Toward interdisciplinary practice and increased social ROI: a case study on downstream effects of integrating UX in cyber system design

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Abstract

Cyber ranges (CR) have gained attention from researchers and trainees for their virtualization and replication capabilities. The growing focus on improving the user experience (UX) with CR aligns with the emphasis on software usability and user acceptance in software development. This case study explores the integration of UX activities, namely expert review and prototyping workshops, in a cybersecurity project aiming at supporting the creation of CR scenarios. Survey and interviews allowed us to both assess participants' UX literacy and identify opportunities and barriers to UX integration. Introducing UX activities increased UX literacy and helped foster a productive and collaborative interdisciplinary team environment.

Keywords: cyber range, cybersecurity, user experience, human-centered design, social ROI

1. Introduction

Cyber ranges (CR) gained attention from researchers and trainees due to their virtualization and replication capabilities. They provide safe training environments for organizations, allowing simulation and observation without risking real-world consequences. For example, CR can simulate a hospital, guiding and observing team reactions without risking damage from deploying malware into the actual equipment. However, there is limited scientific literature regarding the definition of metrics for measuring usability and trainer/trainee satisfaction in CR. This may be due to the challenging requirement of accessing a CR in real conditions and conducting experiments on diverse user profiles.

User experience (UX) encompasses usability and is defined as "user's perceptions and responses that result from the use or anticipated use of a system, product or service" (ISO, 2019). The growing focus on enhancing the UX with CR aligns with the prioritization of software usability to both improve user acceptance and popularize CR. Further, designing usable products helps increase productivity, reduce user errors, minimize needs for training and technical support, and enhance organizations' reputations (Maguire, 2001). Contemporary users are prone to reject systems that offer an inadequate UX, making UX a prerequisite for system adoption (ISO, 2019). Hence, organizations must adopt human-centred design (HCD) to design technologies capable of competing successfully in a saturated global market (Djamasbi and Strong, 2019).

Yet, the scientific literature (Azevedo et al., 2023; Bias and Mayhew, 2005) reports several barriers to the integration of UX in software development models, which reflect lack of UX literacy (Azevedo et al., 2023). These barriers include lack of understanding of UX return on investment (ROI); mistaken belief that performing UX requires no UX expertise or that UX can be performed informally; contentious attitudes towards users, UX practitioners and UX activities; and mistaking UX for aesthetics or user interface (UI). While UX refers to user's perceptions and responses, UI refers to the components of an interactive system (ISO, 2019).

We report how we introduced and conducted UX activities in a cybersecurity project aiming at supporting the creation of CR scenarios (CRS). A notable problem associated with CRS is their mismatch with trainees' profiles, competences, and professional objectives, which severely hinders the ROI and adoption of CR. Overcoming this mismatch requires the adoption of a human-centered approach by multidisciplinary teams comprised of UX, cybersecurity and software development experts. We chose expert review and

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prototyping workshops as key UX activities: the expert review to enhance the graphical user interface (GUI) of the CRS creation tool, and prototyping workshops to design a tool to generate CRS tailored to users while providing adequate guidance for users during CRS execution. The execution of these UX activities raised questions regarding their integration into a multidisciplinary team: How do non-UX project stakeholders perceive UX? What are the barriers and opportunities to UX integration? How do UX activities affect the UX literacy of non-UX project stakeholders? To answer these questions, we used survey and interviews to assess non-UX stakeholders' UX literacy, and identify opportunities for and barriers to UX integration.

We conducted an exploratory case study to understand how UX integration is perceived by non-UX stakeholders. We chose this method because data on perception of UX is scarce and contextual conditions relevant to research questions above cannot be controlled (Baxter and Jack, 2008; Quintão et al., 2020). This allowed us to collect contextual data from multiple data sources and stakeholders' perspectives, and to report an integrated vision of a complex social unit, containing multiple variables.

The contribution of this paper to critical infrastructure and cyber systems is twofold. First, it demonstrates the feasibility of integrating UX activities into a project focused on CRS, which provides a preliminary account of "human-centered cybersecurity". Second, it reports a protocol (procedure, instrument, data format, etc.) to allow the replication of the case study later within the same project or across multiple case studies.

