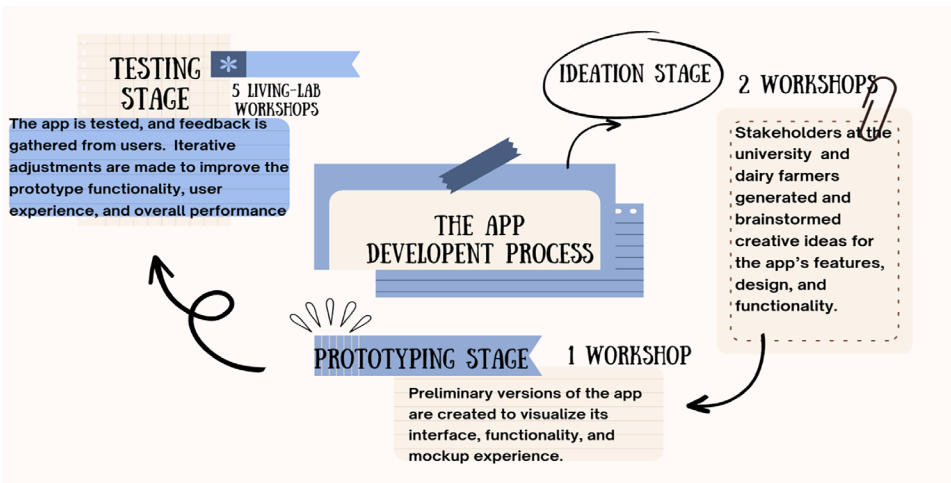
The authors used a qualitative co-creation case study guided by CE principles and utilized the

three stages of Stanford d. school design thinking model (Doorley et al., 2018) to develop the app. The research process consisted of ideation, prototyping, and testing stages, shown in Figure 1. We used this method because it allows partners to design and re-design features that correspond with partners' demands (Kummitha, 2019; Retna, 2016).

Researchers such as Kumar et al. (2016) explain that the ideation phase is for brainstorming solutions. In our study, the ideation phase consisted of two collaborative workshops with partners aimed at generating the initial requirements and

content for the app. The second stage involved creating a usable prototype and mock-up, and the last stage involved hands-on experience to test the functionality and gather feedback on the prototype. We used an iterative approach in our workshops, where the content and design of the prototype dairy app were constantly modified in response to user input and evaluation. Throughout these workshops, partners actively reflected on the practical content and design for the app, as well as their perception of the benefit of being part of the design process.

Figure 1. The Research Process for Developing the Dairy App



Sample Selection

Our study had three distinct categories of partners to ensure comprehensive input for the app's development. The first category included dairy farmers (n=5) and university faculty members of agriculture and environmental science (n=5); they generated content and requirements for the prototype "Beta¹" in September 2019. The second category comprised a software design and development team (n=2) and science, technology, and information faculty members (n=8); they joined the process to create a usable prototype that was pre-tested in January 2020. The last category involved a cohort of dairy farmers (n=45) who tested the app during a workshop at the university in February 2020. Following this, four workshops were scheduled, each comprised of dairy farmers (n=20), one app developer, and six faculty members. These workshops were scheduled for May and June 2020, yet due to the COVID-19 pandemic, these workshops were postponed and instead conducted between February and June 2021.

Data Collection

The data collection procedure followed three steps, with researchers documenting field notes on the app content as well as partners' perceptions of the value of the co-creation process. Initially, qualitative data regarding the app's content were collected during the two workshops of the ideation stage. Researchers used semi-structured questions to guide discussions with partners, prompting them to brainstorm and identify the app features, functionalities, and measurable parameters crucial for meeting dairy farming demands. Participants were prompted with questions such as, "What content would they like to see or include in the app?" Researchers documented all ideas generated.

The second stage, prototype development, allowed the initial ideas to be translated into a tangible app and pre-tested during the mock-up session to ensure it was ready for testing by end users. The final data collection happened during the third stage of the app-testing workshops. Researchers documented partners' qualitative

feedback on the app's content, features, functionality, and usability issues. The app content and design were evaluated using the Keep-Add-Delete method (described in depth in the next section). Our workshops used an iterative approach, continually adapting and improving the content and design of the dairy app prototype based on documented user feedback. Finally, we also documented partners' feedback on how they perceived the value of co-creating the app.

