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UCD–CE Integration: A Hybrid Approach to Reinforcing User Involvement in Systems Requirements Elicitation and Analysis Tasks

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Abstract
Requirements elicitation and analysis tasks in user-centered design (UCD) are pivotal for assessing digital systems' quality and costs. However, these tasks often face challenges due to limited user involvement. This stems from unclear guidelines on ***how*** to conduct activities and engage users effectively to achieve their goals during the development process. This study explored how the integration of collaboration engineering (CE) principles with UCD approach could address these challenges. Using an Applied Science / Engineering approach, a UCD-CE process was designed drawing on the Six-layer model of Collaboration. This model aligns the CE steps with UCD principles (why), practices (what), and methods (how). Data collection tools included structured interviews, questionnaires, and observations, supported by techniques like user stories and dialogues, as well as thinkLets, and patterns of collaboration. Formative and summative evaluations were used to validate the UCD-CE process; and the results underscore its strengths, particularly its efficiency in helping users to complete tasks on time, reducing effort in reaching common goals, fostering high user satisfaction, promoting creativity and productivity, ensuring ease-of-use and learnability, and delivering comprehensive outcomes in requirements elicitation and analysis tasks during the development process. Future research aims to assess the practicality of UCD-CE integration in reinforcing user involvement during the UCD design phase.

Keywords User centred design · Collaboration engineering · Requirements elicitation and analysis · User involvement · Six-layer model of collaboration

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1 Introduction

In recent years, user-centered design (UCD) has been widely adopted in software development for its ability to engage users in identifying their needs and creating efficient and effective systems ((Marchak et al. 2020); (Chokshi and Mann 2018)). UCD is a problem-solving approach that emphasises user involvement in the initial phases of the systems development process ((Duque et al. 2019)). The first three phases of the UCD process—requirements elicitation, analysis, and design—form the foundation for the entire system ((Duque et al. 2019)). These phases significantly influence the development direction, the final quality of the system (Sharma and Pandey, (Sharma et al. 2013)), and the cost of the digital product ((Lane and Sammon 2016)). For example, poorly defined requirements can lead to a system that fails to meet user expectations ((Bani-Salameh and Al Jawabreh 2015)). Activities in these phases include identifying user needs clearly, translating them into system requirements, and iteratively developing user-friendly products (Sharma and Pandey, (Sharma et al. 2013)). These activities require that system developers collaboratively work with end-users to identify their requirements. This collaborative effort ensures that the final system reflects the actual needs of its users ((Bano and Zowghi 2013); (Lopes et al. 2018)).

A key challenge in UCD is limited user involvement during the requirements elicitation and analysis tasks ((Rahimi et al. 2014)). This is due to; lack of detailed guidance on how to conduct activities in these phases ((Duque et al. 2019); Farinango et al. 2018; (Harte et al. 2017)), and insufficient descriptive details and actionable steps on how to engage users to achieve their goals during the development process ((Kashfi 2018); ISO 9241–210, (210, ISO 2019); (Duque et al. 2019); (Harte et al. 2017)). These limitations have a ripple effect that extends beyond just the *"how"* to conduct activities in UCD. They leave practitioners uncertain about how to effectively engage users and translate their needs into design solutions ((Chammas et al. 2015)) nor map user needs to software requirements ((Ardito et al. 2014); (Duque et al. 2019); (Ratwani et al. 2015)). The uncertainties encompass not only the specific techniques for requirements elicitation and analysis ((Harte et al. 2017)) but also broader questions of user participation, including the degree and frequency with which users should be involved ((Duque et al. 2019); Farinango et al. 2018; (Harte et al. 2017); (Kanstrup et al. 2017); (Wilkinson and Angeli 2014)); ISO 2010). The lack of clear guidance on how to involve users during the requirements elicitation and analysis phases of the system development process ultimately leads to the development of systems that miss the mark and compromise user experience ((Kashfi 2018)). (Canny et al. 2021), (Mohammed et al. 2017)), and (Ferreira et al. 2015)) argue that, while a detailed UCD approach is necessary for designing effective systems, it does not guarantee that the final product will satisfy end-users if they are not meaningfully involved throughout the development process.

While several researchers have commendably extended the UCD approach to enhance user involvement during the development process (Mithun et al., (Mithun and Yafooz 2018); (Harte et al. 2017); (Wilkinson and Angeli 2014); (Wallach and Scholz 2012); (Wu et al. 2009)), their efforts primarily focus on outlining *"what"* activities to conduct. These approaches often fall short in providing practical guidance on *"how"* to effectively involve users in carrying out these activities. This prioritises tasks over user engagement, ultimately limiting the impact and value of user participation in UCD requirements elicitation and analysis phases. Scholars have also proposed various solutions to reinforce user involvement in the initial phases of UCD. These include; (a). developing a new design approach or structured methodology that accommodates user needs throughout the development process ((Roy et al. 2016); (Harte et al. 2017)); (b). supporting collaboration between users and healthcare providers (relevant to specific UCD applications), (c). applying tailored guidelines that ensure inclusive design for end-users ((Biljon and Renaud 2016)), and (d). utilising design patterns to guide the development process ((Ning et al. 2019)).

Building on the above proposed solutions, this study identified Collaboration Engineering (CE) as a promising approach to address the identified limitations of UCD. CE aligns well with the characteristics needed for effective user involvement ((Nunamaker et al. 2015); Briggs et al., 2015). Both CE and UCD share the core principle of *"collaboration support",* which involves integrating diverse perspectives from individuals with varied expertise, backgrounds, skills, and problem-solving styles to achieve a common goal (de Vreede 2014). However, despite this shared principle, CE's potential to enhance user involvement during requirements elicitation and analysis tasks within the UCD development approach remains largely unexplored. Collaboration Engineering (CE) is an approach for designing, modeling, and deploying repeatable collaboration processes and technologies to solve complex problems within an organization ((Kolfschoten and Vreede 2007); (Vreede and Briggs 2005)). Accordingly, this study explored how integrating CE principles with UCD could address UCD limitations during requirements elicitation and analysis. The integration aimed to provide UCD with concrete guidance on how to conduct activities and foster user collaboration during requirements elicitation and analysis. The transformation positions UCD as a more practical and impactful approach, ultimately resulting in the design of user-centered systems that genuinely meet user needs and expectations.

2 Overview of UCD and CE Approaches

2.1 UCD Principles, Practices and Methods

Three key aspects are crucial for facilitating the UCD development process, i.e., practices/processes/steps, principles, and methods. Integrating these elements during the development process significantly increases the probability of designing systems that accurately reflects user needs ((Kashfi 2018)).

2.1.1 UCD Principles

These are comprehensive and fundamental laws that underpin many software practices that practitioners need to consider in their work. Principles try to answer "*why*" (motivation behind the practices). They can be incorporated into any methodology or approach ((Chammas et al. 2015; Eggen et al. 2014)). The UCD principles include; *(a)* designs should be based on an explicit understanding of user needs, tasks performed, and the environment, *(b)* user involvement in all phases of the UCD development process, *(c)* designed systems should be driven to meet user needs and requirements, *(d)* design specifications should be iteratively reviewed and refined, *(e)* designs should address user experiences, and *(f)* the team should possess multidisciplinary skills, perspectives and experiences ((Chammas et al. 2015)). However, the abstract nature of UCD principles inhibit it from being effectively applied in practice. This therefore, means that these principles emphasise high-level concepts and guidelines rather than offering detailed, prescriptive instructions ((Kashfi 2018); (Lee 2014); (Becker et al. 2019)). Although UCD emphasises designing products and services with a strong focus on the needs, preferences, and goals of the end-users; its principles do not offer specific, step-by-step methods on how to achieve this in practice.

2.1.2 UCD Practices

These are steps/phases/processes, and they determine '*what*' the practitioners should do to meet the principles of UCD. Thus, practices include activities that practitioners perform in different steps throughout the life cycle of a software system ((Kashfi 2018)). According to Harte et al. (2017), the UCD process has defined activity phases that must meet the requirements/guidelines outlined in the ISO 9241–210 standard. Although there are other phases, the following discussion presents the first three phases of UCD.

Phase 1: Identify the user and specify the context of use (requirements elicitation) – it involves understanding the system's context, identifying user needs and preferences, using techniques e.g., interviews, surveys, observations, storyboards and paper prototypes ((Harte et al. 2017)).

Phase 2: Specify the user requirements (analysis) **–** it involves certifying that the generated requirements conform to the description of the system to be implemented and are correct, complete, and consistent with standards; are not ambiguous, do not contradict the expectations of the stakeholders, and do not contain technical errors (Maalem & Zarour, 2016; (Harte et al. 2017)).

Phase 3: ***Design*** **–** it involves engaging users in a controlled setting to test the system. It usually involves monitoring users as they interface with the different system parts, aiming to identify, prioritise, and address bugs ((Harte et al. 2017)).

Generally, these first three phases are considered the foundation of the software development process upon which the entire software/system is built (Sharma & Pandey, (Sharma et al. 2013)). This is because they involve identifying user needs, interpreting them in a much more understandable form, and translating them into system requirements (Parveen et al. 2014; Sharma & Pandey, (Sharma et al. 2013); Derrick et al. 2013). For the developed system to have an impact on the user experience, UCD principles and practices need to be integrated early in the design process by adapting and aligning them with the already existing software development principles and practices ((Kashfi 2018)). However, the UCD practices are challenged with not providing descriptive details of *"how"* activities should be conducted ((Harte et al. 2017)); hence, the development team usually has insufficient knowledge of how to perform UCD activities during the development process ((Campese et al. 2020)).

2.1.3 UCD *Methods*

Specify *"how"* these practices are performed to satisfy the principles, and impose structure on practices to make them systematic and more successful ((Kashfi 2018)). Some of the UCD methods applied during requirements elicitation and analysis include; workshops, brainstorming, interviews, use cases, and member check validation ((Mithun and Yafooz 2018)). However, these UCD methods lack descriptive details on how to involve and integrate users in the development process (9241–210, 2019; Bazzano et al. 2017; (Duque et al. 2019); Farinango et al. 2018; (Harte et al. 2017); (Kanstrup et al. 2017); (Wilkinson and Angeli 2014)); they also tend to ignore the overall user experience ((Kashfi 2018)).

2.2 User Involvement in UCD

User involvement in UCD refers to the participation of potential users in the system development process ((Barki and Hartwick 1989)). This involvement leads to users perceiving the system as useful, fostering a sense of ownership, and developing a more positive attitude towards the system ((Bano and Zowghi 2013); (Rahimi et al. 2014)). In the UCD approach, there are three categories of user involvement; (i). design with the user – based on user needs and experiences, (ii). design by the user – actively involving users throughout the development process, and (iii). design for the user – using existing data, theories, or models to design systems ((Scariot et al. 2012)).

2.3 The Collaboration Engineering (CE) Approach

To design high-quality collaborative processes involving practitioners and users, CE researchers ((Scariot et al. 2012); (Nabukenya 2012); (Briggs et al. 2006)) developed a structured approach known as the "five-ways framework." This framework includes; the *Way of Thinking* (defines key terms, models, phenomena, and encompasses theories about collaboration quality aspects including productivity, participant satisfaction, commitment and other phenomena) ((Vreede and Briggs 2019)), the *Way of Controlling* (describes methods and measures for managing the quality of the designed artifact and the collaboration process) ((Vreede and Briggs 2019); (Nabukenya 2012)); the *Way of Modelling* (specifies how collaborative processes and group interactions are represented on a useful level of abstraction) (de Vreede et al. (De and Briggs 2003)); the *Way of Supporting* (provides detailed account of tools and technologies used to support design and deployment of solutions) ((Kolfschoten and Vreede 2007)); and the *Way of Working* (explains the structured methods and techniques used for designing and deploying collaboration processes) ((Vreede and Briggs 2019)) to support novices in performing collaborative tasks, to increase insight into the critical steps in designing collaborative processes, to train facilitators and to provide a basis for creating design support tools ((Kolfschoten and Vreede 2007)). The *Way of Working* is divided into two phases; the design phase and deployment phase ((Vreede and Briggs 2019)).