2. Related work

2.1. Challenges associated with CR

CR training centers were previously primarily used by states for military activities (Absil et al., 2016; Ferguson et al., 2014), offering limited and costly configuration scenarios (i.e., infrastructures description) which did not accurately represent trainees' work environments. Moreover, accessibility was restricted to CR centers and required the assistance of human trainers. Advances in cloud and virtualization technologies now enable dynamic creation of realistic configuration scenarios, which faithfully replicate trainees' work environments, thereby enhancing trainees' experience and responsiveness to potential attacks (Costa et al., 2020). Extensive literature exists on textual and visual languages describing realistic configuration scenarios (Costa et al., 2020) and on computer power resource-based selections (Koslovski et al., 2008; Martou et al., 2022). Industry CR (e.g., those offered by Thalès, Fujitsu, and RHEA) integrate these contributions into their platforms, providing usable interfaces (Mengidis et al., 2022) and features to accurately simulate trainees' work environments, including space and power grid scenarios (Mathas et al., 2020). Moreover, a federation of CR, as promoted by the EU commission in the Foresight EU Project, enables scenario and experience sharing among different CR platforms. Hybrid CR incorporating additional equipment enhance realism, particularly for training on IoT systems (Balto et al., 2023; Brilingaitė et al., 2020).

The flexibility of new languages and technologies in dynamic CRS configuration, and the reproduction of realistic working environments are essential to effective cybersecurity training. However, assessing trainees' competences in cybersecurity remains challenging. Trainees often passively follow training without expressing their preferences or understanding limitations, resulting in limited experiential learning. Trainees may achieve exploits in a systematic manner in a CR but struggle to replicate them in real-life settings. Consequently, authorities have defined security levels to be achieved by the trainees and used UX methodologies to enhance acceptance and mitigate the perceived technical complexity of cybersecurity. The European Cyber Skills Framework (ENISA, 2022) provides a basis to measure trainees' skills and select appropriate attack scenarios. Such approaches have been implemented in projects such as COFELET and HackLearn (Katsantonis and Mavridis, 2021).

Neglecting user needs hampers CR's goal to improve trainees' competences. Prioritizing theoretical knowledge over practical performance among trainees hinders the accurate assessment of trainees' technical skills (Labuschagne and Grobler, 2017). Further, misaligning training content and trainees' effective responsibilities results in reduced training relevance and limited application of learned lessons in real-world scenarios (Ghosh and Francia, 2021; Mases et al., 2021). Hence, context-driven and relatable scenarios are key to simulate real-life events (Brilingaitė et al., 2020; Ghosh and Francia, 2021). To promote effective learning, CR designers should consider trainees' task proficiency when creating scenarios, thereby avoiding the inclusion of tasks that exceed trainees' skill level (Vykopal and Barták, 2016; Vykopal et al., 2017). Failure to adapt scenarios to trainees' abilities can lead to boredom (if too easy) or discouragement (if too difficult), resulting in disengagement from the system. Adjusting the difficulty based on individual trainee capabilities is key for maintaining engagement (Brilingaitė et al., 2020; Katsantonis et al., 2019; Vykopal and Barták, 2016; Vykopal et al., 2017). Modeling a sequence of actions, breaking them down into tasks (Braghin et al., 2020), monitoring individual trainees' progress (Vykopal and Barták, 2016), and drawing inspiration from video games in interface design and learning processes (Katsantonis et al., 2019; Katsantonis and Mavridis, 2021) can also enhance CR.

2.2. Human-centered design

Human-centered design (HCD) integrates users' perspective throughout software development to design usable systems, prioritizing user satisfaction and performance (Maguire, 2001). The principles of HCD are: active involvement of users and clear understanding of user and task requirements; appropriate allocation of function between user and system; iteration of design solutions; and multidisciplinary design teams. HCD relies on four activities: understanding and specifying context of use; specifying user and organizational requirements; producing design solutions; and evaluating design (ISO, 2019). HCD involves continuous evaluation of prototypes through user testing to ensure designs meet user requirements.