Application Design Thinking with Co-Creation Activities

Ideation. The primary researcher and author number three facilitated the ideation stage and coordinated the activities during a two-day workshop attended by faculty members (n=5) and dairy farmers (n=5). We first engaged in co-creation activities where farmers and faculty members collaboratively generated ideas for app content. The process involved open discussions and brainstorming sessions to define the parameters and requirements for the app's design. Partners shared their insights, experiences, and preferences regarding the app's functionality, features, and content. They highlighted various parameters as essential content and explained how each could be presented or measured, also creating sketches of the screens that could be included in the app. Suggestions were written on a flip chart to ensure consensus among partners in the workshops, allowing everyone to agree on relevant content. Researchers documented all suggestions, ensuring that each partner's input was captured.

Prototyping. At this stage, we used the ideas generated to develop a functional prototype of the app. Two Belgian software design and development experts (one identified as author four) began work on the prototype. Before it was fully programmed,

a mock-up session was held to present the structure of the prototype. The researcher and five faculty members conducted pre-testing during the mock-up session, contributing knowledge based on their experience with user-friendly design, technical features, and figures to measure different variables. They thoroughly evaluated the prototype, noting improvements and ideas for screen colors, fonts, and UI displays to improve usability and create a user-friendly interface that would work for local dairy farmers. Based on the collaborative feedback and insights, the app developers made prototype Beta¹, called the "Cow Analytics App." It was programmed in English to work on Android smartphones and PC and Mac computers, and required an internet browser such as Chrome, Firefox, or Edge. The Android operating system was chosen because it is the most used among the local population in Uganda.

Testing the Prototype. The testing stage occurred during a workshop held at the MMU computer laboratory and was facilitated by authors one, two, and five. Forty-five dairy farmers actively engaged with the Beta¹ prototype, providing valuable insights into its content and functionality. Selected partners, all smartphone owners, were registered in the app system prior to the workshop, ensuring a focused and prepared testing environment. The workshop took place over the course of an entire day and was divided into six steps. First, participants introduced themselves, and the researcher detailed the purpose of developing and testing the app. Second, each participant received a username and password to install the app on their smartphones. Third, participants logged in and individually explored the application. During this step, we used the "think aloud" process, which meant the participants could speak aloud about their thinking while navigating the app. This approach gave the researchers insights into the

Table 1. Representation of University Partners Engaged at Different Stages During App Development

Partners involved	Ideation stage (n=10)	Prototyping stage (n=10)	Testing stage Workshop at the university (n=52)	Four follow-up workshops (n= 87)
Faculty members	5	8	5	6
App developers	-	2	2	1
Dairy farmers	5	-	45	(n=20x4)

participants' reasoning and facilitated the design and testing processes (Mansson et al., 2020). All partners' concerns were written on a flip chart and in notebooks.

The fourth step was a guided tour of the app. The developers explained all the app's features and guided participants on how to use it. We asked participants to highlight preferred parameters as they explored the app using the "Keep-Add-Delete" process. We used three flip charts indicating Keep, Add, or Delete: "Keeps" were parameters to be retained, "Adds" were new content and features to include or add technical content changes, and "Deletes" were content elements to be deleted. Partners unanimously agreed to keep, add, or delete certain features.

The fifth step was to jointly choose the app name. We used the "idea generation and voting process" (White et al. 2007) to develop a commonly accepted name. Partners proposed names, which were written on a flip chart, and then they voted on a suitable app name. The voting exercise provided insights into the preferred name for the app. Ideas gathered during testing were documented by author six and used to re-design the app for subsequent testing.

Three off-campus follow-up workshops were held to continue testing the prototype and gather feedback on how participants perceived the benefits of co-creating the app. Each workshop engaged 20 different dairy farmers, 6 faculty members, and a Belgian volunteer in hands-on sessions where they interacted with the app, and provided feedback, and discussed their perceived benefit of being part of the co-creation process. We used an iterative approach, wherein the content and design of the prototype were continually modified based on the feedback gathered. The last follow-up workshop was conducted on campus, in which researchers guided 20 dairy farmers through a PowerPoint depicting various app screens. The farmers evaluated all cumulative feedback gathered to check the latest version of the prototype and discuss their perceived benefits of being involved in developing the app.