The design phase consists of the CE reference model ((Vreede and Briggs 2018)) and six steps that are applied when designing the collaboration process ((Kolfschoten and Vreede 2007)). The CE reference model is an organised collection of design aspects that the Collaboration Engineer must consider when designing repeatable collaboration processes ((Vreede and Briggs 2018); (Vreede and Briggs 2019)). There are two versions of the CE reference model: the Six-layer model of collaboration and the Seven-layer model of collaboration ((Read et al. 2012)). This study employed the *six-layer model of collaboration* because it fills the gaps in the seven-layer model of collaboration and ensures that participants' instructions and collaboration tool configurations are included in the behavioural layer ((Vreede and Briggs 2019)).

2.4 The Six-layer Model of Collaboration (SLMC)

The SLMC consists of software, knowledge, hardware, actors, and work practices that enable groups to achieve their goals efficiently and effectively. Therefore, the design of collaboration processes can only occur after the prerequisite steps of this model have been completed in sequence ((Filip et al. 2017)). The SLMC also provides a mental tool for tracing effects of design changes from layer to layer and organising structure for concepts, theories, metrics, phenomena, techniques, best practices, modelling conventions, and design consideration of the collaborative work systems at six different levels of abstraction. As a result, the SLMC models and concepts serve as a completeness check for designers, to ensure that critical issues are considered and resolved promptly in each layer to reduce cognitive load ((Nunamaker et al. 2015); Briggs et al. 2015).

Layers in the SLMC include; collaboration goals, work products, group activities, group procedures, collaboration tools, and collaborative behaviors ((Randrup and Briggs 2015)). Each layer is dependent on the other, and the changes in one-layer influences other layers either directly or indirectly. Design decisions made at one layer may necessitate design changes in layers below or above it. For example, if the goals in the goals layer change, the deliverables (in the products layer) must change to meet the new goals. If the deliverables are changed, the group's activities would likely have to be changed to create new deliverables. Because design choices on a given layer are constrained by design choices in the layer above, the most significant dependencies among the layers all point in the same direction ((Nunamaker et al. 2015)). Each layer in the SLMC addresses different collaboration concerns for collaboration system designers, such as the phenomena of interest, methods for explaining, modeling, and measuring Collaboration. It is distinguished by six ways in which groups progress through their collaborative processes ((Nunamaker et al. 2015); Briggs et al. 2015).

2.5 Advantages of CE

Collaboration Engineering (CE) offers several advantages that enhance user involvement in system development. One key benefit is the use of standardised, repeatable procedures (de Vreede et al. 2009). These procedures act as a guide for facilitators, ensuring a consistent and efficient user experience regardless of the facilitator's prior experience. This streamlines user involvement throughout various the development phases, particularly during crucial stages like requirements elicitation and analysis.

CE fosters a collaborative environment that promotes consensus building and user empowerment. Facilitators guide discussions to ensure all participants are heard and their perspectives are represented. This approach helps to establish a shared understanding of the project goals and user needs. Additionally, CE allows for the strategic allocation of roles within the user group, leveraging individual skills and expertise (e.g., facilitator, group leader, timekeeper, note-taker). This optimised participation leads to richer insights and more effective solutions.

CE employs communication mechanisms, such as anonymous options that boost user self-esteem and encourage participation from all members. This broader range of user perspectives and experiences leads to more inclusive and user-friendly system features. By facilitating clear communication and understanding, CE also helps to reduce misinterpretations of user needs during the analysis phase ((Helquist et al. 2019)). Additionally, CE has been shown to demonstrably reduce the time required for user involvement (Inkpen et al., 2009). This is achieved by streamlining user participation without sacrificing the quality of their input. By making efficient use of valuable user time, CE can contribute to faster overall system development completion.

Last but least, CE has the potential to address the challenge of developers disregarding user input during analysis. CE techniques stimulate creative thinking and shared understanding, ensuring user priorities and requirements are actively considered and acted upon (de Vreede 2014; Amiyo et al., 2012). This reduces the risk of overlooking valuable user insights that could significantly improve the system's functionality and usability.

Overall, CE's strengths align well with the needs of system development, particularly during requirements elicitation and analysis. By providing a structured, efficient, and inclusive approach to user involvement, CE leads to a better understanding and interpretation of user needs, ultimately resulting in more successful systems.

2.6 Complementary Role (Similarities and Differences) Between CE and UCD Approaches

2.6.1 Similarities Between UCD and CE

UCD and CE share similar ideologies of collaboration support; they both integrate perspectives from individuals with different expertise, backgrounds, skills, and problem-solving styles to achieve a common goal. They both exhibit similarities in planning methods, collaborative sequenced activities, and iterative nature ((Azadegan et al. 2013); (Bano and Zowghi 2013); Kolfschoten & de Vreede, (Kolfschoten and Vreede 2009); (Lopes et al. 2018); (Sánchez and Macías 2019)).

UCD 9241–210 standards provide approaches, practices, methods, guidelines, and basic principles followed during the development process ((Chammas et al. 2015); (Kashfi 2018)). Similarly, CE provides guidelines followed during the development process to facilitate a structured description of any design approach or methodology (Briggs, Kolfschoten, & de Vreede, (Briggs et al. 2006); (Nabukenya 2012)). According to Briggs et al. (2006), Kolfschoten and de Vreede ((Kolfschoten and Vreede 2009)), and (Nabukenya 2012)), these guidelines are encapsulated in the "Five Ways Framework." Both UCD and CE guidelines emphasise key aspects—"how" (methods), "what" (practices/steps/processes), and "why" (principles)—during the development process ((Kashfi 2018)).

CE principles play a complementary role in addressing the limitations of the UCD approach. For example, CE principles provide detailed guidance on performing collaborative tasks, enhancing user involvement in requirements elicitation and analysis during the systems development process. Additionally, the tools layer of the SLMC focuses on the selection and configuration of tools to enhance the user experience during the collaborative process, while the behavior layer of the SLMC provides documentation to guide the facilitator on what to do or say during collaboration.

2.6.2 CE Complementary Role to UCD Practices ("what" Aspect)

UCD practices/phases/steps/processes define "*what*" practitioners should do during the development process to adhere to UCD principles ((Kashfi 2018)). However, UCD practices often lack detailed descriptions of how activities should be executed in the systems development process ((Harte et al. 2017)). Consequently, the development teams frequently lack the necessary knowledge on how to effectively conduct UCD activities ((Campese et al. 2020)).

The process layer of the Way of Thinking ((Kolfschoten and Vreede 2007)), Way of Support, and Way of Modelling can address these limitations of UCD practices by emphasising "**what**" practitioners should do to achieve group goals ((Kashfi 2018)). For example, the Way of Modelling offers a high-level map of process design to train and guide practitioners in executing engineered work practices ((Briggs et al. 2003)). Similarly, the "Activities" layer of the SLMC provides descriptive details of tasks that should be carried out to fulfill assigned responsibilities ((Nunamaker et al. 2015)). The process layer of the Way of Thinking delineates phases that specify "***what***" activities are necessary to achieve group goals ((Kolfschoten and Vreede

2007)). Therefore, in terms of "**what**" aspects, UCD practices define the required activities, while the Way of Thinking and SLMC provide a structured approach for how these activities should be conducted. This framework helps development teams understand how to perform each activity efficiently and effectively within the UCD process or practice.

2.6.3 CE Complementary Role to UCD Tools and Methods ("how" Aspect)

While UCD tools and methods offer guidance on "how" to perform development activities ((Kashfi 2018)), they often lack specifics on how to effectively involve users throughout the development process ((Ozcelik et al. 2011)). This can lead to usability issues and neglecting of user experience ((Kashfi 2018)).

Several aspects of CE's "Way of Thinking" ((Kolfschoten and Vreede 2007)) framework mirror UCD methods and tools. These include the pattern and thinkLet layers, design and deployment phases of the Way of Working, Way of Supporting, and the tools and group procedure layers of the SLMC ((Nunamaker et al. 2015)). *What makes them complementary is their focus on "how" to conduct activities.* They provide detailed instructions on iteratively using methods, strategies, and tactics to design and execute work systems with user involvement in mind. For instance, according to Briggs et al. (2015), the Way of Modelling's facilitation process model specifies how user interactions are represented and incorporated. The Agenda Notation Model provides a structured plan for conducting work practices. The Way of Working offers methods for designing and deploying the collaboration process, ensuring user engagement. The behavior layer, procedure layer, and tools layers of the SLMC provide various methods, strategies, tools, techniques, and documentation to guide groups in executing tasks toward their goals (Briggs et al., 2015). The Way of Controlling supplies methods for measuring the quality of designed artifacts, and the Way of Support provides tools and technologies for designing and deploying collaboration processes (Briggs et al., 2015).

Therefore, UCD sets the stage by defining user needs and goals. CE bridges the gap by offering specific guidance on how to involve users during requirements elicitation and analysis. This leads to a more comprehensive and user-centered development process. By integrating CE methods with UCD methods, the development teams gain a richer understanding of "how" to meaningfully engage users throughout the entire process.

2.6.4 CE Complementary Role to UCD Principles ("why" Aspect)

UCD principles focus on the "why" behind achieving development goals. These principles help participants to understand the goal itself, the context in which it will be used, and how they should be involved (((Becker et al. 2019)); ((Gulliksen et al. 2003)); ((Lee 2014))). However, the abstract nature of these principles can make them difficult to apply in real-world projects (((Becker et al. 2019)); ((Lee 2014))). CE offers a solution to this challenge. By integrating specific aspects of CE's "Way of Thinking" framework with UCD principles, we can address the issue of abstractness. For example, the "goals" layer of the SLMC framework in CE focuses on group goals, individual goals, and ensuring everyone is aligned. This can significantly motivate teams to achieve the overall project goal (Briggs et al., 2015). The "products" layer of the SLMC deals with the quality, creativity, and effectiveness of the final product, ensuring it meets user needs (Briggs et al., 2015).

In essence, while UCD principles clearly define the "why," their abstract nature can hinder practical application. CE, with its focus on user motivation and goal understanding, offers complementary solutions. Specifically, the "goals" and "products" layers of the SLMC framework can guide teams towards a deeper understanding of the "why," leading to stronger team cohesion and a product that aligns with user needs. Figure 1 summarises the similarities and complementary aspects of UCD and CE, while Table 1 expands on how CE principles address UCD limitations in terms of "why," "what," and "how" aspects throughout the development process. The table also highlights similarities between the approaches and provides examples of their combined effects.

3 Methods

The study started with a literature review to identify the similarities and differences between UCD and CE. This helped the researchers to understand how these approaches could complement each other. Next, the Applied Science/Engineering approach (AS/E) was employed as one of the modes of inquiry in Design science (((Randrup and Briggs 2015)); ((Briggs and Schwabe 2011))), to facilitate the integration of the UCD approach with CE principles. This approach helped the researchers to investigate how the CE principles could address UCD challenges.