Grounded in HCD, user experience (UX) acknowledges the significance of human factors and aims to satisfy user needs. Kieffer et al. (2020) propose a process reference model (PRM) for UX that describes supporting UX methods for development processes. The UXPRM identifies four classes of UX methods supporting the HCD process, each class corresponding to the level of user involvement in related UX activities: methods without users (class 1), attitudinal methods focusing on user feelings (class 2), behavioral methods focusing on user actions (class 3), and methods combining classes 2 and 3. Similarly, the authors grouped UX artifacts according to their representativeness of the final system, ranging from low-fidelity (lo-fi) to high-fidelity (hi-fi) prototypes.

Expert evaluation is a UX method without users in which one or more UX experts assess system quality using established guidelines, heuristics or criteria, identifying and prioritizing issues. Experts conduct individual analyses, then pool their results collaboratively. Expert evaluation is a versatile method for assessing system quality throughout the development lifecycle (Bias and Mayhew, 2005) and an efficient method for identifying major issues in a system before conducting user tests (Maguire, 2001). Leavitt and Shneiderman (2006) outlined 209 usability guidelines in collaboration with UX experts, using ordinal scales (from 1 to 5) to measure the relative importance and strength of evidence for each guideline. *Relative importance* reflects the importance of each guideline to the success of a system, while *strength of evidence* indicates the level of scientific support for each guideline. For instance, guideline 3:3, "Do Not Use Color Alone to Convey Information", targets individuals with vision impairment and scores 5 in relative importance and 4 in strength of evidence.

Cornerstones of HCD and UX design, prototypes are UX artifacts whose purposes are to turn design ideas into testable mockups and to support continuous user testing against user requirements (Kieffer et al., 2020). Specifically, it is crucial to submit prototypes for test-and-refine iterations (i.e., identify UX problems and fix them during the next iteration). It is equally crucial to secure consensus among the entire project development team regarding the design before coding. Since lo-fi and hi-fi prototypes have their own advantages and shortcomings, UX staff must carefully select an adequate level of fidelity to maximize the ROI from continuous testing. For example, developing hi-fi prototypes (e.g., simulations or operational systems) early is expensive, even more so if the prototype is discarded (Bias and Mayhew, 2005); conversely, in late development, lo-fi prototypes may lack the necessary realism to generate useful data from user tests (McCurdy et al., 2006); results of eye-movement analysis are sensitive to the level of fidelity (Kieffer and Vanderdonckt, 2023). Consequently, lo-fi prototypes are best suited for early design stages, while hi-fi prototypes (e.g., coded prototypes) for later stages (Maguire, 2001).

3. Conducting UX activities

3.1. Context

We implemented the HCD process presented in Figure 1 in an R&D project (2022-2025) aiming to support the creation of CRS. The project involves three stakeholders: a university (UNI), a center of excellence (COE), and an industrial partner (IND) providing the CR. Within UNI, 1^{st}, 2^{nd}, and 4^{th} authors are responsible for UX activities, while the 3^{rd} is responsible for modeling and implementation. The mission of UNI is to (1) implement the HCD process as software development model and (2) design a GUI, model, and implement an approach for CRS generation and guidance. The mission of COE is to implement and integrate the GUI of the CR. All parties entered into a memorandum of understanding, authorizing the collection of research data between parties.

We opted for UX methods without users to

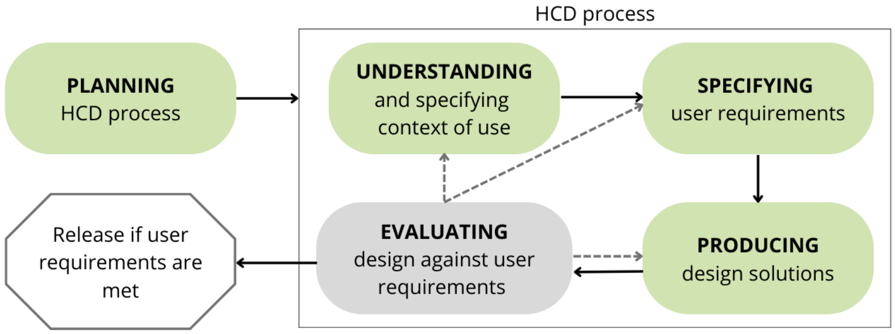

Figure 1. HCD lifecycle (ISO, 2019). Green highlights implemented activities.

