Journal of Software Engineering Research and Development, 2022, 10:4, doi: 10.5753/jserd.2021.1878

Investigating Knowledge Management in Human-Computer Interaction Design

Murillo V. H. B. Castro [Federal University of Espírito Santo | murillo.castro@aluno.ufes.br]
Simone D. Costa [Federal University of Espírito Santo| simone.costa@ufes.br]
Monalessa P. Barcellos [Federal University of Espírito Santo| monalessa@inf.ufes.br]
Ricardo de A. Falbo [Federal University of Espírito Santo | falbo@inf.ufes.br]

Abstract

Developing interactive systems is a challenging task. It involves concerns related to human-computer interaction (HCI), such as usability and user experience. Therefore, HCI design must be addressed when developing such systems. HCI design often involves people with different backgrounds, which makes communication and knowledge transfer a challenging issue. In this scenario, knowledge management can support understanding concepts from different knowledge areas and help learn from previous experiences. Aiming at investigating how knowledge management has supported HCI design and contributed to the development of interactive systems, we performed a mapping study in the literature and analyzed 15 publications reporting the use of knowledge management in HCI design. Following that, we conducted a survey with 39 HCI design professionals to find out how knowledge has been managed in their HCI design practice. In this paper, we present the studies and discuss their main findings. In summary, the results indicate that knowledge management has been used in HCI design mainly to improve product quality and reduce the effort and time spent on design activities. However, there is a need for simpler and more practical knowledge-based solutions to support HCI design. Such approaches would be capable of reaching more HCI design practitioners that could benefit from them.

Keywords: *HCI Design, Mapping Study, Survey, Knowledge Management, Interactive System*

1 Introduction

The interest in interactive systems and their impact on people's life has promoted the study and practice of usability (Carroll, 2014). Usability is a key aspect of a successful interactive system and is related to user efficiency and satisfaction when interacting with the system. For an interactive system to reach high usability levels, it is necessary to take human-computer interaction (HCI) design aspects into account during its development process (Carroll, 2014).

HCI is concerned with usability and other aspects related to the interaction between users and computer systems, necessary to produce more usable software (Carroll, 2014). It involves knowledge from multiple fields, such as ergonomics, cognitive science, user experience, human factors, among others (Sutcliffe, 2014). Due to the diverse body of knowledge involved when designing interactive systems, interactive system development teams are frequently multidisciplinary, joining people from different backgrounds, with their own technical language, terms and knowledge. Collaboration among team members is not straightforward, since HCI designers and developers, for example, look at the same problem under different perspectives, which leads to difficulties that include a lack of a shared vocabulary and harsh epistemological conflicts (Neto et al., 2020). Even the conceptualization of the product may be conflicting among different stakeholders, which hampers communication and knowledge transfer (Carroll, 2014; Rogers et al., 2011).

Developing software is a knowledge-intensive task. Knowledge Management (KM) principles and practices have been successfully applied to support knowledge capture, storage, use and transfer in the software development context in general (Rus & Lindvall, 2002; Valaski et al., 2012). KM can also be helpful to address challenges in the design of interactive systems since it might provide support to capture and represent knowledge in an accessible and reusable way and facilitate collaboration among team members. For example, design solutions developed by an organization can be stored and related to the requirements that motivate them, components and patterns used to build them and evaluation results. As a result, the team can learn from previous experiences and share a common understanding of the system, producing better products and performing processes more efficiently.

Considering the challenges of designing interactive systems, mainly due to the diversity of knowledge and people involved, and the potential of KM to help address those challenges, we decided to investigate the use of KM in HCI design. Although KM can be used in different domains and there are some general motivations for using it (e.g., knowledge structuring) and benefits (e.g., improve knowledge reuse) provided by its use, KM can be applied to solve specific problems in each domain, different techniques can be used, and so on. Thus, the main question that guided our investigation refers to how KM has been used in the HCI design domain. Besides investigating general motivations and benefits observed in the use of KM in the HCI design domain, we also intended to identify specificities of the use of KM in that domain. First, we searched for secondary studies addressing the research topic. Since we did not find any, we decided to perform a systematic mapping in the literature. We analyzed 12 different KM approaches used in HCI design, identified from 15 publications. In general, KM has aided in HCI design mainly by enabling replicability of knowledge and solutions, improving product quality and communication. However, difficulty to generalize knowledge, issues related to features of the system and low engagement of the team have been pointed out as challenges to implement KM in the HCI design context. After investigating the literature, we performed a survey with 39 Brazilian HCI design practitioners that were asked about how knowledge has been managed in HCI design practice. Most participants are concerned with managing HCI design knowledge and perceive that KM helps them to improve product quality and reduce effort and time spent on HCI design activities. They follow organizational or individual KM practices and apply technologies such as brainstorming, mental models and electronic spreadsheets.

This paper presents our studies (the mapping study and the survey) and their main results. It extends our previous work (Castro et al., 2020), in which we presented the main results of our mapping study, by adding information about the survey and presenting a more comprehensive view of the mapping results, updating the search period and providing new information (e.g., new graphs and details about the identified KM approaches). The mapping and the survey results are further analyzed together, providing an overview of the research and practice of KM in HCI design and pointing out some gaps that can be addressed in future research.

The paper is organized as follows: Section 2 provides the background for the paper, addressing HCI design and KM; Section 3 concerns the mapping study; Section 4 addresses the survey; Section 5 provides a consolidated view of the mapping and the survey results; and Section 6 presents our final considerations.

2 Background

2.1 HCI Design

HCI design focuses on how to design a system to support the user to achieve her goals through the interaction between her and the system (Sutcliffe, 2014). It is concerned with usability and other important attributes such as user experience, accessibility and communicability. Usability is the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use (ISO, 2019). It addresses the effort and ease of the user during the interaction, considering her cognitive, perceptive and motor skills. User experience relates to users' emotions and feelings and is essential for interaction design because it takes into account how a product behaves and is used by people in the real world (Rogers et al., 2011). Accessibility refers to the removal of barriers that prevent interface and interaction access. Finally, communicability concerns the ability of the interface to communicate design logic to the user (De Souza, 2005).

HCI design is user-centered, hence it is said User-Centered Design (UCD) (Chammas et al., 2015). UCD is based on ergonomics, usability and human factors. It focuses on the use and development of interactive systems, with an emphasis on making products usable and understandable. It puts human needs, capabilities and behavior first, then designs the system to accommodate them. Its main principles are user focus (its characteristics, needs and objectives), observable metrics (user performance and reactions) and iterative design (repeat as often as needed) (Chammas et al., 2015; ISO, 2019). The term Human-Centered Design (HCD) has been adopted in place of UCD to emphasize the impact on all stakeholders and not just on those considered users (ISO, 2019).

In general, UCD involves: *understand and specify context of use*, which aims to study the product users and intended uses; *specify requirements*, which aims to identify user needs and specify functional and other requirements for the product; *produce design solutions*, which aims to achieve the best user experience and includes the production of artifacts such as prototypes and mock-ups that will be used in the future as a basis for developing the system; and *evaluation*, when the user evaluates the results produced in the previous activities (ISO, 2019).

HCI design can be understood as an intensive knowledge process, requiring effective mechanisms to collaboratively create and support a shared understanding about users, the system, its purposes, context of use and the design necessary for the user to achieve her goals. Therefore, HCI design could take advantage of KM solutions.

2.2 Knowledge Management

According to Schneider (2009), knowledge is a human specialty stored in people's minds, acquired through experience and interaction with their environment. Historically, an organization’s knowledge was undocumented, being represented through the skills, experience and knowledge of its professionals, typically tacit knowledge (Rus & Lindvall, 2002), which made its use and access limited and difficult (O'Leary, 1998).