Data Analysis

Data analysis was based on multiple sources, including primary data about the app's content and design, and collected in various ways, such as through flipcharts used during workshops. The partners' perceived value of their contribution to the app development process was captured through detailed field notes documented during the

workshops. The researchers thoroughly reviewed and categorized the data, and the summaries were then classified based on two key criteria.

The first criteria is user preferences for the app's content, structural design, and usability. We evaluated these preferences across three distinct categories: content (desired functionalities), structure (optimizing how users navigate and locate information within the app, emphasizing practical layout and organization), and presentation (visual appeal, such as balancing screen colours and optimizing text quantity for clarity and user engagement).

The second criterion was experiences over the co-creation journey, including partners' perceived value of their contribution to the app-development process. We evaluated the feedback using a deductive content-analysis approach, identified themes representing our partners' opinions, and used qualitative descriptions to capture the details of these themes. It is important to note that we aim to highlight key themes from the data and convey partners' voices through qualitative descriptions, which encourages a more thorough understanding of their viewpoints.

Ethical Considerations

All partners signed written consent following explanations about this study at the start of the workshops. Also, in a cohort study, partners had minimal risks of causing ethical anxieties and we ensured they felt safe to participate.

Results

This section outlines the feedback gathered during the three design thinking stages regarding the app's development and perceived value in the co-creation process.

Development of Tools that Reflect the Preferences of Diverse Partners

Ideation Stage

Partners suggested parameters for the app—animal identity, feed components, feed supplements, milk yield and quality, animal health, dairy product markets, and animal growth—and provided a thorough description and precise measurements for each parameter. For instance, animal health was described as the well-being of dairy animals, and the farmer could measure and keep a record of the animal's body size and height, the type of treatments given at birth, and when the animal is sick.

Involving partners in the ideation stage

provided a variety of insights. Chiefly, suggestions at this stage centered on animal nutrition. One partner said: “We should develop an application that can monitor animal feeding and milk yield. It should enable farmers to balance feed ratios for dairy animals using locally available feed ingredients” (respondent at the workshop on September 5, 2019).

Prototyping Stage

During the mock-up session where the plans for the prototype were presented, faculty members and the app developer identified areas for improvement, particularly focusing on the app’s interface, functionality, and usability. Errors and technical issues were also identified. For example, one faculty member noted, “I have noticed an error within the app’s interface. The navigation menu has failed to load properly, and some buttons are not responsive.” Another faculty member “observed that certain measurements for parameters within the app are not realistic. For instance, it is not practical to start recording milk volumes in liters with a value as low as 500 liters per cow. And the range provided seems to be big.”

Observations during the mock-up session provided insights into users’ navigation pattern preferences, which were crucial in adjusting the app’s design.

Testing Prototype Beta¹

The testing stage occurred during a partner workshop on February 5, 2020. It fostered iterative learning and improvement, ensuring the app was tailored to the specific needs and context of the dairy farmers who would eventually use it. The partners showed that participation in testing the app highlighted positive enthusiasm and practical challenges regarding the app’s content, structural design, and usability. For instance, they showed keen interest in trying the prototype, indicating their willingness to use new technological tools. This enthusiasm suggests promising potential for the app’s adoption within university CE initiatives with these partners.

Yet practical challenges emerged while testing prototype Beta¹, particularly concerning the dairy farmers’ ability to navigate the app independently. For instance, we observed that some individuals lacked the necessary experience to independently log in and navigate, indicating potential usability issues that needed to be addressed. The challenge was deepened by the variety of mobile phone models among the partners involved in testing

the app. For example, installing the prototype proved challenging for some individuals due to compatibility issues with their specific phone models. One dairy farmer mentioned, “My colleagues are exploring the app’s features, but mine has taken time to open.” Another said, “I have a problem with displaying some app features. The screens are difficult to view, particularly where the app instructs users to double-tap to select the animal.”