Table 1. Criteria to be assessed for each guideline during expert review.

Criteria	Description	Response
Relevance	Relevance of guideline to review	Yes - No
Compliance	Extent to which CR GUI satisfies guideline	Fully - Partially - Not
Recommendation	Prioritization of needs for redevelopment	Must - Should - Could - Would
Confidence	Reviewer's confidence in their independent evaluation	100% - 75% - 50% - 0%

execute understanding, specifying, and producing HCD processes, as recommended by Hussain et al. (2008) when resources such as budget and time are limited. Moreover, we opted for a strategy without users due to their involvement being a pain point for IT-driven stakeholders, unlike stakeholders with a human-centered mindset (Azevedo et al., 2023). Thus, we first conducted an expert review to improve the GUI of CR, which allowed us to get familiar with the existing system and domain. We then conducted prototyping workshops to design a GUI for CRS creation.

3.2. Expert review

One UX researcher from UNI (1^{st} author) and one CR expert from IND performed an expert review of the CRS creation tool's GUI based on a recorded walkthrough of the creation process. Prior to the review, the two experts had met once, at the first coordination meeting between the project's stakeholders. Each expert performed the review independently by rating the CRS creation tool's GUI against Leavitt and Shneiderman (2006)'s usability guidelines according to four criteria: *Relevance*, *Compliance*, *Recommendation*, and *Confidence* (Table 1). In particular, *Recommendation* represents the level of need for redevelopment if the CRS creation tool's GUI does not fully satisfy a guideline using the MoSCoW scale (Clegg and Barker, 1994): Must (major issues) and Should (important issues) requiring immediate attention and swift action for rectification; Could (minor issues) and Would (desirable enhancements) to be addressed if sufficient resources (e.g., time, staff, budget) are available. Once both experts had completed their independent review, they met online several times to consolidate their ratings, i.e., reach a consensus on each of the 209 usability guidelines. If only one expert considered a guideline to be relevant, then the guideline was included in the expert review and the remaining three ratings were left unchanged. Any disagreement regarding *Compliance* required both experts to provide evidence for their rating. The UX expert led *Recommendation* ratings. For *Confidence*, both reviewers' ratings were maintained.

Summary results are presented in Table 2. Of the 209 usability guidelines, 132 were found to be relevant. The CRS creation tool's GUI fully satisfied 102 guidelines, partially satisfied 14, and did not satisfy 16. During the consolidation process, the experts were unable to reach a consensus regarding three guidelines. Hence, they collected direct feedback on these three guidelines from GUI users. The two experts used a survey, which the industrial partner helped administer. All responses were anonymized. They collected N=6 complete responses. Where consensus was not reached, experts rated the guideline's *Compliance* as partial.

Table 2. Expert review summary results: level of compliance (LOC) of the CR GUI with the 132 usability guidelines included in the review.

LOC	Must	Could	Should	Would	Total
Full	-	-	-	-	102
Partial	6	3	4	1	14
None	14	2	0	0	16

3.3. Prototyping workshops

Two UX researchers from UNI (1^{st} and 2^{nd} authors) led ten prototyping workshops with project stakeholders to design the CRS creation GUI. The workshops involved N=6 non-UX participants, all of whom were information technology (IT) and/or CR experts: two from UNI, three from COE, and one from IND (Table 3). Each workshop comprised a minimum of N=3 non-UX experts and the two UX experts, collectively referred to as the prototyping team in the following.

The workshops aimed to produce design solutions for the CRS creation GUI, which would enhance trainees' learning experience and provide trainers with valuable insights for effective guidance and support. We selected lo-fi prototyping as our design method because it supports rapid iterative design (Hussain et al., 2008) and triggers discussions about context of use, user requirements (Kieffer et al., 2020), and GUI layouts (Kieffer and Vanderdonckt, 2023).