Knowledge Management (KM) aims to transform tacit and individual knowledge into explicit and shared knowledge. By raising individual knowledge to the organizational level, KM promotes knowledge propagation and learning, making knowledge accessible and reusable across the entire organization (O'Leary, 1998; Rus & Lindvall, 2002; Schneider, 2009). Knowledge helps software organizations to react faster and better, supporting more accurate and precise responses, which contributes to increasing software quality and client satisfaction (Schneider, 2009). When an organization implements KM, its experiences and knowledge are recorded, evaluated, preserved, designed and systematically propagated to solve problems (Schneider, 2009). Thus, KM addresses knowledge in its evolution cycle, which consists in creating, capturing, transforming, accessing and applying knowledge (Rus & Lindvall, 2002; Schneider, 2009).

In the software process context, KM works for explicitly and systematically managing knowledge, addressing knowledge acquisition, storage, organization, evolution, retrieval and usage. Among other aspects, KM has been applied in the software development context to support document management, competence management, experts identification, software reuse, support learning and product and project memory (Rus & Lindvall, 2002). By investigating empirical studies of KM in Software Engineering, Bjørnson & Dingsøyr (2008) reported that the studies' major focus has been on explicit knowledge and there is a need to focus also on tacit knowledge.

3 Systematic Mapping: KM in HCI Design according to the literature

Considering the challenges involving knowledge transfer and sharing in the HCI design context and the benefits of using KM in the software development context, we decided to investigate the use of KM in HCI design through a mapping study. A mapping study is a secondary study designed to give an overview of a research area through classification and counting contributions concerning the categories of that classification. It makes a broad study on a topic of a specific theme and aims to identify available evidence about that topic (Petersen et al., 2015). Moreover, the panorama provided by a mapping study allows identifying issues in the researched topic that could be addressed in future research. We followed the process defined in Kitchenham & Charters (2007), which comprises three phases:

(i) Planning: In this phase, the topic of interest, study context and object of the analysis are established. The research protocol to be used to perform the research is defined, containing all the necessary information for a researcher to perform the research: research questions, sources to be searched, publication selection criteria, procedures for data storage and analysis and so on. The protocol must be evaluated by experts and tested to verify its feasibility, i.e., if the results obtained are satisfactory and if the protocol execution is viable in terms of time and effort. Once the protocol is approved, it can be used to conduct the research.
(ii) Conducting: In this phase, the research is performed according to the protocol. Publications are selected and data are extracted, stored and quantitatively and qualitatively analyzed.
(iii) Reporting: In this phase, the produced research results are recorded and made available to potentially interested parties.

Next, in Section 3.1, we present the research protocol followed in our study. Section 3.2 summarizes the mapping study results. Section 3.3 discusses the results and Section 3.4 regards threats to validity.

3.1 Research Protocol

This section presents the protocol used in the mapping study. It was defined gradually, being tested with an initial set of publications and then refined until we reached the final protocol, which was evaluated by another researcher, resulting in the protocol used in the study and presented in this section.

The study ***goal*** was to investigate the use of KM in the HCI design context. For achieving this goal, we defined the research questions presented in Table 1.

Table 1. Systematic Mapping: research questions and their rationale.

ID	*Research Question*	Rationale
RQ1	*When and where have publications been published?*	Give an understanding of when and where (journal/conference/workshop) publications about KM in the HCI design context have been published.
RQ2	*Which types of research have been done?*	Investigate which type of research is reported in each selected publication. We consider the classification defined in (Wieringa et al., 2005). This question is useful to evaluate the maturity stage of the research topic.
RQ3	*Why has KM been used in the HCI design context?*	Understand the purposes and reasons for using KM in the HCI design and verify if there have been predominant motivations.

RQ4	*Which knowledge has been managed in the HCI design context?*	Investigate which knowledge items have been managed in the HCI design context, aiming to verify if some of them have been managed more frequently and if there has been more interest in certain HCI aspects.
RQ5	*How is the managed knowledge related to the HCI design process?*	Understand, in the context of the HCI design process, where the managed knowledge has come from and where it has been used.
RQ6	*How has KM been implemented in the HCI design context?*	Investigate how KM has been implemented in the HCI context in terms of the adopted technologies.
RQ7	*Which benefits and difficulties have been noticed when using KM in the HCI design context?*	Identify the benefits and difficulties of using KM in the HCI design context and analyze if there is a relation between them.

RQ1 and RQ2 are common systematic mapping questions that provide a general panorama of the research topic. The other questions aim to investigate why (RQ3 and RQ7), how (RQ4 and RQ6) and when (RQ5) KM has been used in HCI design, which are important questions to provide an understanding of the research topic.

The ***search string*** adopted in the study contains two groups of terms joined with the operator AND. The first group includes terms related to *HCI design*. The general term "Human-Computer Interaction" was used to provide wider search results. The second group includes terms related to *Knowledge Management*. Within the groups, we used the OR operator to allow synonyms. The following search string was used: *("human-computer interaction" OR "user interface design" OR "user interaction design" OR "user centered design" OR "human-centered design" OR "UI design" OR "HCI design") AND ("knowledge management" OR "knowledge reuse" OR "knowledge sharing")*. For establishing the string, we performed tests using different terms, logical connectors and combinations among them, selecting the string that provided better results in terms of the number of publications and their relevance (i.e., the number of publications returned by the search string and, considering a sample, the inclusion of the really relevant ones for the study). If a new term added to the search string resulted in a much larger number of returned publications, without adding new relevant ones to the study, then that term was not considered in the search string. In that sense, more restrictive strings excluded important publications identified during the informal literature review that preceded the study. More comprehensive strings (e.g., those including "usability") returned too many publications out of the scope of interest.

The search was performed in four ***sources***, namely Scopus, Science Direct, Engineering Village and Web of Science. We selected these sources because Scopus is one of the largest databases of peer-reviewed literature. It indexes papers from other important sources such as IEEE and ACM, providing useful tools to search, analyze and manage scientific research. Complementarily, to increase coverage, we selected Science Direct, Engineering Village and Web of Science, which are also widely used in secondary studies recorded in the literature and on other experiences in our research group.

Publications selection was performed in five steps. In *Preliminary Selection and Cataloging (S1)*, the search string was applied in the search mechanism of each digital library used as a source of publications (we limited the search scope to the title, abstract and keywords metadata fields). After that, in *Duplications Removal (S2)*, publications indexed in more than one digital library were identified and duplications were removed. In *Selection of Relevant Publications - 1st filter (S3)*, the abstracts of the selected publications were analyzed considering the following inclusion (IC) and exclusion (EC) criteria: (IC1) the publication addresses KM in the HCI design context; (EC1) the publication does not have an abstract; (EC2) the paper was published only as an abstract; (EC3) the publication is not written in English; (EC4) the publication is a secondary study, a tertiary study, a summary, an editorial or a tutorial. In *Selection of Relevant Publications - 2nd filter (S4)*, the full text of the publications selected in S3 were read and analyzed considering the cited inclusion and exclusion criteria. In this step, to avoid study repetition, we considered another exclusion criterion: (EC5) the publication is an older version of an already selected publication. When the full text of a publication was not available either from the Brazilian Portal of Journals, from other Internet sources or by contacting its authors, the publication was also excluded (EC6). Publications that met one of the six cited exclusion criteria or that did not meet the inclusion criteria IC1 were excluded. Finally, in *Snowballing (S5)*, as suggested in Kitchenham & Charters (2007), the references of publications selected in S4 were analyzed by applying the first and second filters and, the ones presenting results related to the research topic were included in the study.

We used the StArt tool[1] to support publications selection. To consolidate data, publications returned in the publication selection steps were cataloged and stored in spreadsheets. We defined an id for each publication and recorded the publication title, authors, year, and vehicle of publication. Data from publications returned in S4 and

[1] http://bit.ly/StArt-tool

S5 were extracted and organized into a data extraction table oriented to the research questions. The spreadsheets produced during the study can be found in http://bit.ly/Mapping-KM-in-HCI-design.

The first and second authors performed publication selection and data extraction. The third and fourth authors reviewed both. Once data has been validated, the first and the second authors carried out data interpretation and analysis, and again third and fourth authors reviewed the results. Discordances were discussed and resolved.