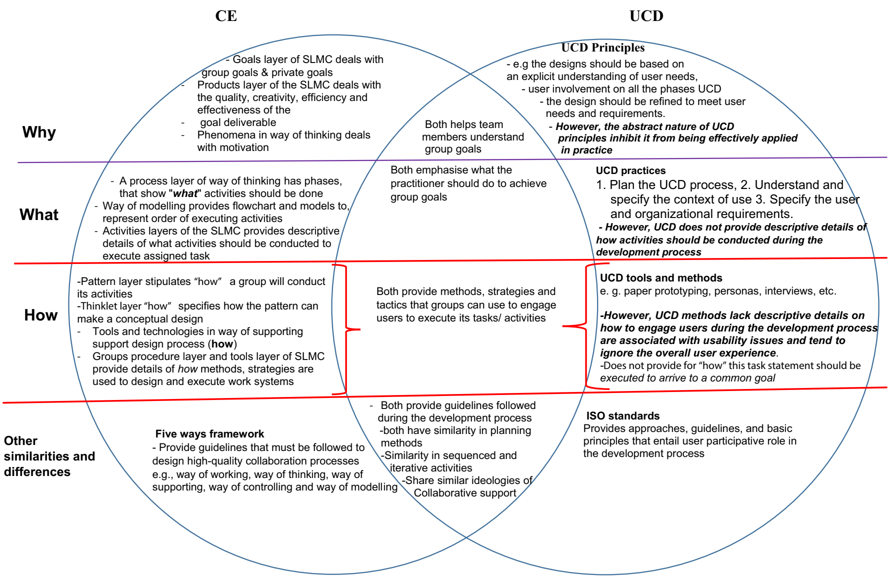

Fig. 1 Similarities and differences between CE and UCD

Table 1 How activities in CE address UCD limitations during the systems development process (i.e.," why", "how", and "what" aspects)

UCD and CE aspects	How UCD is applied during the development process	UCD limitations	CE principles (collaboration six-layer model)	Activities in CE principles that address UCD limitations	Similarities between UCD and CE	Phenomenon of interest (UCD-CE effect/outcome)
Why	UCD principles assist group members in understanding the goal, context of use, how users should interact, and how they should participate in all processes ((Becker et al. 2019)); ((Gulliksen et al. 2003)); ((Lee 2014))	UCD principles are too abstract and cannot be applied as it is in practice ((Gulliksen et al. 2003))	Goals layer concerns goals achieved by group effort ((Nunamaker et al. 2015)); Briggs et al., (2015)	The SLMC's goals layer addresses group goals, personal goals, and goal congruence Briggs et al. (2015) The goals layer plays a complementary role in motivating the group members to achieve the group goal and their personal goals; encourages the group to be committed to achieving the group goal; addresses how groups could achieve productivity and user satisfaction ((Randrup and Briggs 2015)); Briggs et al. (2015) CE activity Identify the goal	The goals layer pertains to UCD principles and step 1 of CE	Productivity ((Vreede and Briggs 2019)) Motivation Commitment Briggs et al., (2007) Satisfaction ((Reinig et al. 2017))

Table 1 (continued)

UCD and CE aspects	How UCD is applied during the development process	UCD limitations	CE principles (collaboration six-layer model)	Activities in CE principles that address UCD limitations	Similarities between UCD and CE	Phenomenon of interest (UCD-CE effect/outcome)
Why	UCD principles are incorporated to provide a set of action statements that practitioners must follow to; ensure that all participants understand the study goal, the context of use, who the users are, who should perform the tasks, and how the tasks must be performed identify multidisciplinary end-users with different skills and expertise to participate in the study. (c) User involvement in all phases ((Gulliksen et al. 2003))	The abstract nature of UCD principles prevents it from being fully applied in practice ((Gulliksen et al. 2003))	Products layer/deliverable layer) concerns the tangible or intangible work products created by the group to achieve group goals ((Nunamaker et al. 2015); Briggs et al. (2015)	The products layer addresses issues of creativity, quality, effectiveness and efficiency of the deliverable, awareness of the problem, participation and gaining multiple perspectives of the non-tangible problem ((Randrup and Briggs 2015)) CE Activities include; Identifying and engaging end-users Negotiating task goals Negotiating task specifications Determining the operational resources required to run the work system	The product layer is related to UCD principles step 2 of CE	Quality ((Briggs and Reinig 2010)) Creativity ((Vreede and Briggs 2019)) Effectiveness ((Good and Omisade 2019)) Efficiency ((Good and Omisade 2019))

Table 1 (continued)

UCD and CE aspects	How UCD is applied during the development process	UCD limitations	CE principles (collaboration six-layer model)	Activities in CE principles that address UCD limitations	Similarities between UCD and CE	Phenomenon of interest (UCD-CE effect/outcome)
What	Practices show what activities are done during the development process ((Kashfi 2018)) Examples of practices include; Plan the UCD process Identify and specify the context of use Specify user and organisational requirements ((Campese et al. 2020)))	UCD practices do not provide descriptive details of how activities should be conducted ((Harte et al. 2017)). Hence, the development team has insufficient knowledge of performing UCD activities ((Campese et al. 2020))	The activities layer is concerned with the structure of the tasks that a group must complete in order to create its deliverables, as well as the conditional logic for task execution order task execution order ((Nunamaker et al. 2015)); Briggs et al. (2015)	SLMC performs the following complementary functions: Stipulates what groups should do to achieve their goals Decompose group goals into manageable chunks. These activities support the planning and creativity of group members when applied together with group support tools ((Randrup and Briggs 2015)) CE Activities; Decompose tasks into work packages that specify the name of the work package input specs and who should participate Creates conditional logic for the sequencing of work packages Stipulates activities for problem identification, alternative generation, validation, and choice	Activities layer pertained UCD practices/steps and step 3 of CE	Ease of use ((Good and Omisade 2019)) Individual objective Van & Berghout, ((Solingen and Berghout 1999))

Table 1 (continued)

UCD and CE aspects	How UCD is applied during the development process	UCD limitations	CE principles (collaboration six-layer model)	Activities in CE principles that address UCD limitations	Similarities between UCD and CE	Phenomenon of interest (UCD-CE effect/outcome)
How (logical design)	Examples of UCD methods used included; Questionnaire Interview Observation Focus group Participatory design Paper prototyping Users' involvement is tailored towards their knowledge and abilities to allow for different levels and forms of involvement, e.g., consultative, collaborative and user-led ((Teles et al. 2019))	UCD methods lack information (descriptive details) on how to engage users during the development process ((Ozcelik et al. 2011)), are associated with usability issues and tend to ignore the overall user experience ((Kashfi 2018))	Group procedure layer, Concerns; methods, strategies and tactics that a group uses to move through to execute its activities ((Nunamaker et al. 2015)); Briggs et al. (2015)	The procedure layer provides methods, strategies and tactics that groups can use to execute their activities; thinkLets can be used to encourage useful interactions among people working toward a common goal ((Nunamaker et al. 2015)). CE activities; Map collaboration pattern to each activity Select collaboration mode for each collaboration pattern Help choose the ideal thinkLets that correspond to the selected pattern of Collaboration	Group procedure layer pertains to UCD methods and step 4 of CE	Social group objective and individual objective Van & Berghout, ((Solingen and Berghout 1999)) Ease of use

Table 1 (continued)

UCD and CE aspects	How UCD is applied during the development process	UCD limitations	CE principles (collaboration six-layer model)	Activities in CE principles that address UCD limitations	Similarities between UCD and CE	Phenomenon of interest (UCD-CE effect/outcome)
How (logical design)	Tools support UCD activities, e.g., personas, scenario-based cases, validation tools, prototyping tools and usability tools for identifying user needs	Lack of adequate UCD tools ((Seffah and Metzker 2004))	The tools layer is concerned with the equipment and technologies that a group uses to carry out its activities. ((Nunamaker et al. 2015)); Briggs et al. (2015)	The tools layer concerns tools and technologies that the groups can use to perform their activities, e.g. flip charts, whiteboards and group support systems ((Randrup and Briggs 2015)); Briggs et al. (2015) CE activities; Select and con*Figure* MeetingWizard tool to restrict counterproductive actions, like accidental deletion of other participant ideas during brainstorming sessions Design transitions between techniques to optimise transitions procedure between tasks, to make it easy to edit available information or change tasks before the next task can begin	The tools layer pertains to UCD methods and tools and step 5 of CE, because they both addressed "how" activities are conducted	Social group objective and individual objective Van & Berghout, (1999)

Table 1 (continued)

UCD and CE aspects	How UCD is applied during the development process	UCD limitations	CE principles (collaboration six-layer model)	Activities in CE principles that address UCD limitations	Similarities between UCD and CE	Phenomenon of interest (UCD-CE effect/outcome)
How (physical design)	Missing in UCD	Missing in UCD	The behavior layer addresses everything that individual group members should say and do in relation to the tools they use to implement the procedures chosen for the group. (Nunamaker et al. 2015)); Briggs et al. (2015)	Provide expert advice on what participants should and should not do with the capabilities provided to achieve their goals Internal documentation embedded in the technology tool guides the group on what to do External documentation assists facilitators in planning, training, preparing, executing, and following up on the work system's execution (Randrup and Briggs 2015))	This layer pertains to step 6 of CE, but is missing in UCD	Social group objective and individual group objective Van & Berghout, ((Solingen and Berghout 1999))

The researchers used the SLMC to develop the work breakdown structure for the integrated UCD-CE process. The SLMC's six layers mirrored the "why," "how," and "what" aspects addressed by both UCD and CE. This similarity facilitated the design of a UCD-CE process using the Design science method.

The designed UCD-CE process was then validated at four healthcare facilities in Uganda. To ensure user participation, the researchers used a two-step sampling approach. First, purposive sampling was used to target specific user groups relevant to the study. Then, the convenience sampling was used to identify participants readily available and willing to engage; and as well, anticipated non-participation due to busy schedules or lack of interest necessitated this approach.

A total of 38 participants were selected based on their reasonable knowledge of electronic health information systems (eHIS) and shared background, fostering a common understanding for comprehensive insights. Participants' roles ranged from Clinicians, Doctors, Nurses, Implementing Partners, Biostatisticians, Counselors, Data Clerks, Lab Technicians, Quality Control Officers, IT Focal Persons, Data Protection and Security Specialists, Data Warehouse Architects, Health Informatics Specialists, to Monitoring and Evaluation Officers. Recruitment of the participants involved obtaining permissions from Gulu University Research Ethics Committee (GUREC-2021–73), and Uganda National Council of Science and Technology (UNCST). Administrative clearance was obtained from District Health Officers (DHOs) in selected districts, system developers' supervisors, and health facility administrators where the study was conducted. Appointments were arranged by the research team to determine suitable times and venues for workshop sessions. Prior to participation, all selected participants received written informed consent forms, which detailed their rights, benefits, risks, and study expectations.

Data was collected through structured interviews, questionnaires, and observations. Techniques like user stories, dialogues, thinkLets, and collaboration patterns were also employed. We used both formative and summative evaluation methods as detailed in Table 2, to assess the effectiveness of the UCD-CE process.

4 Results

4.1 Designing and Executing the UCD-CE Process

The collaboration process sessions mirrored the first two steps of the UCD-CE process. These steps incorporated principles, methods, and activities from both UCD and CE approaches, as detailed in Table 3 and Fig. 2 respectively. While the UCD-CE process can be applied to various systems, this study focused on validating it for eliciting and analysing requirements for eHIS.