These comments underlined the need to ensure compatibility to meet a wide range of devices and user preferences.

Partners also offered input on the prototype’s language of instruction, recommending adding a function that allows users to choose between English and Rutooro. This suggests partners wanted to improve user access by catering to various linguistic preferences. Additionally, partners commented that the app’s home screen was not appealing. One partner stated, “The home screen picture is unappealing to dairy farmers. We should use images of well-known cattle breeds in the Rwenzori region that produce a high milk volume.”

Through the Keep-Add-Delete method, partners unanimously agreed to keep futures such as animal identification, animal feeding, and animal health features from Beta¹. Partners also suggested adding critical new features, such as farm location tracking, employee records, and animal status updates. They also suggested the app cover different feeding methods such as zero grazing, tethering, paddocks, and communal grazing. Other features included tracking animal breeding events with details of insemination dates, sources, expected calving dates, and a summary of the breeding history, including calf records such as names, birth dates, and breeds. They also suggested the app should record monthly milk production with a breakdown of morning and evening yields, as well as data regarding farm equipment and structures, contacts for veterinary doctors, and provide reminders like deworming. They also proposed that the app should allow users to record data offline.

Partners also suggested that several features be removed—in particular, the feature to record milk quality, noting that local dairy farmers lacked the necessary equipment to measure this. One participant commented, “Measuring lactose, protein, fats, butter, aerobic plate count, and coliform mill content is unfeasible. It is better to measure the amount of milk obtained from the

farm.” Thus, the feature for measuring milk quality was deleted. Another requirement proposed for deletion was the record of markets for dairy products.

The dairy farmers proposed four names for the prototype Beta¹: Ngabu App, Rwenzori Dairy App, Smart Dairy App, and Dairy Farmers App. Through a voting exercise, most participants agreed that the prototype should be named Rwenzori Dairy App.

Finally, in an open discussion, partners indicated satisfaction with their active participation in testing the app. They liked the ability to share their knowledge and ideas throughout the process, yet they expressed the need for user training to use the app. A comprehensive list of users’ requirements was adopted, and the app development team re-designed the prototype.

The Structure of Beta²

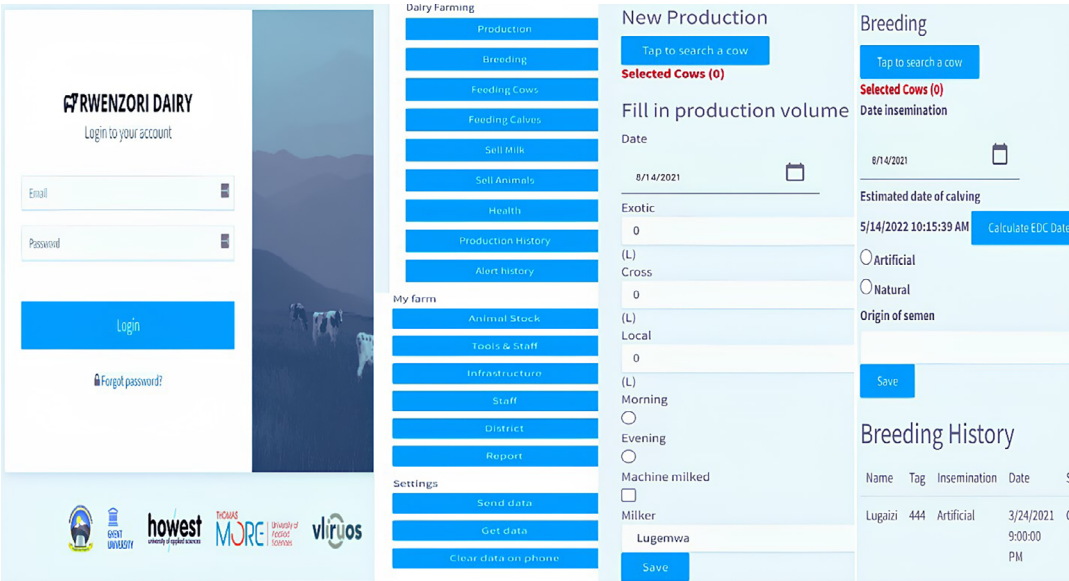
Figure 2 illustrates the structure of Beta², named Rwenzori Dairy App. The user needs to be registered to begin using the app, and the home screen requires a user to log in. The user starts by adding a staff member and one animal. The user can “add a cow” or “add multiple cows” by identifying the animals with a tag, name, or notch. The “add a calf” function allows the user to record the calf’s birth date, name or tag number, and breed. Default values for tools and infrastructures are pre-recorded values that the farmer can adjust based on the farm conditions. The user also enters the “farm’s location” using the district option. By