Quantitative data were tabulated and used in graphs and statistical analysis. Finally, the four authors performed qualitative analysis considering the findings, their relation to the research questions and the study purpose.

3.2 Results

The study considered papers published until October 2020. Searches were conducted for the last time in November 2020. Figure 1 illustrates the followed process and the number of publications selected in each step.

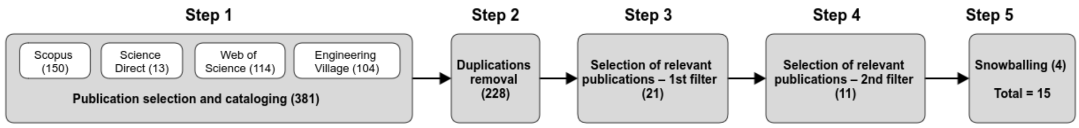

Figure 1. Publication selection process.

In the 1st step, as a result of searching the selected sources, a total of 381 publications was returned. In the 2nd step, we eliminated duplicates, achieving 228 publications (reduction of approximately 40%). In the 3rd step, we applied the selection criteria over the abstract, resulting in 21 papers (reduction of approximately 91%). At this step, we only excluded publications that were clearly unrelated to the subject of interest. In case of doubt, the paper was taken to the next step. In the 4th step, the selection criteria were applied considering the full text, resulting in 11 publications (reduction of approximately 48%). Finally, in the 5th step, we performed snowballing technique by checking the references of the 11 selected publications and identified 4 more publications, which in total added up to 15 publications. When analyzing the publications to identify the KM approaches applied in the HCI design context, we noticed that some publications addressed complementary works from the same research group. Hence, we considered complementary works as a single KM approach when extracting data about RQs 3, 4, 5, 6 and 7. Table 2 shows the list of identified KM approaches, their descriptions and corresponding publications. Two papers were grouped into a KM approach and three other papers were grouped in another KM approach. Thus, we considered a total of 12 different KM approaches found in 15 publications. Along with this and the next section, we refer to the approaches by using the id listed in the table. After Table 2, we present the data synthesis for each research question. Further information about the selected publications, including detailed extracted data, can be found in http://bit.ly/Mapping-KM-in-HCI-design.

Table 2. Selected publications.

ID	Approach	Brief description	Ref.
#01	*Trading off usability and security in user interface design through mental models*	Proposes the development of an Organizational Mental Model through knowledge transfer and transformation, using collaborative brain power from various knowledge constellations to design.	(Mohamed et al., 2017)
#02	*Knowledge management challenges in collaborative design of a Virtual Call Centre*	Proposes a knowledge-based system with the following functionalities: (a) storing design primitives and formal knowledge in an online library; (b) preserving procedures and rules that proved successful in past design problems; (c) formal modeling of knowledge elements that might be applicable for usability improvements; (d) providing multiple mechanisms for knowledge acquisition, preserving, transfer and sharing.	(Sikorski et al., 2011)
#03	*Applying knowledge management in UI design process*	Defines a process to automate the transformation of a task description into an interaction description. First, it identifies and uniformizes existing knowledge about UI design process using knowledge classification techniques. Then, captured knowledge is represented in the form of ontologies, deriving a Task Metamodel and an Interaction Metamodel. This extracted knowledge is integrated to design defining a transformation of task description into interaction description using an intermediate model between them and a two-step transformation.	(Suàrez et al., 2004)
#04	*A knowledge management tool for speech interfaces*	Proposes a knowledge-based system to help developers of speech-driven interfaces learn with previous design solutions. These solutions are collected, made accessible and divided into categories regarding their content type. Solutions with corresponding structures are clustered and compared within their own category, providing designers with a suggestion mechanism based on their desired kind of solution.	(Bouwmeester, 1999)

		There is also a ranked suggestion mechanism of design elements based on available design material and design guidelines.	
#05	*Design knowledge reuse based on visualization of relationships between claims*	Presents a tool that aims to improve design and knowledge acquisition by exploring relationships between claims. It allows a better search and retrieval mechanism to a design knowledge repository, which is obtained by applying KM strategies (generalize, classify, store, retrieve) to claims.	(Wahid, 2006; Wahid et al., 2004)
#06	*Design knowledge reuse and notification systems to support design in the development process*	Presents a system connected to a design knowledge repository based on claims. It allows teams to leverage knowledge from previous design efforts by searching for reusable claims relevant to their current project and to extend the repository by updating existing claims and creating new ones.	(Chewar et al., 2004; Chewar & McCrickard, 2005; J. L. Smith et al., 2005)
#07	*Exploring knowledge processes in user-centered design process*	Proposes a conceptual framework that guides the design process based on five propositions: (1) designers and users should be actively included as actors in the process since they both have the knowledge needed for a successful design; (2) this knowledge possessed by them is context-specific; (3) there is useful knowledge that has not been articulated by both users and designers and, therefore (4) knowledge processes transforming tacit knowledge into explicit knowledge by users and designers are linked and should be combined; and finally, (5) resulting knowledge obtained along the process is embedded into concepts, products or services.	(Still, 2006)
#08	*Lessons learnt from an HCI repository*	Concerns about the implementation of a knowledge repository using Windows Help Files. It is maintained by a group within the organization that receives content updates from the team and properly inserts this new material into the repository. New versions are released from time to time and distributed as physical copies to be installed on each computer.	(Wilson & Borras, 1998)
#09	*A pattern language approach to usability knowledge management*	Presents a KM system that used principles of use case writing and pattern languages to describe problems found in user testing sessions and the following solutions to them. Patterns can be retrieved by forms with filters, text search and database queries. Filters include goals and subgoals, being useful respectively to show all problems related to a specific user goal and possible solutions and to provide insights of what interactions or devices have been problematic regardless of user goal.	(Hughes, 2006)
#10	*An expert system for usability evaluations of business-to-consumer e-commerce sites*	Proposes a knowledge-based system to help with e-commerce usability evaluations. A knowledge engineer is responsible for acquiring and representing knowledge, eliciting knowledge from textual, non-live sources of expertise about design guidelines that affect the usability of 11 e-commerce elements. The elicited knowledge is consolidated and presented in a form of rules in the expert system.	(Gabriel, 2007)
#11	*A framework for developing experience-based usability guidelines*	Presents a KM system to manage design guidelines contextualized by usability examples. The system allows designers to describe their current problems and requirements and then search for cases with similar characteristics. They can also follow hyperlinks to more general guidelines, which also point to other cases and search from a list of hierarchically arranged guidelines and follow other related guidelines and cases. The system is initially seeded with organization-wide usability guidelines and is updated as new projects are developed.	(Henninger et al., 1995)
#12	*Prototype evaluation and redesign: structuring the design space through contextual techniques*	Proposes a method based on contextual inquiry and brainstorming to identify usability issues in interface evaluations and derive proper design solutions to them. First, interface evaluation sessions are conducted with users when they share their perceptions while interacting with a high-fidelity prototype of the system. Those sessions are recorded and, later, relevant comments are transcribed into usability flaws. In a second moment, there are brainstorm meetings where developers, designers and HCI specialists propose design solutions to the previously identified usability flaws.	(A. Smith & Dunckley, 2002)

Publication year and type (RQ1): Figure 2 shows the distribution of the 15 selected publications over the years and their distribution considering the publication type. Papers addressing KM in the HCI design context have been published since 1995 in Journals and Conferences (no Workshop publications were found). Conferences have been the main forum, encompassing 73.3% of the publications (11 out of 15). Four papers (26.78%) were published in journals.

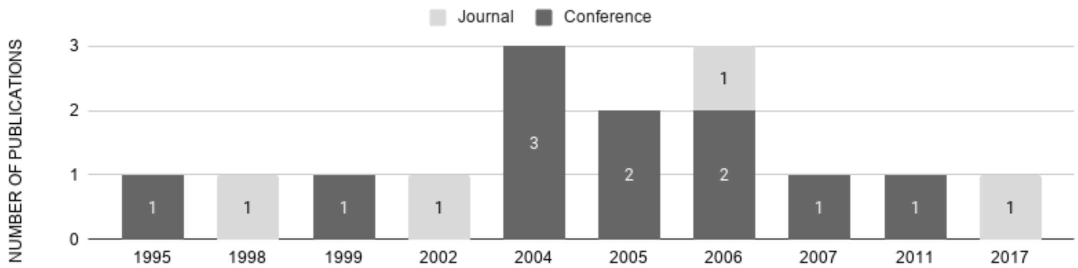

Figure 2. Publications over the years.