Prior to the workshops, the prototyping team broke down the future system into design chunks (e.g., assessment of trainees' competences). We ran five 2-hour in-person workshops, each focused on one design chunk. Each workshop started with participants independently sketching and presenting a solution, which triggered discussions about the context of use and user requirements. Then, the team consolidated the solution on a whiteboard for real-time visualization, discussed and collectively agreed upon the GUI layout (Fig. 1, producing). To increase the fidelity of the data model (McCurdy et al., 2006), we organized five 4-hour online workshops, during which participants worked in pairs to create questions for assessing trainees' competences in IT and cybersecurity.

Our multidisciplinary approach allowed us to simultaneously address UX and IT requirements and constraints. Specifically, the discussions proved instrumental to identify the features necessary to CRS creation, thereby enabling recognition of distinct user needs, user requirements, and user profiles (e.g., trainees, CRS designers), as well as interaction flows between these user profiles (Fig. 1, understanding and specifying). While breaking down the user journey into steps, participants aimed to minimize friction and prevent bottlenecks, thereby optimizing the UX.

4. Methodology

4.1. Study goals

The goal of this case study is to investigate the social ROI of UX integration in the context of a cybersecurity project aimed at supporting the creation of CRS. Shaver and Braun (2008) define social ROI as the perception that human factors and ergonomics initiatives provide benefits, influencing both internal (increased management "buy-in") and external ROI (strengthened corporate image through positive customer perceptions and demonstrated trustworthiness). The specific objectives are to investigate how project stakeholders perceived UX and to identify the barriers and opportunities to UX integration within the specified project. To this end, we combined survey and interview to assess project stakeholders' UX literacy and collect data on problem recognition (i.e. the ability to recognize problems with the UX of systems). Table 3 presents the sampling strategy.

4.2. Survey

We administered the survey proposed by Azevedo et al. (2023) to N=11 participants between the ages 30 and 60, experienced in information technology, cybersecurity, or both (Table 3). We sampled participants from each stakeholder based on their participation in UX activities and their job function. The sample only included project stakeholders: the two expert review participants (one CR expert and a CRS creation tool's GUI user), the six workshop participants, and the three project supervisors. The survey contains six modules, each module addressing one UX attribute (Table 4). We asked participants to rate their level of agreement with statements using a 5-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree). Completion of the questionnaire required about five minutes.

4.3. Interview

We conducted a follow-up interview with N=6 participants, comprising one project supervisor and one UX activity participant from each stakeholder (Table 3). Prior to their participation, participants were required to read and electronically sign a consent form. We interviewed and recorded participants via an online video conference tool. The interview covered two additional topics related to the survey: UX integration and prospects for UX. The questions associated with UX integration read: "How do UX activities integrate into or modify the current software development model?" and "How did the introduction of UX activities affect your job?". The questions associated with prospects for UX read: "Why would you consider or not consider using UX for other projects?" and "What kind of information related to UX do you expect or would like to see to help decision-making?". Each question provided additional insights into stakeholders' current beliefs regarding UX.

Table 3. Participant sampling broken down per stakeholder. IT: researchers and developers, AS: academic staff, TM: top managers. Experience expressed in years. x: participation in UX activities, survey and/or interview.

Stakeholder	Participant	Age	Experience	Review	Workshops	Survey	Interview
UNI	AS1	[40-39]	15			x	x
UNI	IT1	[30-39]	8		x	x	
UNI	IT2	[30-39]	7		x	x	x
COE	IT3	[40-49]	2.5		x	x	
COE	IT4	[40-49]	18		x	x	x
COE	IT5	[30-39]	13		x	x	
COE	TM1	[50-60]	23			x	x
IND	IT6	[30-39]	14	x		x	
IND	IT7	[50-60]	31		x	x	
IND	IT8	[30-39]	13	x		x	x
IND	TM2	[40-49]	20			x	x
median	-	40.0	15.0	-	-	-	-

Table 4. Survey UX attributes and their summary descriptions.