Step 1: Task Diagnosis – this step aligns with the goals layer and the deliverables/products layer of the Six-Layer Model of Collaboration and UCD principles, focusing on the "why" aspect—why a goal is established and what kind of deliverable is ideal for achieving it. The workshop's goal and deliverables were defined, target users identified, roles clarified, tasks specified, and operational resource requirements determined. UCD principles were integrated with CE principles to create

Table 2 Shows the evaluation framework used during formative and summative evaluation of the UCD-CE process

Dimension	Evaluation criteria	Version of iteration	Focus of the evaluation	Form of evaluation	Evaluation method and techniques used	Category of participants	Role of participants
Goal (e.g., efficiency, validity) Efficacy	Efficacy (the degree to which the artefact produces desired effect) Venable et al. (2012)	Version 1	Manually go through the designed artefact step by step to identify errors, inconsistencies that might occur when the process is executed Gather feedback to make improvements. Improve the quality of the artefact	Formative evaluation	Dry run to check for errors in the process	Experts	Identified errors Provided suggestions on how to address the identified errors Modifications were made to make the UCD-CE artefact more effective, efficient, and aligned with the main goal of this study)

Table 2 (continued)

Dimension	Evaluation criteria	Version of iteration	Focus of the evaluation	Form of evaluation	Evaluation method and techniques used	Category of participants	Role of participants
Environment (consistency of the UCD-CE process with the people and utility)	Validity (the degree to which the UCD-CE process worked correctly) Generality Consistency with the organisation, technology and people	Version 2	Validate the UCD-CE artefact changes made based on feedback of version 1 Investigate the degree to which the UCD-CE process works correctly Validate the UCD-CE artefact to ensure that it follows the design principles and work process in the organization Refine the UCD-CE process based on feedback obtained	Formative evaluation	Structured walk-through Dry run	Experts	The second iteration was done to improve the UCD-CE artefact under development Identified defects in usability Verified that the suggested concerns in the feedback were addressed Verified whether the UCD-CE process was working correctly The feedback from the experts was applied to improve the UCD-CE process before it was released to the target users for summative evaluation

Table 2 (continued)

Dimension	Evaluation criteria	Version of iteration	Focus of the evaluation	Form of evaluation	Evaluation method and techniques used	Category of participants	Role of participants
Structure and activity	Effectiveness Efficiency Quality of the deliverable User satisfaction Ease of use Social group objective individual group objective Social group objective	Version 3	Validate the UCD-CE process for its overall effectiveness, efficiency, ease of use Investigate whether the UCD-CE process facilitates reinforcing during requirements elicitation and analysis tasks Use feedback from version 3 to refine the UCD-CE process before it is rolled out	Summative evaluation	Field study simulation of the UCD-CE process Structured walk-through Interview Observation Questionaires	Primary users (practitioners) Secondary users	Verified that the concerns provided in version 2 were addressed Simulation of the UCD-CE process was done in a case study setting in which participants interacted with the UCD-CE process to elicit and analyse user requirements based on their needs. This interaction resulted into a list of feedback and suggestions on how to improve the UCD-CE process Participants were asked to assess the UCD-CE process based on a set criterion Experienced professionals assessed the quality of the outcome of the UCD-CE process A final UCD-CE process was produced after refinements were made according to the feedback obtained in version 3

action statements for practitioners. Due to the abstract nature of UCD principles, which hinders practical application ((Gulliksen et al. 2003)), these principles were complemented with the goals layer and deliverables layer of the Six-Layer Model and step 1 of CE. This combined approach aimed to; (a) motivate group members to achieve the main and personal goals, (b) encourage group formation to achieve defined goals, (c) promote commitment to the main goal due to goal congruence, and (d) address how groups can achieve productivity and user satisfaction through teamwork (Briggs et al. 2015).

Step 2: Task/Activity Decomposition – this step pertains to the activities layer of the Six-Layer Model of Collaboration and UCD practices. It determines the activities practitioners perform throughout the development process ((Kashfi 2018); (Briggs et al. 2015)). Involving users in the first two phases of UCD helped the development team to understand the user needs and demonstrate value for user input ((Wallach and Scholz 2012)). However, UCD processes lack detailed guidance on how to perform UCD activities during requirements elicitation and analysis. The activities layer of the Six-Layer Model was applied to address this challenge, stipulating what groups must do to achieve their goals and decomposing these goals into manageable tasks through problem identification, planning, selection, review, and evaluation. These activities supported planning and enhanced creativity among participants.

The primary goal was divided into smaller tasks, and the primary activities and deliverables of the UCD-CE collaboration process were determined. These activities were assigned to suitable patterns of collaboration, characterised by six patterns; a) generate—number, relevance, effectiveness, originality, and thoroughness of ideas, (b) reduce/converge—quality of ideas, (c) clarify—ambiguity reduction and mutual assumptions, (d) organise—shared understanding of concepts, cognitive load, and relationships, (e) evaluate—projections of potential consequences, influence on goal attainment, and (f) build commitment—willingness to contribute to group effort ((Briggs et al. 2015)). Each pattern has an associated phenomenon. For example, the "generate" pattern reports on the number, relevance, originality, and thoroughness of ideas generated by combining existing ideas or expanding on them.

Step 3: Activity ThinkLet Choice – this step addresses the "how" aspects related to the process layer of the collaboration model and UCD methods. ThinkLets are essentially strategies, tactics, and methods that guide the group activities. The choice of thinkLets was based on factors like scope, context, feature, applicable situations, intended results, and compatibility with the output of the preceding thinkLets. A classification map of thinkLets based on the collaboration patterns was created to identify suitable combinations. The choice of thinkLets was also influenced by the study goals, practitioner skills, and anticipated results (Kolfschoten & Rouwette, (Briggs et al. 2006)). Each activity in the collaboration process was matched with a suitable thinkLet based on the criteria such as the purpose and conditions (more details in Table 3). Table 3 illustrates how the tasks in the first two phases of UCD were decomposed into activities, assigned collaboration patterns, and matched with thinkLets during the requirements elicitation and analysis tasks (as discussed in steps 2 and 3).

Table 3 Application of the UCD-CE collaboration process in EHIS requirements elicitation and analysis tasks

UCD process	UCD tasks	UCD methods used	UCD principles	CE process steps	CE principles in ce tasks	CE tasks decomposed into activities	Collabora-tion pattern	Thinklets	CE method and tools used
Specification of context of use	Determined the goal, deliverable and environment in which users use the system Determined target user categories, roles and characteristics Established the context of use of current systems Validated the current system to understand user experiences encountered while using eHIS Identified user needs	Observation Literature review Personas workflow analysis document analysis Focus groups scenarios	Applied to identify multidisciplinary stakeholders, ensure all participants understood the goal and user involvement in all the phases, and provided a set of action statements for practitioners to follow	**Step 1 CE:** Task diagnosis and activities layer of the six-layer model of Collaboration The goals layer and products layer of the six-layer model of Collaboration	Identified study participants Defined Workshop goals and deliverables Defined User role and practitioner's role Negotiated task specifications Determined operational resource needs The goals layer motivated participants to identify and achieve group goals and personal goals. The products layer deals with gaining multiple perspectives of the problem to ensure the quality, creativity, effectiveness and efficiency of the deliverable	Identified the business process in the health facility-Categorised the business process Prioritize the business process-Identified systems used in the business process Elaborated and categorised the systems Determined priority of system to discuss through voting Identified relevant user needs -based on experiences they encountered in the business process Elaborated and categorized the identified user needs in the business process Determined the priority of the user need through rating Select and discuss user story prioritization Decide if group understanding of user story is achieved	Generate Converge Evaluate Diverge converge Evaluate Diverge Converge Evaluate Build consensus Build consensus	FreeBrainstorm FastFocus Strawpoll FreeBrainstorm Popcornsort Crowbar Leafhopper FastFocus Strawpoll Crowbar Moodring	Brainstorming Workshop Dialogue

Table 3 (continued)

UCD process	UCD tasks	UCD methods used	UCD principles	CE process steps	CE principles in ce tasks	CE tasks decomposed into activities	Collabora-tion pattern	Thinklets	CE method and tools used
Specification of requirements	Conducted a needs assessment to explore/identify user needs Translated user needs into a set of functional and non-functional requirements Reduced ambiguities and set priorities for identified user needs Consolidated the elicited user requirements and record it in a document Adopt recommendations/ solutions	User stories Scenarios Brainstorming Focus groups Questionnaire workflow analysis Member check validation	The design should be based on an explicit understanding of user needs; tasks performed and the environment User involvement in the phases of UCD development process The designed systems should be refined/driven so that it meets user needs and requirements The design specifications should be iteratively reviewed and refined The design should address user experience	Step 2: Task/activity decomposition Step 3: Activity ThinkLet choice Step 4: Agenda building Step 5: Design documentation Step 6: Design validation In addition, the activities layer, the group procedure layer, the tools layer and the behaviors layer were also applied	Stipulated what the group must do to achieve its goals Decomposed group goals into smaller dependent tasks Determined activities for achieving the main goal and deliverables of the UCD-CE collaboration process The activities layer of the six-layer model of Collaboration stipulated what the groups had to do to achieve the goal The procedure layer provided strategies, tactics and methods for executing its activities and invoking useful interactions towards group goals The tools layer guided on the technology groups can use to perform its activities	Decomposed user needs into tasks and subtasks Consolidated key ideas from the list of generated comments Determined priority of the decomposed user need Generated a list of the digital system should do if it is to complete the work it is intended to do) Consolidated key ideas generated Prioritize the list of generated ideas through voting Confirmed level of consensus Confirm level of consensus reached	Diverge Converge Evaluate Diverge Converge Evaluate Build consensus Build consensus	Dealer-schoice Bucketbriefing Bucketwalk Leafhopper Bucketbriefing Strawpoll Build consensus Moodring	Brainstorming Workshop Dialogue