The venues of each selected publication were also analyzed to investigate if they were more related to HCI, KM or Software Engineering (SE). Table 3 summarizes the venues of the selected publications and indicates their main focus. Figure 3 presents the distribution of the venue orientation across the publications. 53.3% of the publications (8 out of 15) were published in HCI venues and the remaining of the publications are divided into KM (26.7%) and SE (20.0%) venues.

Table 3. Venue orientation of the selected publications.

Ref.	Venue	Area
(Mohamed et al., 2017)	Behavior & Information Technology	HCI
(Sikorski et al., 2011)	International Conference on Knowledge-Based and Intelligent Information and Engineering Systems	AI
(Wahid, 2006)	Conference on Designing Interactive Systems	HCI
(Suàrez et al., 2004)	Conference on Task Models and Diagrams	HCI
(Bouwmeester, 1999)	International ACM SIGIR Conference on Research and Development in Information Retrieval	Information Retrieval
(J. L. Smith et al., 2005)	IEEE International Conference and Workshops on Engineering of Computer-Based Systems	Software Engineering
(Chewar et al., 2004)	International Conference on Computer-Aided Design	Design
(Wahid et al., 2004)	IEEE International Conference on Information Reuse and Integration	Data Science
(Chewar & McCrickard, 2005)	Hawaii International Conference on System Sciences	Information Systems
(Still, 2006)	European Conference on Knowledge Management	KM
(Wilson & Borras, 1998)	International Journal of Industrial Ergonomics	HCI
(Hughes, 2006)	Journal of Usability Studies	HCI
(Gabriel, 2007)	ISOnEworld Conference	Information Systems
(Henninger et al., 1995)	DIS - conference on Designing interactive systems: processes, practices, methods, and techniques	HCI
(A. Smith & Dunckley, 2002)	Interacting with computers	HCI

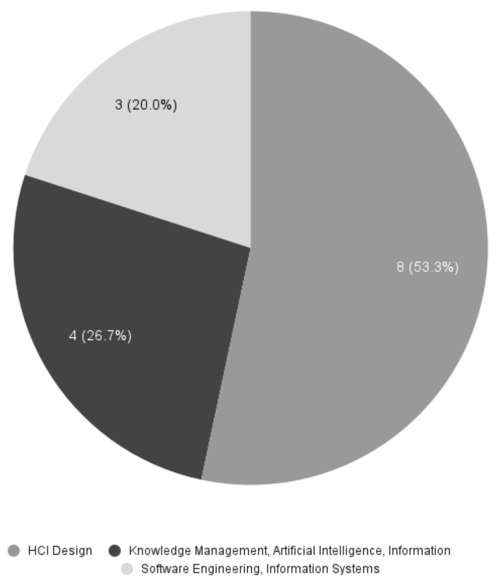

Figure 3. Venue orientation of the selected publications.

Research Type (RQ2): Figure 4 presents the classification of the research types (according to the classification proposed in Wieringa *et al.* (2005)) reported in the 15 selected publications. 13 publications (86.7%) propose a solution to a problem and argue for its relevance. Thus, they were classified as *Proposal of Solution*. Five of them (33.3%) also present some kind of evaluation, being one (6.7%) evaluated in practice (i.e., also classified as *Evaluation Research*), and four (26.7%) investigating the characteristics of the proposed solution not yet implemented in practice (i.e., *Validation Research*). One publication (6.7%) refers exclusively to *Evaluation Research*, discussing the evaluation of KM in an industrial setting, and another is a *Personal Experience Paper*, reporting the experience of the authors in a particular project in the industry.

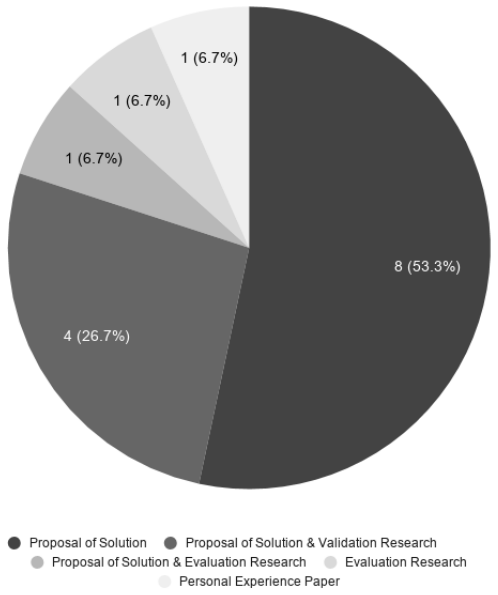

Figure 4. Research type of the identified publications.

Motivation for using KM in HCI design (RQ3): we identified six reasons for using KM in HCI design, as shown in Table 4. Some approaches presented more than one motivation, thus the total sum is greater than 12.

Table 4. Motivations for using KM in HCI design.

Motivation	Approaches	Total
Improve product quality	#01, #02, #04, #05, #06, #07, #10, #11, #12	9
Reduce design effort	#02, #03, #08, #09, #10	5
Reduce design time	#04, #05, #08	3
Reduce design cost	#05, #10	2
Improve design team performance	#06	1
Improve HCI design learning	#06	1

Nine approaches (75%) use KM to improve product quality, most of them concerning usability. These approaches aim to provide benefits related to the quality of the interactive system in terms of its interaction with users. For example, approach #11 is proposed to help developers to design effective, useful and usable applications. Approach #01, in turn, aims to improve alignment between design features and users' requirements. Seven approaches (58.3%) are motivated by improving one or more aspects related to the HCI design process, namely: effort, time and cost. From these, reducing effort is highlighted. Five approaches (41.7%) use KM to reduce design effort, mainly by not depending on internal usability experts to perform HCI design activities. Approach #02, for example, applied KM to decrease the need for experts to support the design team with their knowledge and experience, due to lack of knowledge to be reused. Approaches #04, #05 and #08 were motivated by reducing HCI design time through the reuse of previous solutions implemented for similar problems. Reducing costs in the HCI design process was the motivation for approaches #05 and #10, which focus on minimizing the involvement of external usability experts in the process and conducting usability evaluation more effectively. Approach #06 aimed to improve design team performance by providing support for team coordination and collaboration. This approach also aimed to improve HCI learning for the students involved in the project.

Managed knowledge in HCI design (RQ4): Analyzing the publications, we identified 24 different types of knowledge items managed by the KM approaches, as shown in Table 5. Some items are shown in the same line to save space. The most common knowledge items have been *Design Guidelines* and *Design Solutions*, addressed by four approaches, followed by Test Results, addressed by three approaches. We noticed that, in the context of HCI design, KM approaches have dealt with only one (#10) or two (#01, #03, #05, #06, #09, #11 and #12) different knowledge items.

Table 5. Managed knowledge items.

Knowledge Item	Approaches	Total
Design Guidelines	#04, #08, #10, #11	4
Design Solutions	#02, #04, #07, #08	4
Test Results	#02, #04, #12	3
Claims	#05, #06	2
Design Features	#01, #12	2
Design Patterns	#09, #11	2
Lessons Learned	#04, #08	2
Usability Measures	#02, #08	2
Claims Relationships	#05	1
Design Changes	#06	1
Design Feature Checklists; Design Methods; Design Processes; Design Standards; Design Templates; Interface Objects	#08	1
Interaction Model; Task Model	#03	1
Scenarios; Test Scenarios	#02	1
User Knowledge; User Needs	#07	1
User Requirements	#01	1
User Tasks	#09	1

We identified four different HCI aspects addressed by the identified KM approaches. The main aspect is *Usability*, which is treated in all the identified approaches. Two approaches (#03 and #08) also address *Ergonomics*. #03 and #04 focus on particular types of design or interfaces. The former focuses on *Task-based Design* while the latter on *Speech Driven Interfaces*. Figure 5 shows the HCI aspects addressed in the identified KM approaches. The sum exceeds 12 because some approaches address more than one aspect.