UX attributes	Description
HCD understanding (HCD)	Users, tasks, and environments should be prioritized during the development process, while UX research should be integrated as an integral part of development
UX understanding (UUX)	UX encompasses utilitarian (e.g., efficiency, effectiveness) and non-utilitarian (e.g., stimulation, aesthetics) concepts, and is key to product acceptance, adoption, and trust
Attitude towards users (ATU)	Users should be at the center of development rather than being treated as passive recipients, and their needs and expectations should be effectively managed and addressed
Awareness of UX ROI (ROI)	UX activities contribute to product attractiveness, reduce the need for training and technical support, and may reduce development costs and time
Barriers (BAR)	Lack of sufficient resources (i.e., time, budget, staff), skills, and conflicts with existing software development models can hinder UX integration
Opportunities (OPP)	Poor UX design can lead to project or product failures. Prioritizing UX in development helps mitigate needs for user training and technical support

5. Results and discussion

The results and discussion are focused on the case study instance (i.e., survey and interview participants, project, UX activities performed in the project). We present results according to each of the three themes identified in the collected data: beliefs around HCD, barriers to UX, and social ROI of UX. Table 5 shows survey mean scores on a normalized scale ranging from 1 (poor answer) to 5 (good answer). We reversed scores for items using a negative form.

5.1. Beliefs around HCD

Survey participants demonstrated a strong grasp of HCD (M=4.09), although UX was not systematically integrated into the development cycle, which implies a lack of user involvement, user requirement analysis, and/or user testing. For example, TM1 and TM2 acknowledged they rely on developers for GUI design. Despite regarding UX integration as important to successful system sales, TM2 expressed hesitancy in hiring UX staff, preferring the occasional involvement of freelancers. TM1 shared a similar perspective, stating that UX is only necessary when the system is intended for daily usage.

Further, survey participants strongly agreed design should be guided by user tasks, user goals, and UX evaluation. The interview brought to light the importance of HCD in identifying user requirements (IT2) and aligning the system with user needs (IT4). For example, TM1 emphasized the need to establish UX requirements before transforming them into system requirements. Both IT2 and IT4 welcomed small, frequent iterations. Interview participants advocated for early UX evaluations with users, focused on task completion (TM1, AS1) and satisfaction (AS1), which shows that they understood UX constructs can be measured. Notably, stakeholders more experienced with software development demonstrated greater understanding of HCD (COE M=4.37 vs. UNI M=4 and IND M=3.87).

Table 5. Survey mean scores broken down per participant and UX attribute. AVG: average score across participants; IT: researchers and developers, AS: academic staff, TM: top managers.

Stakeholder	Participant	HCD	UUX	ATU	ROI	BAR	OPP	Follow-up interview
UNI	AS1	3.00	3.17	2.25	3.00	3.00	3.75	x
UNI	IT1	4.25	3.67	3.75	3.75	3.75	2.00	
UNI	IT2	4.75	3.67	4.00	3.00	4.50	2.00	x
COE	IT3	4.25	3.33	3.50	4.00	3.25	2.75	
COE	IT4	5.00	4.50	3.00	4.00	4.25	2.50	x
COE	IT5	4.50	3.83	3.75	3.75	2.25	2.50	
COE	TM1	3.75	3.82	3.00	3.50	3.75	3.50	x
IND	IT6	4.00	4.17	3.25	4.25	4.25	3.25	
IND	IT7	3.75	4.00	3.25	3.50	4.00	4.00	
IND	IT8	3.75	3.67	2.25	3.25	3.25	3.50	x
IND	TM2	4.00	4.00	3.50	3.75	4.00	2.75	x
AVG	-	4.09	3.80	3.23	3.61	2.95	3.75	-

5.2. Barriers to UX

Survey participants acknowledged graphic design and UX design are distinct and should not be performed by the same person. However, interview participants consistently confused UX and UI. Conflation of UX with UI may arise from encountering UX primarily through guidelines and best practices (IT4), and suggests lack of UX literacy. Lack of UX literacy led to mistaken beliefs, such as believing that checking for font consistency and contrast would ensure good UX (IT4), or separating UX from functionality selection (TM1).