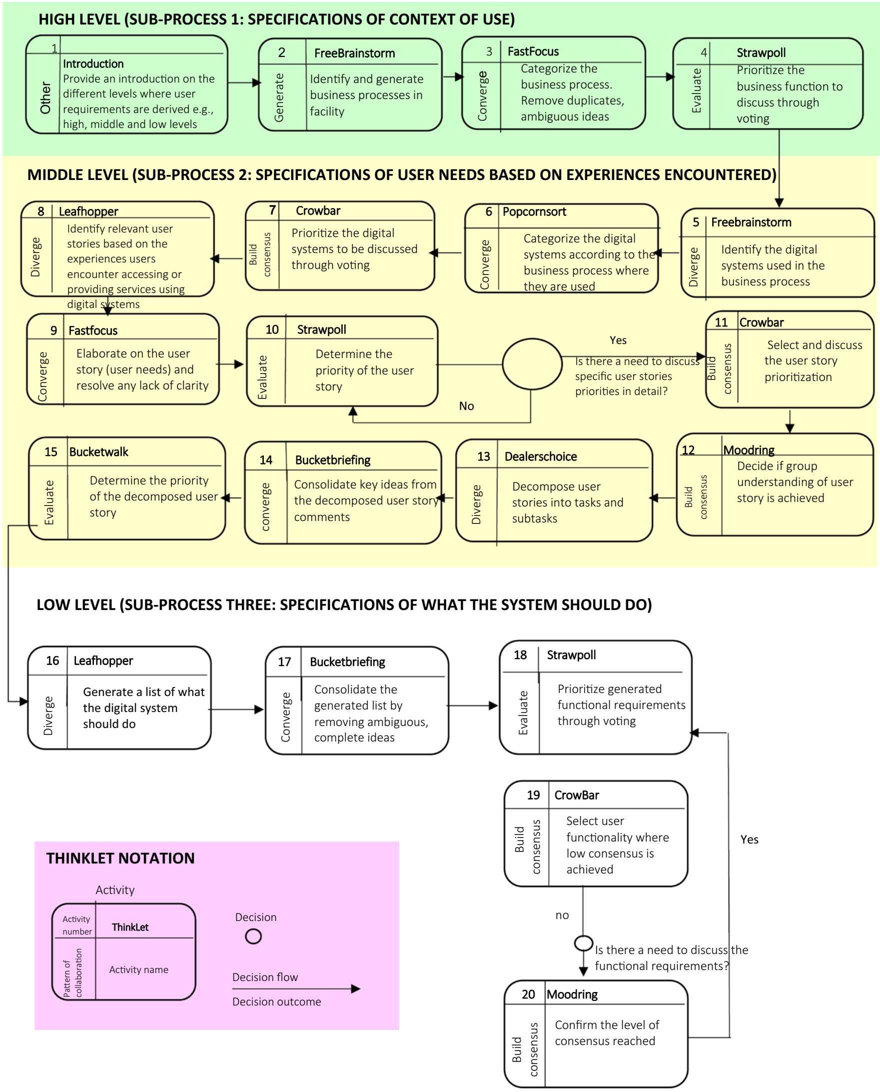

Fig. 2 Shows the hybrid UCD-CE collaboration process

Step 4: Building the Agenda – this step aimed to create a collaborative work environment suitable for novices with minimal training. It involved defining variables for each task to ensure smooth execution. For instance, goals, specified breaks, presentations, time allocation for each task, specific questions asked, instructions were determined and provided. Additionally, information like the voting criteria, voting scale, topics, categories, and the (GSS) was provided. This ensured outputs from one activity could be used in the next step. The session duration was one hour and thirty minutes. This step aligns with the "how" aspects addressed by the tools layer and some aspects of the Behavior layer of the Six-Layer Collaboration Model, as well as UCD tools and methods ((Briggs et al. 2015); (Kashfi 2018)). The Tools layer focuses on the equipment and technologies used, such as whiteboards, flipcharts, and the MeetingWizard GSS ((Briggs et al. 2015)). The CE activities included; i). selecting and configuring tools – the MeetingWizard GSS facilitated the collaboration process by guiding participants through each step with embedded instructions; and ii). designing transitions between techniques – the MeetingWizard GSS configurations allowed optimal transitions between tasks, hence simplifying the process for novices.

Step 5: Design Documentation – this step focused on capturing knowledge and ensuring smooth implementation by practitioners. To facilitate knowledge transfer to practitioners, brief explanations of each thinkLet's purpose and usage were produced. All information gathered from interviews and questionnaire responses was recorded. Researchers analysed this data to understand the factors influencing outcomes at each stage of the collaboration process, whether user instructions facilitated task completion, and whether user involvement in requirements elicitation was enhanced compared to the traditional approaches. The MeetingWizard GSS automatically recorded all workshop participant data. Two types of documentation were created to support practitioners and users; i). *Internal documentation* to make it simple for practitioners to read, comprehend, and follow the instructions, all thinkLets, thinkLet scripts, objectives, tasks, activities, and design agenda sequence activities were documented. This documentation enabled the facilitator to guide participants in several tasks. e.g., voting, flipping/categorisation, and brainstorming sessions that guided participants in several tasks, etc. and ii). *External documentation* where; *a)* a script was written to guide practitioners on planning, preparing, executing, and following up on the work system; this script enabled the facilitator to guide stakeholders/users to identify their needs based on their experiences, and *b)* Collaboration modes for each collaboration pattern was selected to reinforce the work product quality in terms of cognitive load, time, cost, motivation, and user satisfaction.

User participation was adapted based on their knowledge and abilities to ensure effective engagement during the requirements elicitation and analysis tasks. This allowed for differing levels and forms of user involvement. The collaboration modes used included; a) Consultation (the facilitator asked users to provide their perspectives), b) Collaboration (the facilitator concurrently worked with the end-users by guiding them on how to execute the assigned tasks and share their ideas until they reached consensus), and c) User-led (users participated by taking charge of generating requirements that they thought met their needs).

Step 6: Design Validation – the UCD-CE process underwent three iterations in real-life settings using structured walkthroughs. These were conducted with primary users to assess; how well the process works, how it helps to reinforce user involvement in requirements elicitation and analysis tasks, areas for its improvement, and the quality of the requirements generated using the hybrid process.

4.2 Evaluation of the UCD-CE Process

Both formative and summative evaluation methods were used to assess the UCD-CE process. The formative evaluation focused on identifying errors and areas for improvement within the UCD-CE process. The summative evaluation investigated the overall rigor and relevance of the UCD-CE process as detailed in Table 2. The evaluation criteria were based on the dimensions recommended by Prat et al. (2014); these included; (i). efficiency (time to complete tasks, quality of deliverable, number of errors made, number of requirements generated), (ii). effectiveness (quality of deliverable, user satisfaction, participant creativity), (iii). ease of use (clarity of instructions, consistency, feedback), (iv). completeness (level of detail), (iv). usability (learnability, efficiency), (v). individual objective (ability to work as a team to accomplish tasks, timeliness, number of requirements generated by each participant), and (vi). social group objective (group productivity, quality of facilitation process).

The data was analysed using SPSS version 25.0. The Likert scale consisted of seven responses which was coded from 1–7, where 1 = strongly disagree (SD), 2 = disagree (D), 3 = disagree somewhat (DS), 4 = undecided (Un), 5 = agree somewhat (AS), 6 = agree (A) and 7 = strongly agree (SA). The analysis commenced by assessing the internal reliability of the questionaires used, using Cronbach's alpha. The estimate of the internal reliability of the instrument was quite acceptable (Cronbach's alpha = 0.928, number of items = 49). The data had five factors and each factor had several items. The first part of the analysis was carried out on the Likert-type items. The results were presented in terms of percentage. Such a basic element of analysis made it possible to identify the item(s) with which the users disagreed (D) strongly disagreed (DS), were undecided (Un), somewhat agreed (AS), agreed (Agree) plus strongly agree (SA). The second part of the analysis was carried out on the five factors; users' view of the agenda format, facilitation process, design guidelines, techniques used to generate requirements and user satisfaction. Each of these factors consisted of 2–15 items.

4.2.1 Evaluation of the Agenda Format

When evaluating the agenda format, the majority of participants (over 70%) agreed on its items, indicating that most found it acceptable and aligned with their expectations. However, 38.5% indicated that they made a few errors by following the instructions, suggesting that a subset of users had difficulty understanding them, leading to errors. Additionally, 84.2% of the participants mentioned that the provided instructions enabled them to understand group goals, demonstrating a relatively high level of clarity and effectiveness in conveying the group's objectives. Moreover, 92.1% of the participants found the instructions easy to follow, indicating that participants generally found the instructions to be clear and user-friendly as shown in Table 4. While users generally agreed with the agenda format and found the instructions easy to follow, a notable proportion admitted to making errors due to not following the instructions properly. These

Table 4 Participants' views on the agenda format

Evaluation of Agenda scale		Primary users Format (N = 38)	
		N	Percentage%
The meeting agenda, summarized all the required information for me to understand group goals	SD + D + DS	0	0.0
	Un	1	2.6
	As	5	13.2
	A + SA	32	84.2
I took less time to learn what is required of me to accomplish the set tasks	SD + D + DS	6	15.8
	Un	1	2.6
	AS	2	5.3
	A + SA	29	75.3
The instructions provided, guided me on how to carry out each assigned activity, which made me to actively contribute to achieving group goals	SD + D + DS	0	0.0
	Un	0	0.0
	AS	6	15.8
	A + SA	32	84.2
I made many errors by following the instructions of the facilitator	SD + D + DS	14	36.8
	Un	1	2.6
	AS	8	21.1
	A + SA	15	38.5
The instructions were clear and easy	SD + D + DS	0	0.0
	Un	1	2.6
	AS	2	5.3
	A + SA	35	92.1
More information needs to be added on the instructions provided for me to understand what I am supposed to do next	SD + D + DS	14	36.8
	Un	0	0.0
	AS	9	23.7
	A + SA	15	38.5

findings underscore the importance of clear and effective instructions to facilitate successful participation and understanding in group activities. Table 4 shows participants' views on the agenda format.

4.2.2 Evaluation of the Facilitation Process

When participants were asked about the facilitation process, the majority (A + SA = above 80%) agreed on all items, indicating that most found it acceptable and in alignment with their expectations. Specifically, 94.8% of participants agreed that they found it easy to follow the instructions provided by the facilitators (see Table 5 for detailed participants' views). Furthermore, 92.2% of participants confirmed that the instructions were useful in guiding them on how to perform the next assigned tasks during the requirements elicitation and analysis tasks. Most

Table 5 Users views on the facilitation process

Facilitation Process scale	Process	Primary users (N = 38)	
		N	Percentage %
I found it easy to follow instructions provided by facilitators	SD + D + DS	1	2.6
	Un	0	0.0
	AS	1	2.6
	A + SA	36	94.8
The instructions provided, guided me on how to do the next assigned tasks	SD + D + DS	1	2.6
	Un	1	2.6
	AS	1	2.6%
	A + SA	35	92.2%
The instructions provided, saved my time in completing the assigned activity, because I was not easily distracted during the exercise	SD + D + DS	0	0.0%
	Un	0	0.0%
	AS	3	7.9%
	A + SA	35	92.1%
The instructions provided, inspired me to actively participate in all the activities	SD + D + DS	1	10.0%
	Un	0	0.0%
	AS	3	7.9%
	A + SA	34	82.1%
The instructions provided, enabled me to get a shared understanding of group goals and tasks	SD + D + DS	1	2.6%
	Un	1	2.6%
	AS	4	10.5%
I was given clear instructions that inspired me to think creatively	SD + D + DS	1	2.6%
	Un	1	2.6%
	AS	1	2.6%
	A + SA	35	92.2%

participants (84.3%) reported that they were able to get a shared understanding of the group goals (82.1%) and felt inspired to think creatively (92.2%). As a result, 92.1% of participants confirmed that they saved time dedicated to accomplishing the assigned tasks, due to ease of following the instructions (94.8%).

These results confirm that the UCD-CE process enhances communication between users and the development team during requirements elicitation and analysis. This stands in contrast to the view that the traditional UCD approach often suffers from poor communication, making it difficult to articulate user needs and leading to wasted time spent clarifying participant questions.

Below are some of the qualitative responses that complement the above quantitative results;

> *"The process really helped us to make more informed decisions, in a much faster way." **Data Officer**.*
> *"The instructions were easy to understand; for instance, the way the generation of ideas and voting was done, could be easily understood by even a lay person". **Clinician***

These responses highlight the clarity and effectiveness of the instructions provided during the UCD-CE process. Specifically, the process of generating ideas and conducting voting was designed to be easily graspable, even for individuals without specialised knowledge or expertise. This indicates that the instructions were accessible and user-friendly, facilitating participation and understanding among all participants. The qualitative feedback corroborates the high levels of agreement observed in the quantitative data regarding the clarity and user-friendliness of the instructions. It provides insights into the reasons behind the agreement percentages and offers a participant's perspective on the process effectiveness. Overall, the combination of quantitative and qualitative data confirms that the majority of participants found the agenda format and instructions acceptable, though a subset encountered difficulties in following the instructions, leading to errors. These findings underscore the importance of clear and effective instructions to facilitate successful participation and understanding in group activities during requirements elicitation and analysis. In contrast, some scholars argue that the application of UCD during requirements elicitation and analysis is often hindered by poor communication between users and the development team, leading to challenges in articulating user needs and resulting in wasted time spent clarifying participant questions.