selecting the “production” screen, the user can fill the production for one or more cows. The user can also sell milk and save information by using the “sell milk” screen and filling in details about the milk’s date, volume, and price. To record breeding, the user must first select the cow, then enter the date, origin, type of insemination (natural or artificial), and estimated calving date. There are default values to record the feeding for calves and cows. The “animal health” screen records information like deworming, spraying, drug, cost, and treatment date. The app also offers important notifications for vaccinations, deworming, spraying, and the expected delivery date for the animals. The “send data” function allows users to sync data from the phone to an external database. The data is stored and encrypted to avoid unauthorized access.

Testing Prototype Beta²

The follow-up workshops were held on February 24, April 10, May 8, and June 5, 2021, with each workshop engaging 20 different dairy farmers. These workshops focused on testing the content and functionality of the app Beta², making iterative modifications, and collecting feedback on participants’ perceptions of their roles in the co-creation process. During the last workshop, partners demonstrated good acceptance of the app content and technical design, and there were no new ideas for expanding the app. The feedback showed that they found the app’s content simple to understand, and they reported satisfaction

Figure 2. TheThe Structure of the Rwenzori Dairy App (Beta²)



with its capabilities, notably the capacity to keep documents online. They also commented on the university's unique approach to improving dairy record-keeping methods. Dairy farmers expressed positive experiences with the app. One mentioned,

"The application operates well on my smartphone, and I am happy to store information regarding dairy farming on my phone" (Workshop on February 24, 2021). Another said, "I like the milk production function and the instant monthly income calculation from selling milk. The app will guide me in knowing whether I will get profits from the farm." (Workshop on February 24, 2021).

Another dairy farmer said:

"Working on this dairy app has been one of the most rewarding experiences. For instance, what is interesting to me is the app's ability to calculate the expected animal delivery date accurately when the information is entered. I believe I will not lose my calves anymore." (Workshop on May 8, 2021).

In another quote, a participant expressed that he was anxious to record events on my farm with his smartphone, even without an internet connection. He said he was pleased that vital farm records will remain safe.

Furthermore, more, one participant reflected on his previous experience with MMU and stated:

"As mentioned in our previous interaction with some faculty members, tick resistance to acaricide drugs is still challenging. I am happy to record the types of animal treatment using this app. If the university does more research about these ticks, I am ready to provide information through this app." (Workshop on June 5, 2021).

The inherently iterative nature of the design thinking process guaranteed that issues could be resolved through modification until the app fit the preferences of the end-users. And although the feedback from the final workshop was favorable, it is crucial to acknowledge our preparedness to undertake further design iterations and organize additional workshops if necessary.

Partners Perceived Value of the Co-Creation Process

When asked how they perceived the value of being part of the co-creation process, their responses were largely positive. We identified five broad themes that emerged from the documented feedback: deeper connection to the engagement outcomes, deeper connection to the institution, empowerment to share their knowledge, performing a service for themselves, and digital competency. Each theme is described below, using verbatim quotes from partners.

Deeper connection to the engagement outcomes

Partners reported solidly positive feelings for the app, citing the continuous incorporation of their ideas into its design. Their feedback depicted a strong sense of ownership and awareness of the benefits of co-creating the app. As one dairy farmer expressed:

"I feel we have generated realistic content for the app rather than depending on university-generated designs. My colleagues, for example, have provided good ideas regarding various animal diets and clear functions for our app. I found the knowledge-sharing experience helpful, and we should always aspire for this kind of engagement to design our tools for our community activities." (Workshop on February 24, 2021).