Moreover, interview participants believed UX is mostly necessary for non-IT users, dismissing its importance to all users. Yet, they agreed UX reduces user needs for training and technical support. In addition, survey participants agreed users have limited ability to express their preferences. According to TM2, users lack a clear understanding of their own needs, thus user requirement specification necessitates developer intervention. This finding is consistent with Law and Lárusdóttir (2015)'s, and may explain developers' preference for UX evaluation over UX research (i.e. test design ideas over understanding users).

Some project stakeholders understand UX better than others (UNI *M*=3.44, COE *M*=3.87, IND *M*=3.96), likely due to increased exposure to UX. TM1 reported COE's developers had limited exposures to UX during their studies, which may have contributed to developers' difficulties in moving from a techno- to user-centered mindset (Hjartnes and Begnum, 2018). Similarly, survey participants' poor attitude towards users (*M*=3.23) may be explained by their lack of experience with UX methods involving users.

Survey stakeholders perceived UX ROI differently, although scores in ROI are relatively close (UNI *M*=3.25, COE *M*=3.81, IND *M*=3.68). Specifically, only IND acknowledged financially benefiting from UX despite their insufficient UX resources. For example, IT8 mentioned encountering difficulties when analyzing user feedback or choosing appropriate UX methods. In contrast, neither COE nor UNI prioritized UX, as their R&D projects aim at delivering functioning systems, and publications in their field do not integrate UX as review criteria.

Despite early UX activities preventing expensive late design changes and reducing development time and costs (Hjartnes and Begnum, 2018), UX participants believed the opposite. This misunderstanding of the UX ROI likely arises from misunderstanding UX itself. Interview participants understood UX helps reduce redevelopment needs (TM2) and the number of iterations (IT4), and that UX-IT synchronized parallel tracks prevent UX from "blocking" developers (IT8). Nevertheless, believing UX increases costs and time led them to undervalue UX ROI in technology-driven projects. For example, IT4, IT8, and TM2 prioritized efforts on technology development, arguing UX is only necessary when a GUI needs a visually appealing design (e.g., for non-IT users), since UX does not cover high-level project requirements (TM2).

In summary, the suboptimal perception of both UX ROI and users was a major issue which required addressing. Users should not be disregarded since the key principle of UX is to understand users' experiential response when interacting with a system (Law and Lárusdóttir, 2015). To that end, project stakeholders need sufficient UX literacy to efficiently participate in UX activities and share responsibilities (Kuusinen, 2015). However, project stakeholders were open to discussion and tried to overcome their preconceptions about users by putting themselves in users' shoes.

5.3. Social ROI of UX

Project supervisors believed integrating UX activities enhanced project stakeholders' UX literacy, ranging from awareness of users (AS1) to UX integration into back-end design (TM1-2). Survey participants stressed the significance of UX pragmatic attributes (e.g., usability, efficiency), especially when the system alters users' work processes (AS1); identifying challenging user tasks, non-obvious flow elements, and common errors (IT8); and improving the ease of use (IT4). Interview participants considered understanding and specifying UX activities to be key, for example, when setting priorities and goals (TM1, IT4). Moreover, TM2 believed UX staff should be included in decision-making processes, since UX goals aid project planning and clear expectation setting, as supported by MacDonald (2019). UX activities were recognized for achieving user acceptance, steering the project (IT2), designing human-centered data-models (TM1-2), and facilitating communication between front and back-end developers (TM2).

Interview participants believed UX facilitates communication between different stakeholders: 1) clients and development teams; 2) users and developers; 3) users and designers; and 4) developers and designers. First, TM2 stated that UX helped communication between IND and its clients by simplifying the conveyance of user requirements through graphical representations. Second, TM2 thought UX helps bridge the understanding gap between users and developers by reminding developers that they design for actual users. Third, UX artifacts such as prototypes, help designers communicate design solutions to users (TM2). Last, design focused UX activities promote frequent communication between designers and developers, which provides developers with clear objectives (IT4), and aligns software development with UX work, leading to a more efficient development process (Jones and Thoma, 2019).