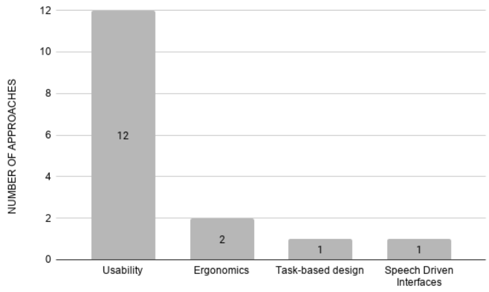

Figure 5. HCI aspects addressed in KM approaches.

When knowledge is captured and used (RQ5): Table 6 shows when HCI design knowledge has been captured and when it has been used along the HCI design process. Three approaches capture and use knowledge throughout the whole process. Eight approaches (66.7%) use knowledge when producing design solutions. A smaller number (six, 50%) capture knowledge in this activity. The behavior is the opposite in design evaluation: more approaches are capturing (five, 41.7%) than using (three, 25%) knowledge in this activity. Only one (8.3%) approach captures knowledge during requirements specification.

Table 6. Capture and use of knowledge along the HCI design process.

Activity (ISO, 2019)	Knowledge Capture	Knowledge Use
Specify requirements	1 (#01)	0
Produce design solutions	6 (#02, #03, #04, #07, #10, #11)	8 (#01, #02, #03, #04, #07, #09, #11, #12)
Design Evaluation	5 (#02, #04, #09, #10, #12)	3 (#02, #09, #10)
Whole cycle	3 (#05, #06, #08)	3 (#05, #06, #08)

Technologies used in KM approaches (RQ6): Table 7 shows the technologies (systems, methods, tools, theories, etc.) used in the analyzed KM approaches. The most common technologies were *knowledge-based systems* and *knowledge repositories*, which are used in three approaches. For example, #04 proposes a knowledge-based system to help developers of speech-driven interfaces learn with previous design solutions. #08, in turn, proposes the implementation of a knowledge repository using Windows Help Files.

Knowledge management systems and *knowledge-based analysis* were used in two approaches. A knowledge management system is proposed in #09 to describe problems detected in user test sessions and the respective solutions and in #11 to describe design problems and requirements and then search for usability examples with similar characteristics and hyperlinks to more general related guidelines. Knowledge-based analysis, in turn, was used in #03 and #07 combined with other technologies, such as *ontology* and *model transformation* (#3) and *conceptual framework* (#7).

Other technologies such as *brainstorming, contextual inquiry, heuristic evaluation* and *mental models* were used in only one KM approach.

Table 7. Technologies used in KM approaches in HCI design context.

Technology	Approaches	Total
Knowledge-based System	#02, #04, #10	3
Knowledge Repository	#05, #06, #08	3
Knowledge Management System	#09, #11	2
Knowledge-based Analysis	#03, #07	2
Ontology; Model Transformation	#03	1
Conceptual Framework	#07	1
Contextual Inquiry; Brainstorming-based Technique	#12	1
Mental Model; Internalization Awareness; Observation; Behavioral Interviews; Absorptive Capacity; Heuristic Evaluation	#01	1

Benefits and challenges of using KM in HCI design (RQ7): Table 8 summarizes the benefits and difficulties reported in the publications. Two approaches (#04 and #10) did not report any benefit or challenge in using KM in HCI design. Considering the 10 other approaches, it can be noticed that, in general, more benefits than difficulties were reported.

The most reported benefit was to enable replicability of domain or context knowledge. For example, #07 reached wide scope applicability because of the common conceptualization proposed as a conceptual framework. On the other hand, the most reported difficulty was that knowledge is often too specific for a given context. For example, in #11 it is stated that the approach is best suited for contexts in which common customer needs are being addressed in similar application domains.

Table 8. Benefits and difficulties of using KM in HCI design context.

Benefits	**Approaches**	**Total**
Enable replicability of domain/context knowledge	#03, #06, #07, #09, #12	5
Improve product quality	#02, #05, #06, #12	4
Improve communication	#01, #03, #11	3
Increase team engagement/empowerment	#02, #06	2
Increase organizational integration	#03, #08	2
Reduce design effort	#03, #12	2
Improve design conceptualization	#03, #07	2
Promote standardization	#02	1
Increase productivity	#11	1
Promote organizational competitive advantage	#02	1
Decrease implementation and maintenance effort	#08	1
Decrease implementation and maintenance costs	#08	1
Difficulties	**Approaches**	**Total**
Knowledge is often context-specific	#02, #06, #09, #11	4
Issues related to features of the KM technologies	#05, #06, #09	3
Low team engagement/empowerment	#01, #05, #08	3
User involvement	#07, #12	2
Integration of the KM approach into the organization	#06, #11	2
KM implementation and maintenance effort	#08, #09	2
Lack of consensus about HCI design conceptualization	#01, #02	2

3.3 Discussion

Taking the period of publications into account (RQ1), we can notice a long-term effort regarding the use of KM in HCI design, since this topic has been targeted by researchers for more than 20 years. However, the low average of publications per year (0.6 since 1995) shows that the topic has not been widely addressed. We can also notice that most of the publications are from the 2000s decade. The low percentage of journal publications, which generally require more mature works, can be seen as a reinforcement that the research on this topic is not mature enough yet. Besides, results about the research type (RQ2) show that only 40% of the works included some kind of evaluation, being only 13% evaluation of solutions in practice. This can be a sign of difficulty in applying the proposed approaches in industry, which reinforces that research on this topic is not mature enough yet and there seems to be a gap between theory and practice.

Concerning RQ3, we can notice that using KM in HCI design has been motivated mainly by delivering better products to users or optimizing the HCI design process in terms of effort, time and cost. Improving the performance of the HCI design team was also mentioned, which is consistent with the other motivations related to the HCI design process since increasing performance can contribute to decreasing effort, time and cost. By analyzing the results of approaches that applied some validation or evaluation, we noticed that only two (#03 and #12) provided results related to the initial motivation for using KM in HCI design (reduce design effort and improve product quality, respectively). The other publications were more focused on validating or evaluating features or functionalities of the proposed solutions. A common concern in several publications was the need for HCI design expert consultants, which can increase HCI design cost and effort. Capturing and reusing knowledge contribute to retaining organizational knowledge and reducing dependence on external consultants. Another concern refers to communication problems. A. Smith & Dunckley (2002) highlight that barriers to effective communication between designers, HCI specialists and users, due to their differing perspectives, affect product quality. KM solutions are helpful in this context.

Usability has been the focus of the KM initiatives in the HCI context (RQ4). In fact, this is not a surprise, because usability has been one of the most explored HCI aspects in the last years. Moreover, this property is quite comprehensive and includes other important aspects of HCI design, such as learnability, memorability, efficiency, safety and satisfaction (ISO, 2019). However, there are other important properties not addressed in the analyzed papers, such as user experience, communicability and accessibility. The knowledge items managed by the KM approaches are quite diverse. Design solutions, guidelines, test results and design patterns are some knowledge items found in different publications. Despite the variety of knowledge items, we noticed that most of the approaches (66.7%) manage up to two different knowledge items. By analyzing the coverage of the approach in terms of single or multiple projects, we found out that four approaches (#01, #03, #07 and #12) manage knowledge involved in a single project, while the other eight approaches are more extensive, accumulating knowledge from multiple projects. In order to elevate knowledge reuse to the organizational level, a KM approach must comprehend multiple projects in that organization.