Deeper connection to the institution

Partners expressed that their active involvement instilled a feeling of being part of MMU. They felt their voices were valued, leading to a deeper sense of belonging to the university. Here, one of the dairy farmers expressed enthusiasm to participate in future university engagements:

"We would want to participate in more co-creation activities to give our university more significant support in creating engagement activities. This experience has helped us appreciate the need to be part of the university CE activities." (Workshop on April 24, 2021).

Empowerment to share their knowledge

Partners perceived a difference between the collaborative approach used in this research versus other experiences where they were required to attend faculty-led training sessions. They identified

a sense of empowerment that had not been present in previous university CE interactions. One participant made an interesting point about the possibilities for empowerment as a result of being part of the co-creation process:

“I enjoyed the free atmosphere where we could share ideas while testing and suggesting variables and functions for our app. I have learned from my colleagues several ways to combine animal drugs for animal care, and how to prepare animal feeds”. (Workshop on May 8, 2021).

They further noted how recording data will improve their farming. As one partner highlighted:

“Learning about these new technologies through partnership with MMU has been an opportunity to learn more about new ways of keeping farm records. Without this exposure, we would have lost out on possibilities to improve our farms.”(Workshop on May 8, 2021).

Performing a service for themselves

The partners explained that participating in the app development process was mutually beneficial. They highlighted that the app was more effective because of their involvement in its development, indicating that their part of the process was necessary and for their benefit. They expressed that their involvement in the development impacts not just one or two partners but the larger community that will use the app. One dairy farmer said, “Our journey in this co-creation has been eye-opening, revealing the impact of our collective efforts. Being involved is more important than waiting for the university to do things for us.” (Workshop on June 5, 2021).

Digital competency

While some dairy farmers noted that participating in the co-creation process provided some skills and understanding about how to use the basic functions of the app, they also stated that their experience during the workshops was insufficient to adequately learn and use the dairy app to its fullest extent. As one partner said:

“Ok, I have been involved in this process, but I don’t feel confident about starting to use the app. I need to spend more time with my friends to explore the app and learn

how to navigate its features.”(Workshop on June 5, 2021).

This highlights the importance of additional training and collaborative activities to ensure all dairy farmers have the necessary skills to maximize the app’s potential effectively.

Overall, the dairy farmers expressed the importance of collaboratively designing the app, recognizing that this approach benefits the institution, themselves, and the broader community that will use the app. Their responses showed that inclusive design enhances greater relevance and usability, ensuring the app effectively meets the needs of its intended audience.

Discussion

This section discusses the findings related to the research objectives, and the significance, implications, limitations, and suggestions for future research.

Discussion of the Findings

Findings on the Efficacy of the Co-Created App Development Process

Noting a lack of activities that actively engage university-community partners in creation processes, this study aims to contribute to advancing the reciprocal knowledge-sharing process for successful university-community partnerships. The findings can be interpreted through the three stages of the design thinking model used to develop the Rwenzori Dairy App, and how partners perceived the benefit of being part of the creation process.

We found that the collaborative engagement in the ideation stage was an opportunity for partners to share their unique knowledge regarding dairy farming and necessary record keeping. Yet some parameters suggested during the ideation stage were eventually deemed impractical and were deleted during the testing stage, which suggests that five faculty members and five dairy farmers during the ideation stage were, to some extent, insufficient to ensure the app’s content was feasible or aligned with broader user needs. This observation is consistent with the findings of (Liljedal & Dahlgren, 2018), who found that the absence of target users during the development process could influence consumers’ product evaluation. As shown by Trischler et al. (2019), effective collaboration requires continuous engagement, often engaging a broad range of users and stakeholders early and throughout the development process to ensure that

solutions are practical and meet user needs.

Our results from the prototyping stage support the findings from Mirri et al. (2018), which show that actively engaging target consumers in prototype and design activities frequently results in better and more gratifying solutions. Our findings also align with Kumar et al. (2016), as the partners in our study proved cooperative and offered valuable insights to ensure the app remained relevant and user-friendly for dairy farmers and the university. Moreover, experience from this stage revealed the importance of close engagement from several partners (Avram et al., 2020; Pereira & Russo, 2018; Trischler et al., 2019), suggesting that such engagement could enable the development of personalized technology that adheres to end-users' expectations. This hands-on approach could also enhance the acceptance of CE tools.