4.2.3 Evaluation of Design Guidelines

When participants were asked to rate the design guidelines used to elicit and analyse user requirements during the collaboration process, most ($A+AS \geq 80\%$) agreed with them as shown in Table 6. Most participants (78.9%) expressed satisfaction with the guidelines. Notably, 86.9% of participants felt that their contributions were taken into consideration. Furthermore, 89.5% reported that they generated requirements that reflected their needs, and the same percentage (89.5%) indicated that following the guidelines helped them to minimise errors.

These results suggest that the design guidelines were effective in supporting user involvement to create high-quality requirements and minimise errors during the requirements elicitation and analysis tasks. The high satisfaction rates underscore the importance of clear and inclusive guidelines in facilitating successful collaboration and ensuring that user needs are accurately captured. This indicates that the UCD-CE approach is successful in including user preferences during the requirements gathering task.

While the UCD approach offers a valuable framework for requirements gathering, relying solely on it can be limiting (Baek et al. 2008). The UCD process lacks clarity on how to prioritise user opinions and effectively integrate user preferences into the development process; consequently, important user needs might be inadvertently overlooked. The UCD-CE process addresses this limitation by providing a structure for incorporating user inputs effectively.

Below is a qualitative response that complement the quantitative results on the ease of use of the UCD-CE collaboration process;

> "*Initially I had no idea on how the system works, which was a bit challenging for me, because I wasted some time trying to learn it. However, with the*

Table 6 Participants' views on the design guidelines

Design Guidelines	Primary Users (N = 38)		
	scale	Number	*percentage*
The guidelines supported me on how to complete the assigned tasks on time	SD + D + DS	0	0.0
	Un	0	0.0
	AS	4	10.5
	A + SA	34	89.5
I used the guidelines provided by the facilitators to generate requirements that accommodate/reflect my needs on time	SD + D + DS	0	0.0
	Un	0	0.0
	AS	4	10.5
	A + SA	34	89.5
The support and guidance I got from the guidelines helped me to generate requirements with less errors	SD + D + DS	0	0.0
	Un	0	0.0
	AS	4	10.5
	A + SA	34	89.5
The guidelines were clear and easy to understand, which made it easy for me to understand how to accomplish the next tasks	SD + D + DS	0	0.0
	Un	0	0.0
	AS	2	5.3
	A + SA	36	94.7
I am satisfied with this approach of eliciting requirements, because it helped me easily identify my needs	SD + D + DS	0	0.0
	Un	2	5.3
	AS	6	15.8
	A + SA	30	78.9
I am happy that my contribution was not ignored	SD + D + DS	1	2.6
	Un	0	0.0
	AS	4	10.5
	A + SA	34	86.9

guidance of the facilitator, I was able to figure out how to use it; and once I did, I enjoyed the participatory approach". **Nurse.**

This statement reflects a journey from initial difficulties and challenges due to lack of familiarity with the system to a more positive and enjoyable experience. The presence of a facilitator to provide guidance was instrumental in this transition, highlighting the importance of support and guidance in helping users to navigate and appreciate new systems or processes. The high percentages of users who expressed satisfaction with the guidelines are consistent with the qualitative feedback that users were pleased with them. This alignment between the quantitative and qualitative data strengthens the study's overall findings, demonstrating that the UCD-CE process effectively engaged users and resulted in requirements that genuinely reflected their needs. These results underscore the benefits of the UCD-CE process in enhancing user satisfaction, fostering a greater sense of contribution, and ensuring more accurate alignment of requirements with user needs. The effectiveness of the UCD-CE process is particularly evident when compared

Table 7 Participants' views on user stories and dialogue used during the collaboration process

Item of requirements on brainstorming and dialogue scale		Primary users (N = 38)	
		N	%
Brainstorming (think freely and generate as many ideas as possible)	SD + D + DS	1	2.6
	Un	0	0.0
	AS	2	5.3
	A + SA	35	92.1
Dialogue (exchange ideas with other team members)	SD + D + DS	2	5.3
	Un	0	0.0
	AS	1	2.6
	A + SA	35	92.1

to the traditional UCD approach, which often faces challenges in prioritising user voices and accurately reflecting their preferences in the design task.

4.2.4 Evaluation of the Requirements Generation Techniques

These results are presented in two parts as shown in Tables 7 and 8 respectively. Table 7 summarises users' perception on the brainstorming and dialogue techniques used during the requirements elicitation and analysis tasks. The majority of the participants (92.1%) agreed with the techniques used, indicating a high level of satisfaction with the methods employed. This suggests that participants valued the elaborate methods and techniques used to elicit and analyse their needs. Below is an example of the qualitative response that complements the quantitative results;

> *"The brainstorming sessions were particularly effective. They allowed us to think creatively and express our needs clearly. The dialogue technique also ensured that everyone's voice was heard and considered in the final requirements." –* ***Data Officer***

The feedback highlights the effectiveness of the brainstorming and dialogue techniques in facilitating creative thinking and ensuring comprehensive user involvement. The high level of agreement observed in the quantitative data is consistent with the qualitative feedback, reinforcing the conclusion that the techniques used were successful in capturing and addressing user needs.

The high percentages of users who agreed with the requirements generation techniques, combined with supportive qualitative feedback, demonstrate the effectiveness of these techniques in involving users during the requirements elicitation and analysis tasks. This underscores the value of using comprehensive

Table 8 Participants' views on techniques applied to engage them during requirements elicitation and analysis tasks

Techniques used during the collaboration process scale		Primary users (N = 38)	
		N	%
The techniques used facilitated me to complete my assigned activities on time	SD + D + DS	1	2.6
	Un	1	2.6
	AS	1	2.6
	A + SA	35	92.1
The techniques used helped me to make less errors (mistakes) while doing the assigned activities	SD + D + DS	1	2.6
	Un	2	5.3
	AS	5	23.7
	A + SA	30	80
The techniques used increased my productivity while working with team members	SD + D + DS	1	2.6
	Un	1	2.6
	AS	4	10.5
	A + SA	32	84.2
The collaboration process used helped to ensure that the generated requirements were complete	SD + D + DS	0	0.0
	Un	4	10.5
	AS	5	13.2
	A + SA	29	76.3
It was easy for me to understand the instructions to complete my assignment	SD + D + DS	0	0.0
	Un	1	2.6
	AS	7	18.4
	A + SA	30	80.0
It took me less effort to understand and carry out each activity	SD + D + DS	1	2.6
	Un	1	2.6
	AS	2	5.3
	A + SA	34	89.5
The information provided helped me get a shared understanding of group goals	SD + D + DS	0	0.0
	Un	2	5.3
	AS	2	5.3
	A + SA	34	89.4
The techniques used made it easy for the groups to reach a consensus on which requirements should be considered	SD + D + DS	0	0.0
	Un	3	7.9
	AS	5	13.2
	A + SA	30	78.9
The techniques used helped the groups to improve the quality of the recommendations and opinions provided (requirements gathered)	SD + D + DS	0	0.0
	Un	2	5.3
	AS	2	5.3
	A + SA	34	89.5

and inclusive methods to ensure that user needs are thoroughly captured and addressed.

4.2.5 Evaluation of the Techniques used for Requirements Generation

Table 8 shows the participants' perspectives on the techniques employed during the collaboration process. When asked to rate the effectiveness of these techniques, the participants highly rated them. The techniques facilitated the participants in several ways; completing assigned activities within the allocated time (92.1%), enhancing productivity when collaborating with team members (84.2%), minimising errors during task execution (80%), ensuring the comprehensiveness of the requirements (76.3%), improving the quality of gathered requirements (89.5%), consensus-building on the requirements (78.9%), promoting a shared understanding of group goals (89.4%), aiding comprehension of instructions, and successful task completion (80.0%).

These findings indicate that the techniques used, such as user stories and dialogues, were effective in enabling participants to articulate their needs, enhance productivity, reduce errors, and ensure completeness of the generated user requirements. These results support the assertions made by Konaté et al. (2014) regarding the efficacy of user stories in capturing comprehensive requirements. Furthermore, they affirm Laporti et al.'s (2009) claim that user stories foster improved communication among participants, reducing ambiguity and inconsistencies in their perspectives.

Below are some of the qualitative responses that complement the quantitative results on the techniques used during the UCD-CE collaboration process;

> *"Everything was done seamlessly; for instance, when I provided my ideas, the facilitator waited for other people in the meeting to also provide their ideas; then we came to a conclusion after a mutual understanding on the most common problem among us all, through voting".* **Pharmacist**

The interview response indicates that the process was effective, collaborative, and conducive to reaching a shared conclusion based on everyone's input and consensus.

> *"It was easy to use, because it had many processes that we could easily follow. For example, brain storming our ideas, cleaning and eliminating the ideas and voting for the best ideas".* **Records Assistant**

The feedback suggests that the process was effective in facilitating idea generation and selection while maintaining simplicity and user-friendliness, making it easy for participants to engage in various activities. The qualitative results provide insights into how these techniques helped the users to achieve their goals; i.e., understand and follow instructions, reduce the effort required to carry out activities, achieve a shared understanding of group goals, and reach consensus on desired requirements. Overall, the qualitative and quantitative findings strongly support the conclusion that the Group Storytelling techniques were effective in helping users to achieve a variety of positive outcomes, as earlier confirmed by Konaté et al. (2014), and Laporti's ((Laporti et al. 2009)). In other words, this research is in support with existing studies on the benefits of such techniques in requirements gathering and collaborative processes.

4.2.6 User Satisfaction with the Collaboration Process

This section explores user satisfaction with the collaborative approach used during the requirement elicitation and analysis tasks. Table 9 summarises the positive participants' responses (strongly agree and agree) on various aspects of the collaboration process.

A large majority of participants (over 80% agreeing with most variables) expressed satisfaction with the collaboration process. Nearly all participants (94.8%) felt their active involvement led to a collaborative outcome that reflected their needs. They were happy to be part of the process (92.1%). Participants (94.7%) believed the captured requirements would significantly enhance the existing eHIS. A significant portion (86.8%) felt valued as co-designers due to the consideration given to their opinions. Compared to previous methods, a substantial majority (73.6%) preferred this involving collaborative process. Looking ahead, a strong majority (89.5%) expressed their intent to utilise this collaborative technique for gathering user requirements in their future projects.

The study findings highlight a more detailed level of user involvement compared to Rahimi et al. (2014), whose research indicated limited user involvement in the initial phases of system development using the UCD approach. This study aligns with ((Bano and Zowghi 2013)), who emphasise the benefits of effective user involvement in the early development phases. They propose that such involvement can potentially reduce time and cost by eliminating the need for extensive user involvement in later stages. Table 9 provides a detailed breakdown of participant satisfaction with the UCD-CE process.

The following participant's quote highlight their positive experiences with the collaborative process;

> "*For the first time I may say I am the happiest to be part of this meeting. Because all along they have been gathering this information from the top management, and not from us who are at the lower cadres, yet it is us who are facing most of the system challenges. Participants are freely given the opportunity to freely decide on what challenges they want to talk about to clean up any glitches*". **Monitoring and Evaluation Officer:**

This quote suggests a significant shift from previous practices. The participant appreciates being included and feels their voice is finally heard. The freedom to discuss challenges openly fosters a more collaborative and positive environment.