Concerning knowledge use and capture (RQ5), at first, we expected that knowledge was captured and used in the same activity of the HCI design process. Therefore, results showed us that the same knowledge could be produced and consumed in different parts of the HCI design process. For example, there are more approaches capturing knowledge in the design evaluation activity than using it. This reinforces the iterative characteristic of HCI design, where knowledge obtained in evaluation activity in one cycle can be used to improve the design in the next cycle.

Different technologies have been used to implement KM in the HCI design context (RQ6). The most common are system-based approaches that use software to support the KM process and store knowledge. We expected this result because KM systems, knowledge-based systems and knowledge repositories are widely adopted technologies in the KM area. On the other hand, only two approaches use specific HCI techniques, namely contextual inquiry and heuristic evaluation. This may indicate that KM traditional approaches are suitable for addressing KM problems in HCI design (what was indeed expected) and that HCI techniques can be used to address specificities of the HCI design domain. Earlier steps of the development of KM solutions, such as knowledge analysis and modeling, are also addressed in some publications. Moreover, there is also concern with later steps, like the integration of the KM system into the organization. Some approaches combine different technologies, which can be a sign that the use of different techniques is a good strategy to address a more complete KM approach in HCI design.

As for the benefits and challenges of using KM in the HCI design context (RQ7), when categorizing the findings, we noticed that several of them are benefits and challenges of using KM in general. However, by analyzing the context of each KM approach, we can better understand how the findings relate to HCI design. For example, regarding the benefit *improve communication*, the works highlight the use of KM to support communication among the different actors involved in the HCI design process. In #10, communication between HCI specialists, designers and users is mediated by prototypes aiming at an agreement about the system design. In #01, KM facilitates the elicitation of the user's knowledge for the designer to apply it to the design. In #03, KM reduces errors of interpretation and contextualization among the people involved in the system design.

Some of the identified challenges and benefits are opposite each other. For example, there is the challenge of *low team engagement* on one hand and the benefit of *increasing team engagement* on the other hand. We kept both because they were cited in different publications, thus under different perspectives. Moreover, we can see the challenge as a difficulty that, when overcome by the use of KM, can be turned into a benefit.

By analyzing the most cited benefits and challenges, we noticed that the generality level of the knowledge is an important question in a KM approach. The most cited benefit points to knowledge replicability in a specific context/domain. The most cited challenge points to the fact that it is difficult to generalize knowledge. Looking at data from RQ5, we noticed that approaches handling knowledge from multiple projects reported the knowledge generalization challenge, while approaches handling knowledge in a single project reported easy replication of knowledge. Thus, the generality level of knowledge should be determined by the context where the KM approach will be applied. When dealing with a high diversity of knowledge and contexts, it becomes harder to produce general knowledge to be widely used to solve specific problems and be adopted in different contexts. One way of achieving improvements in replicability is using knowledge-based analysis methods, as reported by approaches #03 and #07.

Based on the panorama provided by the mapping study results, in summary, we can say that KM has not been much explored in the HCI context; it has been used mainly to improve software quality and HCI design process efficiency; it has focused on usability; and the KM approaches have been based on systems and repositories. As for benefits, KM has enabled knowledge replicability, improved product quality and communication. The main difficulties have been to generalize knowledge, address issues related to features of the system and low engagement of the team.

3.4 Threats to Validity

As with any study, our mapping study has some limitations that must be considered together with the results. Following the classification presented by (Petersen et al., 2015), next we discuss the main threats to the mapping study results.

Descriptive Validity is the extent to which observations are described accurately and objectively. To reduce descriptive validity threats, a data collection form was designed to support data extraction and recording. The form objectified the data collection procedure and could always be revisited. However, data extraction and recording still involved some subjectivity and was dependent on the researcher's decisions. An important limitation in this sense is related to the classifications we made. We defined classification schemas for categorizing data in some research questions. Some categories were based on classifications previously proposed in the literature (e.g., type of research (Wieringa et al., 2005)). Others were established during data extraction, based on data provided by the analyzed publications (e.g., RQ4). With an aim towards minimizing the threat, data extraction, classification schemas and data categorization were done by the first and second authors and reviewed by the other two authors. Discordances were discussed and resolved. However, determining the categories and how data fit them involves a lot of judgment. Thus, different results could be obtained by other researchers.

Theoretical Validity is determined by the researcher's ability to capture what is intended to be captured. In this context, one threat refers to the sources. We used four digital libraries selected based on other secondary studies in Software Engineering. Although this set of digital libraries represents a comprehensive source of publications, the exclusion of other sources may have left some valuable publications out of our analysis. ACM was not included in the sources because Scopus covers most of its publications. However, there are HCI publications indexed by ACM and not indexed by Scopus, which may have jeopardized the mapping results. To minimize this risk, we performed snowballing. Another threat refers to the fact that the study focused on scientific literature and did not include other alternatives, such as grey literature, that could enhance the systematic mapping coverage. Hence, extending this study with a multivocal literature review through grey literature analysis could complement and enrich the obtained results.

There are also limitations related to the adopted search string. Even though we have used several terms, there are still synonyms that we did not use. For example, since KM is a subjective area, many publications may have addressed KM aspects using other words such as "collaboration" and "organizational learning", which were not covered by our search string. Moreover, we did not include HCI and KM acronyms alone (HCI was combined with "design"), which could be an additional threat. However, the string includes the full terms referring to HCI and KM and we believe that it is probable that publications including the acronyms also include the full terms in either their title, abstract or keywords. Hence, our search string might have covered them anyway.

The researcher bias over publications selection, data extraction and classification is also a threat to theoretical validity. To minimize this threat, as we previously said, the steps were initially performed by the first and second authors and, to reduce subjectivity, the other two authors performed these same steps. Discordances and possible biases were discussed until reaching a consensus.

Finally, *Interpretive Validity* is achieved when the drawn conclusions are reasonable given the data obtained. The main threat in this context is the researcher bias over data interpretation. To minimize this threat, like in the other steps, interpretation was performed by the first and second authors and reviewed by the other two. Discussions were carried out until a consensus was reached. However, subjectivity still relies on qualitative interpretation and analysis.

Even though we have treated many of the identified threats, the adopted treatments involved human judgment, therefore the threats cannot be eliminated and must be considered together with the study results.

4 Survey: KM in HCI Design practice

The systematic mapping provided information about KM approaches to support HCI design according to the literature records. After conducting the mapping study, we performed a survey with 39 Brazilian HCI design practitioners to investigate KM in HCI design practice.

A survey is an experimental investigation method usually done after the use of some technique or tool has already taken place (Pfleeger, 1994). Surveys are retrospective, i.e., they allow to capture an "instant snapshot" of a situation. Questionaries and interviews are the main instruments used to apply a survey, collecting data from a representative sample of the population. The resulting data are analyzed, aiming to draw conclusions that can be generalized for the whole population represented by that sample (Mafra & Travassos, 2006). In this work, we intended to reach many participants and analyze data objectively and quantitatively. Thus, in our survey, we decided to use a questionnaire containing objective questions.

We followed the process defined in (Wohlin et al., 2012) which comprises five activities. *Scoping* is the first step, where we scope the study problem and establish its goals. *Planning* comes next, where the study design is determined, the instrumentation is considered and the threats to the study conduction are evaluated. *Operation* follows from the design, consisting in collecting data which then are analyzed and evaluated in *Analysis and Interpretation*. Finally, in *Presentation and Package,* the results are communicated.

Next, in Section 4.1 we present the survey planning and execution. Section 4.2 concerns the survey results. Section 4.3 discusses the results and Section 4.4 presents threats to validity.

4.1 Survey Planning and Execution

The study ***goal*** was to investigate aspects related to KM in HCI design practice. Aligned to this goal, we defined the ***research questions*** presented on Table 9, which were based on the systematic mapping research questions and results.

Table 9. Survey: research questions and their rationale.