In the testing stage, dairy farmers' commitment to providing feedback provided a deeper and more nuanced understanding of user preferences, as highlighted in a study by Ting and Lewkowicz (2015) on testing tools with users before implementation. Our study confirms the findings of Filieri (2013), which show that user involvement in the testing process leads to a clearer understanding of the context of the app, which in turn improves usability and promotes greater adoption. As a recommendation, future development initiatives should consider expanding testing phases to include iterative feedback loops and hands-on training sessions to ensure users are familiar with digital tools before they are implemented on a larger scale. The testing stage also confirms findings from previous co-creation studies (Evans et al., 2015; Leavy, 2012), which show that involving users creates an opportunity to discover new and contextual ideas. Additionally, our study supports the findings of Triste et al. (2018) that farmer participation yields valuable contributions to initiatives that affect them.

Integrating design thinking with CE principles ultimately resulted in a more user-friendly app. The iterative process and continuous feedback improved the usability of the app, adapting its content and functionality to the needs of the end-users. Moreover, involving dairy farmers in co-creation suggests positive adoption, as they developed a sense of ownership over the final app. The study, therefore, suggests that with the active participation of community members in the development of tools, stakeholders feel more invested in the outcome, leading to stronger

partnerships and greater acceptance of the final product.

Findings on Partner Perceptions of the Co-Creation Process

Critically, we explored partners' perceived value of co-creating the Rwenzori Dairy App. Notably, their feedback indicates a significant shift in their feelings of connection with the university. Rather than perceiving themselves as passive consumers of university-led efforts, they expressed gratitude for the university's active engagement throughout the app development process. This active participation from the university helped the farmers feel appreciated, establishing a solid feeling of inclusion and cooperation. Partners also perceived a sense of connection to the co-created outcomes, reflecting trust in the utility of the app. To some extent, this view is consistent with the results of Kenny and Regan (2021), who observed that jointly built tools become relevant to partners and build trust in the subsequent outcomes.

Furthermore, the dairy farmers' satisfaction in their roles as innovative co-creators demonstrates the transformative power of the design thinking method in empowering partners to share their ideas. The farmers felt empowered and recognized the value of their knowledge, seeing it as beneficial to the university, the farming community, and themselves. This synergy contributed to improved CE outcomes, and we suggest future CE initiatives adopt a similar co-creation approach that empowers participants and values their knowledge to generate mutually beneficial solutions.

The design thinking process enabled partners to interact with prototypes of the digital tool, and their feedback revealed unexpected problems and usability concerns—demonstrating the value of developing and testing with end-users. Testing revealed challenges with technology literacy, as some partners required hands-on support to install and test the app. This underscores the necessity of further digital training literacy and future CE initiatives to facilitate digital engagement skills. Offering support targeted to different degrees of technological skill may boost engagement and assure successful involvement.

Overall, our research complements practical insight for implementing co-creation (e.g., Ribes-Giner et al., 2016) and designing services with community stakeholders (Drain et al., 2017; Jaeger et al., 2012). The experiences from this study show how it would be challenging for a university to design appropriate solutions without the input

of its partners, demonstrating the importance of creating democratic university structures that acknowledge community stakeholders' contributions when developing tools. We thus support co-creation through the design thinking model for structuring university CE activities (Mirri et al., 2018; Trencher et al., 2017). Furthermore, beyond its direct function as a digital tool for data storage and management on farms, the app is crucial for improving sustainable university CE through continuous data sharing and open communication between faculty members and farmers. The Rwenzori Dairy App could promote a lasting partnership and increase the long-term impact of the initial CE project.

Study Limitations and Future Research

We acknowledge the limitations of this study and hope to suggest new directions for future research. One fundamental limitation of our study is that, whereas co-creation and design thinking principles advocate for equitable engagement from all partners, we had difficulties achieving equal participation from all dairy farmers in the co-creation process. Specifically, the initial ideation involved only five dairy farmers, and we tested the app exclusively with those owning smartphones, which may not have reflected the broader Rwenzori dairy farming community. This constraint may create selection bias and limit the generalizability of our findings to dairy farmers with access to smartphone technology. Future studies should aim to include a diverse range of participants, including those without smartphones, to ensure technology tools are relevant to all segments of the farming community.