> "*The fact that this process is highly hinged on the nine principles of digital development, a well proven UCD approach which is a universally agreed upon approach and UCD theories, makes it a good process*". **Implementing Partner:**

The feedback shows the implementing partner's confidence in the process due to its well-established theoretical foundation. The grounding in UCD principles and proven methodologies increases trust and promotes wider adoption. These two quotes exemplify positivityamong participants; i.e., they approve of

Table 9 Participants' views on satisfaction of the UCD-CE process

User Satisfaction scale		Primary (N = 38)	
		N	%
I am satisfied with the requirements generated in this workshop session, because they reflect my needs	SD + D + DS	0	0.0
	Un	1	2.6
	AS	4	10.5
	A + SA	33	86.9
I am satisfied with the technique used to generate requirements because it helped me to freely participate by providing my opinion and recommendations	SD + D + DS	2	5.3
	Un	0	0.0
	AS	2	5.3
	S + SA	34	89.4
It was easy to reach an agreement/consensus with the other group members	SD + D + DS	1	2.6
	Un	2	5.3
	AS	4	10.5
	S + SA	31	81.6
I am happy that my contribution/recommendations were considered in the requirements that were generated	SD + D + DS	0	0.0
	Un	0	0.0
	AS	1	2.6
	A + SA	37	97.4
If these recommendations are adopted, they will improve the existing systems	SD + D + DS	0	0.0
	Un	0	0.0
	AS	2	5.3
	A + SA	36	94.7
I intend to use this technique to generate requirements in future	SD + D + DS	0	0.0
	Un	0	0.0
	AS	4	10.5
	A + SA	34	89.5
I accept the outcome of this process because they reflect my needs	SD + D + DS	0	0.0
	Un	0	0.0
	AS	6	15.8
	A + SA	33	84.2
I appreciate my role as a co-designer because my opinions in generating and analysing requirements were considered	SD + D + DS	0	0.0
	Un	0	0.0
	AS	5	13.2
	A + SA	33	86.8
I think systems will be more accessible, if they used the requirements that are generated using this process	SD + D + DS	0	0.0
	Un	0	0.0
	AS	6	15.8
	A + SA	32	84.2
This process of generating and analysing requirements is better than the previous methods we used	SD + D + DS	0	0.0
	Un	2	5.3
	AS	8	21.1
	A + SA	28	73.6

Table 9 (continued)

User Satisfaction scale		Primary (N = 38)	
		N	%
I have a sense of ownership on the requirements that were generated because I fully participated in generating them	SD + D + DS	1	2.6
	Un	1	2.6
	AS	7	18.4
	A + SA	29	76.4
I accept the outcome of the process, because I participated in generating and analysing the requirements	SD + D + DS	0	0.0
	Un	1	2.6
	AS	1	2.6
	S + SA	36	94.8
I am happy I was actively involved in this collaboration process session	SD + D + DS	0	0.0
	Un	1	2.6
	AS	2	5.3
	A + SA	35	92.1
I liked this process of generating and analysing requirements	SD + D + DS	0	0.0
	Un	1	2.6
	AS	5	13.2
	A + SA	32	84.2
Rate your commitment to the results of this process	SD + D + DS	1	2.6
	Un	0	0.0
	AS	3	7.9
	A + SA	34	89.5

the process' effectiveness and its applicability in various contexts to effectively capture user needs.

4.2.7 Results from the Observation Checklist

An observation checklist assessed participant behavior and interaction during the collaborative process. This evaluation aimed to determine two key aspects; the level of user involvement and the quality of user requirements generated. Table 10 presents the detailed results.

The observations revealed a high level of user engagement. Most participants (N = 5, M = 4.6, SD = 0.54) actively participated in the collaboration process and appeared to enjoy it (N = 5, M = 4.8, SD = 0.45). They found the process user-friendly and engaging. Notably, participant energy levels were high at times (N = 3(60.0), 2(40.0), SD = 4.4(0.54)), particularly during discussions about their experiences with existing systems and brainstorming solutions for improvement.

The user requirements generated during the process were closely aligned with known functional requirements (N = 5, SD = 5.0), indicating a clear focus on capturing practical needs. Additionally, these requirements were deemed suitable for translation into design specifications (N = 5.1, SD = 5.0). This suggests a strong foundation for translating user input into actionable design elements.

Both observers and participants expressed a strong sense of shared ownership over the process outcomes. This highlights the collaborative nature of the UCD-CE approach. Participants appreciated how the process prioritised generating authentic requirements that directly addressed their needs.

4.2.8 Measuring Agreement on User Requirements

The consensus measure was applied to understand difficulties in group decision-making and rank the level of agreement between individual participants. According to Tastle and Wierman (2007), consensus (Cns) means agreement towards a declarative statement among a sample group. If an equal number of participants choose their responses in two extreme cases, e.g., strongly agree or strongly disagree on a Linkert scale, this means there is no consensus; hence Cns = 0. If participants choose responses in the same category on a Linkert scale, then this group shows full consensus Cns = 1. A consensus value inside the interval will be produced by additional combinations of response patterns (0, 1). According to Tastle and Wierman (2007), consensus is measured by the formula below;

$$Cns(x) = 1 + \sum_{i=1}^{n} p_i log_2\left(1 - \frac{|x_1 - \mu|}{d_x}\right) \quad (1)$$

X is the measure of the response, e.g., on a scale of 1 to 10, some people will vote for 2 or more. n is the number of the categories in an ordinal scale, X_i is the degree of agreement in category $_I$ (how many voted on a scale of 1 to 10). P_i is the probability of the occurrence of x_i (P_i is the probability from voting e.g., here we calculate the consensus for all the activities and agree that this item is either important or not important.). d_x ¼ X_{max} X_{min} is the width of categories on the measurement scale. µx is the mean/ average score of the overall agreement/ participant activity e.g., Out of the activities, how many people voted or abstained; Out of the activities, how many people voted or abstained. Dx is a range between lower scale and higher scale e.g., 10–1 = 9 which is a constant number. When this definition is applied to a 5-point Likert scale; for example, we find that n = 5, $_i$ ranges from 1 to 5 and d_x = 5—1 = 4. During the UCD-CE collaborative process, participants prioritized the generated user requirements through voting based on a scale of 1 to 10. However, when the above formula is run, results remained the same as that of Linkert scale of 1 to 5. The rule-based technique used for ranking was developed and presented in Table 11, while Table 12 shows the mean, consensus and ranking of user requirements generated during the collaboration process.

4.2.9 Ranking, Mean, and Consensus Values used for Ranking

To rank the generated requirements, Table 11 was used to construct Table 12. Table 12 shows the ranking of the activities that led to the final set of users'

Table 10 Participants' level of participation, usability, interaction, and quality of user requirements generated

	1	2	3	4	5	M(SD)
	N(%)	N(%)	N(%)	N(%)	N(%)	
How involved were the users during the collaboration process	0(0.0)	0(0.0)	0(0.0)	2(40.0)	3(60.0)	4.6(0.54)
How long did the collaboration take?	0(0.0)	0(40.0)	1(40.0)	3(20.0)	1(0.0)	2.8(0.83)
Do users seem to enjoy the collaboration process (ease of use)	0(0.0)	0(0.0)	0(0.0)	1(20.0)	4(80.0)	4.8(0.45)
Are user's needs generated associated with the functional requirements?	0(0.0)	0(0.0)	0(0.0)	0(0.0)	5(100.0)	5.0(0.00)
Can the requirements elicited be translated to design specifications?	0(0.0)	0(0.0)	0(0.0)	0(0.0)	5(100.0)	5.0(0.00)
How were the users interacting with the group support system?	0 (0.0)	0 (0.0)	0 (0.0)	2 (40.0)	3 (60.0)	4.6 (0.54)
Were all the participants engaged in the collaboration process?	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (100.0)	5.0 (0.00)
Were there point when energy level high?	0 (0.0)	0 (0.0)	0 (0.0)	3 (60.0)	2 (40.0)	4.4 (0.54)
Was the facilitator prepared?	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (100.0)	5.0 (0.00)

Scale Key: 1 = very low; 2 = low; 3 = somewhat; 4 = high; 5 = very high

Table 11 the Rule-based technique for ranking

		Consensus	
Mean	High	Low	
	High	High	Low
	Low	High	Low

Table 12 Mean, consensus and ranking of users' requirements generated during the collaboration process

Scales of 1–10,

Activity	Abstain	1	2	3	4	5	6	7	8	9	10	M	Consensus	Rank
1	2	1				1		1	1		2	6.83	0.45	5
2	2								2	1	3	9.17	0.86	1
3	2					1			1	2	2	8.5	0.75	2
4	2		1			2		1	1	0	0	4.5	0.69	4
5	2					2			1	2	1	7.67	0.67	3

The total number of participants in this collaboration session N = 8. 2 abstained while 6 fully participated. Rank = sort (M*Cons). Activity = user requirements to prioritise through voting

requirements to consider. To rank the activities, the mean score was multiplied by the consensus value, and the results were sorted in a descending order. Activity 1 exhibited a low consensus, indicating significant disparity and disagreement among participants regarding that user requirement. However, if the mean score is high and the consensus is also high, it indicates agreement regarding the activity. Conversely, if the mean score is high but the consensus is low (approaching 1 or 0), the ranking for that activity should be lower.

Table 13 provides an example of Users' requirements for District Health Information System version 2 (DHIS2) generated at the three levels; high level (business process), middle level (user requirements), and low level (functional requirements).

5 Discussion

The main contribution of this paper lies in the development of a hybrid UCD-CE process that reinforces user involvement during requirements elicitation and analysis tasks of the systems development process. The literature review findings highlight intriguing similarities between UCD and CE in terms of; ***shared ideologies*** (i.e., collaboration, iteration, and multidisciplinary teamwork ((Azadegan et al. 2013); (Bano and Zowghi 2013); Kolfschoten & De Vreede, 2009; (Konaté et al. 2014); (Lopes et al. 2018); (Sánchez and Macías 2019)), and ***shared focus,*** i.e., " what" (practices), " why" (rationales and goals), and "how" (methods and approaches) ((Kashfi 2018); Sanchez et al., (Sánchez and Macías 2019); Lee et al., (Lee 2014); (Becker et al. 2019); (Kolfschoten and Vreede 2009); (Gulliksen et al. 2003); (Kashfi 2018); Nabukenya et al., (Nabukenya 2012); (Filip et al. 2017)). Furthermore, this study

Table 13 The different levels where users' requirements generated for DHIS2 were elicited

Levels where requirements were elicited and analysed		
High level (Business process) / user Role	Middle level (User experiences)	Low level (Functional requirements)
Data management/ Data ware house architect	I experience the problem of errors in data entry, because of the current set evaluation rules in the system	As the Data Warehouse Architect, there is a need for improvement in the evaluation rules within DHIS2 to address the issues of data entry errors
Records Department/ Data Officer	The data score card does not provide indicators	As a Data Officer, the scorecard in the data quality tool should be improved to cater for all indicators
Health information systems support	Since the data visualisation is not customised, system users at lower-level experience challenge in understanding complex data or identifying key insights. Hence leading to inefficient decision making and time wastage	As a Health Informatics Specialist, the system should customise public visualisations/ data analysis to improve data use at all levels
Health information systems support	The system takes time to provide real time data. This delays decision making and sometimes makes us provide incomplete information especially if the data is needed urgently	As a Health Informatics specialist, the system should provide real time data reflected on the dashboards as and to when it comes through
Data management/ data ware house architect	The system has so many duplicates, most times you enter the same information more than once	As a Data protection and data security specialist the system should flag duplicate records for clients with closely matching parameters to improve data quality
Records Department/ records officer	The system visualisation is complex to understand	As a records officer, the system visualisation should be improved to make it more informative and basic for users at all levels to improve the use of data collected
Records Department/ Records officer	The system restricts us from accessing the previous data entered in the system. we must go back to manual system of accessing the data when it is needed, which is time wasting	As a records officer, the system should not restrict us from accessing previous data that we shared, because there are scenarios where we need to access and reuse the same data
Records Department/ Data officer	In the records department, we experience a problem of unstable internet, which often disrupts our work	As a Data officer, the system should have an offline version to avoid disruptions in doing work when the internet is off

explored how the SLMC and Way of Thinking address limitations of UCD practices by offering; details on iterative application of methods, strategies, and tactics using patterns & thinkLet layers, and clarification of goals and principles behind methods (goals & products layers & Way of Thinking). This holistic approach addresses all aspects of “what,” “why,” and “how” across both methodologies, leverages strengths the SLMC in addressing the identified UCD limitation and ensures continuous improvement and adaptiveness throughout the design process.