ID	Research Question	Rationale
RQ1	*Which stakeholders have been involved in HCI design practice?*	Identify which stakeholders have been involved in HCI design practice, which helps identify different perspectives and information needs in HCI design.
RQ2	*Which knowledge has been involved in HCI design practice?*	Investigate which knowledge has been involved in HCI design practice, particularly knowledge items (e.g., design solutions, guidelines and lessons learned) and design artifacts (e.g., wireframes, mockups and prototypes) used as sources of knowledge or produced to record useful knowledge.
RQ3	*Which HCI design activities have demanded better KM support?*	Investigate which HCI design activities have needed better support of KM (e.g., because there have not been enough knowledge resources to support their execution).
RQ4	*How has KM been applied in HCI design practice?*	Investigate how KM principles have been applied and identify technologies (e.g., tools, methods, etc.) that have been used to support knowledge access and storage in HCI design practice.
RQ5	*Which benefits and difficulties have been noticed when using KM in HCI design practice?*	Identify benefits and difficulties that have been experienced by practitioners when applying KM in HCI design practice and verify if practitioners have experienced more benefits or difficulties.
RQ6	*Which goals the use of KM in HCI design practice has contributed to achieving?*	Identify which goals the use of KM in HCI design has contributed to, aiming to figure out predominant reasons for using KM in HCI design practice.

The ***participants*** were 39 Brazilian professionals with experience in HCI design of interactive software systems. The participants profile was identified through questions regarding their current job positions, education level, knowledge of HCI design and practical experience in HCI design activities. Most participants (79.5%) declared to play roles devoted to HCI design activities (nine UX/UI designers; six UX designers; four product designers, two designers, two UX research designers, one art director, one IT analyst & UX designer, one interaction designer, one lead designer, one lead UI designer, one staff product designer and one UI designer). Others 20.5%) play roles that perform some activities related to HCI design (one programmer, one requirement analyst, one chief growth officer, one product owner, one IT analyst, one IT manager, one marketing manager and one project leader). Although these roles cannot be considered HCI design experts, we did not exclude these participants because they declared to have practical experience and knowledge in HCI design (probably acquired in their previous job and academic experiences). Moreover, even playing roles not dedicated to HCI design, they are often involved in HCI design in some way. Eight participants (20.5%) had masters' degrees, 26 (66.7%) had bachelor's degrees, and five (12.8%) had not yet finished bachelor's degree courses.

All participants declared theoretical knowledge of HCI design. Four of them (10.3%) declared low knowledge (i.e., knowledge acquired by himself/herself through books, videos or other materials). 16 participants (41%) declared medium knowledge, acquired mainly during courses or undergraduate research. Finally, 19 participants (48.7%) declared high knowledge (i.e., they are experts or have a certification, Masters or Ph.D. degree related to HCI design). Some areas of the courses cited by participants that declared medium or high knowledge are Design (46.2%), Computer Science (38.5%), Arts (28.2%), Social Communication (15.4%) and User Experience (7.7%). The participants were allowed to choose more than one option, hence the sum of the values is over 100%. Other areas such as Anthropology, Neuroscience, Information Science, Psychology were also mentioned by one participant each. 26 participants (66.7%) declared more than three years of experience in HCI design practice, 11 participants (28.2%) declared between one and three years and two (5.1%) declared less than one year.

The ***instrument*** used in the study consisted of a questionnaire composed of 10 objective questions. Most answer options for each question were defined based on the mapping study results. For example, when asked about the goals achieved with the help of KM in HCI design (RQ6), the options provided to the participants refer to the goals we found in the mapping study. However, some options were rewritten in a way that could enhance participants understanding (e.g., we changed "test results" to "previous design evaluation results" on RQ2) and others were added based on the authors' knowledge and experience (e.g., we included forums, blogs and social networks in RQ4). Furthermore, most questions also allowed the participant to provide additional information in text boxes to complement his/her answers. For example, besides selecting goals from the list provided in the question related to RQ6, the participants were also allowed to include new goals in their answers. The questionnaire is available at http://bit.ly/Questionnaire-KM-in-HCI-design.

The ***procedure*** adopted in the study consisted in sending the invitation to participate in the study, receiving the answers, verifying them, consolidating and analyzing data. The invitation was posted in discussion groups on Facebook, LinkedIn and Interaction Design Foundation's website[2]. The authors also sent the invitation by email to potential participants. Since the platforms did not inform how many people visualized the posts, we could not infer the percentage of invites that led to answers

Before sending the invitation, we performed a pilot with three participants. Considering the participants' feedback, we improved the questionnaire aiming to ensure that the questions were clear and understandable. The invitation to participate in the study was posted on social media and sent by email on December 16th, 2020. We received answers until January 11th, 2021. We received 40 answers to the questionnaire, however, after analyzing the participants profile related to HCI design knowledge and experience, we excluded one participant who reported to have low knowledge and experience with HCI design and did not answer some of the questionnaire questions. After that, each provided answer was verified and data was consolidated and analyzed against the research questions.

4.2 Results

In this section, we present the data synthesis for each research question.

Stakeholders involved in HCI design practice (RQ1): aiming to identify stakeholders involved in HCI design practice, we asked the participants to identify the stakeholders they directly interact with within their HCI design practice. As it can be seen in Table 10, *developer* has been the most common stakeholder involved in HCI design practice, being mentioned by 37 participants (94.9%). Following that, *project manager*, *designer*, *user* and *client* were mentioned, respectively, by 34 (87.2%), 33 (84.6%), 27 (69.2%) and 26 (66.7%) participants. *Product owner* was cited by three participants (7.7%) and others (*business analyst*, *customer experience analyst*, *data analyst*, *HR people*, *product manager and scrum master*) were mentioned only once.

Table 10. Stakeholders involved in HCI design practice.

Stakeholder	Number of participants	%
Developer	37	94.9%
Designer	34	87.2%
Project Manager	33	84.6%
Client	27	69.2%
User	26	66.7%
Product Owner	3	7.7%
Business Analyst	1	2.6%
Customer Experience Analyst	1	2.6%
Data Analyst	1	2.6%
HR People	1	2.6%
Product Manager	1	2.6%
Scrum Master	1	2.6%

Knowledge involved in HCI design practice (RQ2): first, the participants were asked about the *knowledge items* they use or produce during HCI design activities. We consider as knowledge items pieces of knowledge that can be useful in HCI design, such as lessons learned, standards, guidelines and patterns. Figure 6 presents the results of this question. Some items have been used and produced by a high number of participants: *organizational design standards* (used by 34 participants, 87.2%, and produced by 26 participants, 66.7%), *lessons learned* (used by 34 participants, 87.2%, and produced by 24 participants, 61.5%), *guidelines* (used by 34 participants, 87.2%, and produced by 22 participants, 56.4%) and *libraries of design components or elements* (used by 32 participants, 82.1%, and produced by 23 participants, 59%). Other knowledge items have also been used by many participants, but produced by a smaller number, such as *examples* (used by 34 participants, 87.2%, and produced by 14 participants, 35.9%), *design solutions from the organization* (used by 35 participants, 89.7%, and produced by 18 participants, 46.2%) and *design solutions from outside the organization* (used by 35 participants, 89.7%, and produced by 11 participants, 28.2%). In general, HCI design practitioners have used and produced different knowledge items (11.1 and 6.6 in average, respectively).

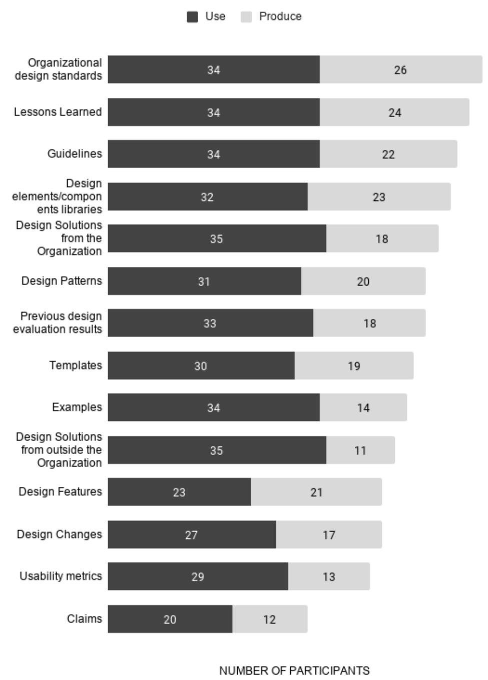

Figure 6. Knowledge items used and produced in HCI design practice.