Another limitation of our study relates to the nature of design thinking, which emphasizes addressing partners' needs. However, we encountered instances where participants' ideas were either ambiguous or fell outside the scope of our study. For example, some partners suggested incorporating records for poultry, piggery, and banana growing into the app. While these ideas were valuable, accommodating all suggestions proved challenging, given our study's specific focus on dairy farming. We, therefore, propose that future iterations of the app explore broader agricultural management functionalities to cater to a broader audience. Moreover, when applying design thinking to other CE activities, it is critical to communicate the goal of the process to all partners.

Finally, due to the COVID-19 pandemic,

it was risky to convene in person during the app's prototyping and testing stages. Participants frequently suggested postponing the workshops, which delayed app development.

Significance and Implications

This research contributes to the growing literature on design thinking and co-creation within CE initiatives. The results provide valuable insights for developing more effective CE strategies with implications for policymakers, practitioners, and community partners. Drawing on the theoretical underpinnings of co-creation and design thinking, this study highlights the importance of incorporating diverse partners' perspectives to ensure solutions align with real community needs. The findings of this study are of particular importance as they demonstrate the effectiveness of the design thinking technique, particularly its iterative approach and emphasis on empathy—both of which are crucial components for successful CE initiatives. Moreover, the iterative nature of design thinking ensures a deeper understanding of community needs, enhancing the relevance of CE initiatives. Therefore, integrating iterative, empathetic design thinking into CE initiatives could enable practitioners and policymakers to establish more meaningful solutions that the community embraces.

Beyond the immediate outcomes, the app developed in this study serves as a platform for ongoing collaboration between the university and community partners. The continual interaction with the app has created opportunities for improvements in agricultural practices and faculty research activities. This study underscores the potential for long-term, impactful CE beyond a one-time intervention, establishing a model for sustained partnerships between the university and its partners.

Finally, the findings from this study have significant implications for both practice and future research on the use of technology in CE initiatives, highlighting how such innovations can strengthen the university's roles in advancing CE solutions. The app testing and feedback workshops provided partners with an open forum to discuss ideas and challenges and ultimately showed that our co-creation process did not fully equip all partners with the skills to use the app effectively. This highlights the importance of active engagement, ongoing support, and training to ensure technology is successfully implemented and adopted.

Conclusion

This paper demonstrates the potential of applying co-creation and design thinking to university CE initiatives, focusing on partners' engagement in developing an app. Through iterative ideation, prototyping, and testing, incorporating direct input from stakeholders, the Rwenzori Dairy App was developed to address the needs of local dairy farmers. Directly involving partners in the design process led to the successful development of an app, showcasing the tangible benefits of co-creation and design thinking in CE and community-focused initiatives. The three stages of the design process were intended to engage diverse university partners in a co-creation experience that addressed their needs while contributing to long-term CE goals. One key finding is the varying levels of technological literacy, which must continue to be addressed to maximize the app's impact and ensure all stakeholders can fully engage with and benefit from CE innovations.

We also intentionally examined partners' perceived value in co-developing the app. Notably, the partners reported a significant change in their relationship with the institution, from passive recipients of university efforts to active participants. Dairy farmers and other partners acknowledged the university's commitment and highlighted the transformative power of co-creation.

Finally, this research contributes to the growing discourse on collaborative strategies to strengthen universities' roles in CE initiatives. It serves as a fundamental step for future studies to examine the intersection of design thinking and co-creation in CE interventions while promoting innovative solutions that meet the needs of local communities. Detailing the lessons learned from this study can guide future university-community engagements, particularly those involving the development of technological tools, by showcasing the efficacy of processes that promote active partner participation.

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Authors' Contributions

Nyanzi Alice Sheila: Conceptualization, original draft preparation, writing. Leo van Audenhove and Chang Zhu: Conceptualization, review. Mugenyi Kintu Justice and Mark Kaahwa: Review, editing. Ivo De Pauw and Nyanzi Alice Sheila: Data analysis.

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