The project benefited from the social ROI of UX activities. First, the key elements for efficient collaboration include close proximity, early and frequent communication, shared understanding of user requirements, collective problem solving and decision-making, and knowledge and skills crossover (Jones and Thoma, 2019). Successful integration of these key elements in this project supported the internal ROI of UX (i.e., ROI that can be attributed to staff). Second, efficient communication, especially between developers and designers, requires some UX literacy. Common ground is key for integrating UX principles and gaining support for projects (MacDonald, 2019). The external ROI of UX (i.e., ROI that can be attributed to the system) is evident in IND's satisfaction with the work and expressed interest in continued collaboration. Last, incorporating users indirectly through HCD methods, communication, and meetings contributed to process and team morale improvement (Hussain et al., 2008). The positive working relationship within the team, evident in the pleasant atmosphere during meetings and after-work events, demonstrates the social ROI.

5.4. Recommendations

To address challenges to UX integration posed by low UX literacy (Azevedo et al., 2023), we recommend performing UX activities without users first and then gradually involving users in the project lifecycle. Methods without users are both less resource intensive and quickly provide external UX ROI (Hussain et al., 2008). Similarly, we recommend engaging stakeholders in early design phases, since our findings indicate that prototyping workshops conducted early enhanced stakeholders' UX literacy. This aligns with findings by Buis et al. (2023), who also found that UX activities such as lo-fi prototyping help foster a shared understanding of users.

For replication purposes, we recommend following this protocol: (1) conduct UX activities; (2) sample participants from project stakeholders according to their job function and involvement in UX activities; (3) administer the UX literacy survey; (4) conduct a follow-up interview with a subset of survey participants; and (5) triangulate data collected from survey and interview, using the same UX attributes. In accordance with Quintão et al. (2020), we recommend collecting additional data for triangulation using complementary methods (e.g., diary, observation, ethnography), thereby increasing the reliability of the case study.

5.5. Reliability and validity

This exploratory case study presented characteristics inherent to case studies and qualitative research: no control over the setting, small sample size, narrative data, no intent to statistically generalize findings, nor demonstrate cause-and-effect (Quintão et al., 2020). Its reliability and validity should be discussed in terms of construct and external validity, the relevance of internal validity being insignificant in exploratory case studies (Quintão et al., 2020).

Overall, we collected 286 survey records (26 items x 11 participants) and 24 interview records (4 questions x 6 participants), which enabled us to triangulate a sufficient amount of data, and thereby increase construct validity (Quintão et al., 2020). In addition, due to the multidisciplinary nature of the team, we relied on stratified sampling to ensure that the population's characteristics were properly represented in the samples. The survey sample included one supervisor per stakeholder (AS1, TM1, and TM2), the four researchers most involved in UX activities (IT1-2 and IT4-5), and four team members who provided occasional support for UX activities (IT3 and IT6-8). We proceeded similarly for the interview (Table 3). As a result, both samples are representative of the project's population, which allows us to maintain defensible external validity.

6. Conclusion and future work

This exploratory case study reported implementation of UX activities in a cybersecurity project aimed at supporting the creation of CRS. We investigated how non-UX stakeholders perceived UX and how conducting UX activities without users affected the development of a CRS GUI. Bounded to the case study instance, our findings show UX activities yielded social ROI, evident through improved UX literacy, collaboration and communication, and expressed satisfaction from the industrial partner. The social ROI of UX facilitated the transition from parallel multidisciplinary, to integrated interdisciplinary teamwork. Moreover, early engagement of project stakeholders in UX activities without users facilitated the integration of UX activities within a project marked by limited UX literacy. Moving forward, we must conduct UX evaluation with users to validate solutions derived from the expert review and prototyping workshops, thereby improving the UX with the future system.

We proposed a protocol for measuring UX literacy and identifying barriers and opportunities to UX integration. This protocol allowed us uncover barriers to UX integration, such as misconceptions about UX ROI. Future work must also include the replication of this protocol within multiple cases to identify patterns based on similar or contradictory results and provide elements for the development of a theory for UX integration. Successful UX integration has the potential to enhance work experiences, aligning with the concept of transforming work into a more enjoyable endeavor, as advocated by Browne and Green (2022).

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