5.1 How UCD-CE Process can be Applied During UCD Requirements Elicitation and Analysis Tasks

This study shows how the integration of UCD and CE methods, principles and practices was done, i.e., demonstrates the viability of a UCD-CE collaborative process in UCD requirements elicitation and analysis tasks. For the integration to take place, we emulated the first two steps of UCD process into the six steps of CE approach. We identified layers of SLMC that were similar to the different aspects of the UCD process and CE steps in order to find commonalities. These shared layers became the foundation for integration. Thereafter we incorporated both UCD (user-centeredness, iteration, and early & continuous user involvement) with CE principles, practices and methods (structured collaboration, use of collaboration tools, and facilitation techniques) to create a framework for collaborative user participation in each task.

We elaborated how tasks can be decomposed into manageable activities using CE principles (collaboration patterns and thinkLets) and guide participants on *how* to execute the requirements elicitation and analysis tasks, within the shortest time possible. This ensured that participants understood the tasks and expected outcomes. It also facilitated active participation through encouraging open communication and guiding users through challenges they might encounter.

The Leafhopper thinkLet facilitated users to generate more ideas using user stories. Other thinkLets aided the removal of ambiguous and redundant ideas, as well as prioritising requirements. This study confirms Konaté et al. (2014)’s assertion that the amalgamation of Leafhopper thinkLet with user stories is an effective way of generating user needs, and requirements, because it ensures completeness of the requirements elicited, and more informed decision-making on how best to map user needs to design specifications.

While this study shares a common ground with Azadegan & Harteveld (2014), and Konaté et al. (2014) in recognising the significance of collaboration and user involvement in requirements elicitation; it’s however, distinct regarding its integration of UCD “what” aspects with CE “how” aspects to enhance user involvement throughout the requirements elicitation and analysis process. In contrast, studies by ((Azadegan et al. 2013)) and Konaté et al. (2013), pursue different objectives. Azadegan & Harteveld (2014) developed a collaboration process tailored to eliciting high-level user requirements, whereas Konate et al. (2013), took an approach that separates engineering and collaboration aspects in the context of requirements elicitation.

5.2 The Effect of Integrating CE with UCD Design Principles in eHIS Development Process

The study findings showed that participants were positive about the UCD-CE process regarding its efficiency, effectiveness, ease of use and user satisfaction. These findings indicate that the UCD-CE process reinforced user involvement during requirements elicitation and analysis tasks. **They felt that the UCD-CE process (1) enabled them to express their needs based on their experiences, and (2) facilitated their collaboration in completing the set task before moving on to the next tasks. (3) This suggests that the users felt heard and valued, and that their input was considered useful.**

Furthermore, consensus building among the participants suggests that the UCD-CE process was effective in bringing together different perspectives and finding a common ground. Moreover, the fact that the participants found the instructions to be clear and easy to understand, and that they were able to easily execute the assigned tasks, indicates that user involvement was reinforced. This is because clear instructions make it easier for users to participate in the requirements elicitation and analysis tasks and contribute to their unique perspectives and feedback.

Moreover, the ability to easily understand and execute tasks suggests that users were able to actively engage and make meaningful contributions. Finally, the overall satisfaction of participants with the collaboration process is a strong indication that user involvement was achieved; that is, it suggests that users felt that their time was valued and that their contributions were appreciated. We also observed that there were fewer distractions and less deviation from what was being discussed. Although few people abstained from the tasks, the effect of their abstention didn't have much impact on the results.

This study, aligns with the assertions made by Konaté et al.(2014), Azadegan & Harteveld (2014), Geisser and Hildenbrand (2006) that group support tools help to improve communication, collaboration, promote self-awareness, and reflection among participants. Accordingly, given that the study results show a generally positive attitude in using the UCD-CE process; we confirm that this process is effective in reinforcing user involvement during requirements elicitation and analysis tasks.

Though Agile-UCD integration is considered a leading option for use in the software development process; it still faces challenges in prioritising UCD activities, synchronising efforts of UCD practitioners and neglect of functional requirements (Losada 2018). Consequently, there is still disagreement on how UCD practices should be considered during the requirements elicitation and analysis phases; as its activities do not fully cover all UCD activities and principles (Losada 2018). On the contrary, UCD-CE integration applies a hybrid of UCD and CE principles, practices and methods to strengthen user involvement, ensure rigor during requirements elicitation and analysis, and holistically address the UCD challenges discussed in the introduction section. Therefore, based on the advantages of the UCD-CE process discussed above, we argue that integrating these two approaches, if implemented as prescribed, would reinforce user involvement in the requirements elicitation and analysis phases of any systems development project.

5.3 Study Contributions to Research and Practice

i. *Design of a Hybrid UCD–CE Collaborative Process* – this process integrates CE design principles into the first two phases of UCD (i.e., requirements elicitation and analysis). This integration leads to a systematic approach that not only defines the tasks involved, but also outlines how to collaboratively perform them. This ensures reinforced user involvement and enables comprehensive and effective capture of user needs.
ii. *Providing User Involvement Guidelines* – it offers practical guidance on "what" and "how" users should be involved during UCD systems requirements elicitation and analysis tasks.
iii. *Defining CE Design Requirements for UCD Integration* – it identifies CE design requirements that can be seamlessly integrated into the UCD process, specifically to **reinforce user involvement** in the systems development requirements elicitation and analysis tasks.
iv. *Strengthening User Involvement during systems Development* – this research argues that by merging the first two phases of the UCD process (outlined in ISO 9241–210) with CE design principles, user involvement during requirements elicitation and analysis tasks, is likely to be substantially strengthened. This is achieved by combining the "what" aspects of UCD (defining tasks) with the "how" aspects of CE (collaborative execution of tasks).
v. *Enhancing User Involvement in Information Systems Development – the research* contributes to the field of Information Systems by providing a UCD-CE process that can be used by system developers to reinforce user involvement during requirements elicitation and analysis. This hybrid approach fosters meaningful user engagement throughout the entire development process, leading to the design of efficient and effective systems that align with user needs. When implemented correctly, this UCD-CE process can potentially boost productivity during the requirements elicitation and analysis tasks, consequently leading to the efficiency and effectiveness of the systems developed.
vi. *Facilitating User-Centric System Design for Policymakers* – the UCD-CE process offers valuable guidance for policymakers and funders. By utilising this approach, they can gather requirements that align with user needs, enabling the design of systems that cater to those needs rather than being imposed upon them.

5.4 Implications to the UCD Community

i. The study demonstrates a process for reinforcing user involvement throughout the requirements elicitation and analysis tasks. This can be particularly beneficial for UCD practitioners, as it offers a way to address challenges related to effectively involving users during these tasks when developing systems.
ii. The integration of CE and UCD is based on the recognition that both approaches have complementary aspects. It encourages the UCD community to explore the

synergy between UCD's "*what*" aspects and CE's "*how*" aspects for more effective and optimal user-driven requirements elicitation and analysis.

iii. The study explicitly addresses limitations of the traditional UCD approach, such as lack of clarity on "*how*" activities should be conducted, the abstract nature of UCD principles, and variations in methods that can lead to incorrect interpretations of user needs. UCD community can leverage from these insights to improve their practices.

iv. The UCD-CE process not only reinforces user involvement, but also contributes to the efficiency and rigor of requirements elicitation and analysis tasks. UCD practitioners can apply the study findings to streamline their processes and improve the quality of user requirements.

v. The study promotes a holistic approach to UCD, focusing on improving the entire user experience during the requirements elicitation and analysis phases. UCD practitioners can incorporate the UCD-CE process to ensure that user needs are comprehensively addressed.

vi. The UCD-CE process' formative and summative evaluation evidences its effectiveness regarding integration. This empirical evaluation offers reassurance to the UCD community seeking practical and validated methods.

vii. Although the study is specific to eHIS development, the integrated UCD-CE process is potentially applicable to various information systems fields. UCD practitioners across domains can draw inspiration from this research to reinforce user involvement when eliciting and analysing user requirements for systems for other domains.

6 Conclusion

For any development process to take place in UCD, the following three aspects have to be considered; principles, practices/process and methods. UCD literature provides evidence that all these three aspects have limitations. Of the limitations identified, the most notable was that the UCD process that does not provide descriptive details of *"how"* activities should be conducted; hence, the development team usually has insufficient knowledge of how to perform UCD activities during the development process. The abstract nature of UCD principles inhibits it from being effectively applied in practice. UCD methods lack descriptive details on how to involve and integrate users during the development process.

This study sought to address the UCD challenge of limited user involvement in requirements elicitation and analysis by enriching the UCD-CE "***what"*** with the CE – *"**how**"* aspects to reinforce user involvement during the initial phases of the systems development process. To achieve this integration, we utilised the Six-layer model of Collaboration as a basis for developing the work breakdown structure of the UCD-CE process. This decision was made because the layers of the Collaboration model align closely with the steps involved in CE and the UCD approach, particularly in terms of addressing the "why," "how," and "what" aspects within their respective processes. By considering these aspects, we were able to create a cohesive UCD-CE process using the Design Science method.

Despite the technology constraint, i.e., unstable internet that affected smooth running of the GSS (MeetingWizard) workshops, the evaluation results confirmed that the hybrid UCD-CE process offers valuable guidance for executing tasks during requirements elicitation and analysis. It encourages participants to examine their experiences from diverse perspectives, fostering a comprehensive exploration of potential solutions. This approach facilitates open contributions and allows all participants, including those who may be reserved, to freely express themselves. It promotes collaborative teamwork among participants in the discovery and refinement of their needs and contributions. Furthermore, the hybrid approach guides participants through the process of ranking and prioritising tasks until a consensus is reached.

Importantly, this hybrid approach ensures that requirements are elicited both for and by the users. Within this process, UCD cultivates empathy with end-users, helping them to better understand the problems they are tasked to solve; while CE introduces tools that offer guidance and support for end-users in accomplishing their tasks, encouraging critical thinking for innovative problem-solving. Additionally, this hybrid approach ensures that system developers capture and comprehend user needs before translating them into design specifications. Moreover, the UCD-CE process holistically addresses the UCD challenges identified in its process, methods and principles.

Finally, the study reveals that GSS are time-efficient, as system developers can simultaneously elicit requirements from all user categories and automatically categorise generated user requirements. In summary, the integration of both UCD and CE approaches empowers participants to approach requirements elicitation and analysis tasks from diverse viewpoints, ultimately enhancing the comprehensiveness and rigor of the requirements.

Our future work involves investigating the feasibility of the UCD-CE process applicability during the UCD design phase, i.e., how it can reinforce user involvement during this phase of the UCD development process. Our goal is to contribute towards the ongoing evolution of methodologies and practices in the research fields of Human–Computer Interaction and Information Systems, with the overarching goal of continually improving the user experience and system quality.

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Declarations

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