[2] https://www.interaction-design.org

The participants were also asked about design artifacts they use or produce during HCI design activities. We use the term design artifact to refer to documents, models, prototypes and others that record information about the design solution. Figure 7 shows the results. *User requirements*, *scenarios* and *interaction models* were the most cited artifacts used during HCI design. On the other hand, *wireframes*, *functional prototypes* and *mockup*s were the most cited artifacts produced during HCI design.

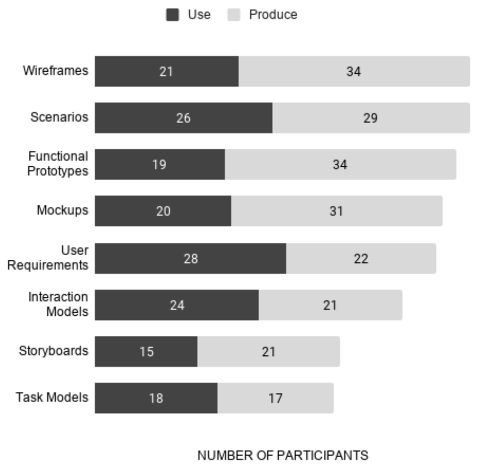

Figure 7. Design artifacts used and produced in HCI design practice.

We also asked the participants to inform whether the artifacts used and produced by them sufficiently provide all information needed to describe the HCI design solution (i.e. if the knowledge recorded in the artifacts is enough for the implementation and evaluation of the solution). 26 participants (66.7%) answered "yes" and 13 (33.3%) answered "no". Eight out of the 13 participants pointed out they missed information about personas, user research data and usability tests. These 13 participants were also asked about the ways the missing information is communicated. The results are presented in Table 11. *Annotations* and *talks* have been the most used ways (eight participants, 61.5%) to complement the information provided in design artifacts. Seven participants (53.9%) reported the use of *meetings*, while one used *documentation* or *specific tools*. The participants indicated that annotations and talks had been used informally, while meetings, documentation or tools have been used systematically, following organizational practices.

Table 11. Ways to obtain missing information.

Method	Number of participants	%
Annotations	8	61.5%
Talks	8	61.5%
Meetings	7	53.9%
Documentation or Tool	1	7.7%
None	1	7.7%

HCI design activities demanding better KM support (RQ3): taking the HCI design activities established by ISO 9241-210 (ISO, 2019) as a reference, the participants were asked to judge whether the knowledge resources (e.g., knowledge items, artifacts) used by them have provided sufficient knowledge to support each activity. Figure 8 presents the results. In general, most participants consider that they have access to enough knowledge to perform HCI design activities. *Produce design solutions* has the highest number of participants (31 participants, 79.5%) reporting to have had sufficient knowledge to perform it. On the other hand, *evaluate design solutions* has the highest number of participants (10 participants, 25.6%) declaring that the available knowledge has not been enough. Sixteen participants (41%) declared to have not had sufficient knowledge to support at least one HCI design activity. They pointed out that, in order to address the lack of knowledge, they have performed user research, searched for successful use cases, talked to stakeholders, and looked at the literature.

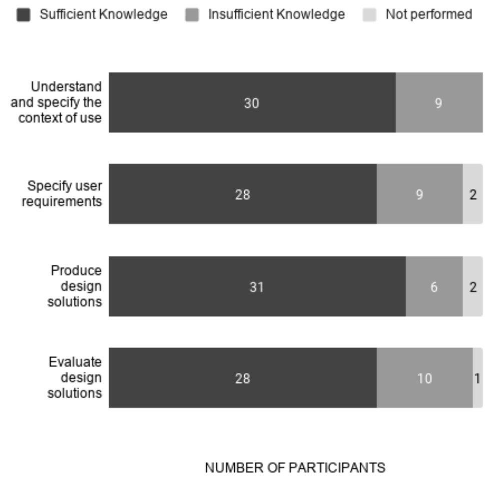

Figure 8. Available knowledge to support HCI design activities.

How KM has been applied in HCI design practice (RQ4): Figure 9 shows the approaches that have been used to support knowledge access or storage in HCI design practice. *Brainstorming* and *blogs* have been the most used ways to access knowledge (28 participants, 71.8%), followed by *mental models* and *electronic documents and spreadsheets* (26 participants, 66.7%). Except for *blogs*, those have also been the most used ways to store knowledge: *brainstorming* has been used by 27 participants (69.2%); *mental models and electronic documents and spreadsheets* by 24 (61.6%). *Ontologies* have been the less used way by the participants. Only 7 participants (18%) have used ontologies to access knowledge and 5 participants (12.8%) have used it to store knowledge. Concerning knowledge storage, *social networks* (6 participants, 15.4%) and *forums* (8 participants, 20.5%) have also not been much used. In general, the approaches shown in Figure 9 have been more used to support knowledge access than to support knowledge storage.

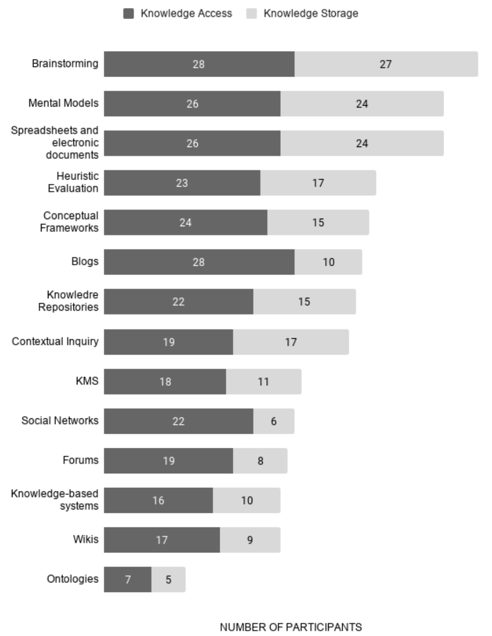

Figure 9. Approaches to support knowledge access and storage in HCI design.

Benefits and difficulties of using KM in HCI design practice (RQ5): 34 participants (87.2%) reported performing KM practices to support HCI design activities. 16 of them (41.0%) have followed institutionalized organizational practices, while 18 (46.2%) have performed on their own initiative. These 34 participants were asked about the benefits and difficulties they have perceived in using KM to support HCI design. The results are summarized in Table 12 and Table 13.

Table 12. Benefits of using KM in HCI design practice.

Benefit	Number of participants	%
Enable replicability of domain or context knowledge	27	79.4%
Promote standardization	26	76.5%
Improve communication	25	73.5%
Increase productivity	24	70.6%
Reduce design effort	24	70.6%
Improve product quality	23	67.6%
Improve design conceptualization	20	58.8%
Improve team learning	18	52.9%
Reduce dependency on specialists	18	52.9%
Increase team engagement or empowerment	17	50.0%
Increase organizational integration	16	47.1%
Reduce design cost	16	47.1%
Promote organizational competitive advantage	11	32.4%

Table 13. Difficulties of using KM in HCI design practice.

Difficulty	Number of participants	%
Low team engagement or empowerment	16	47.1%
KM implementation and maintenance effort	15	44.1%
Integration of the KM approach into the organization	15	44.1%
Lack of consensus about HCI design conceptualization	14	41.1%
Find relevant knowledge to a given context	13	38.2%
Low user involvement	9	26.5%
Issues related to features of the KM technologies	8	23.5%
Unclear business model	1	2.9%

Goals to which the use of KM in HCI design practice has contributed (RQ6): Aiming to identify the predominant reasons for using KM in HCI design practice, the participants were asked how much KM support to HCI design contributes to achieving certain goals. The goals presented to them were identified in the systematic mapping as motivations to perform KM in the HCI design context. Figure 10 shows the results.

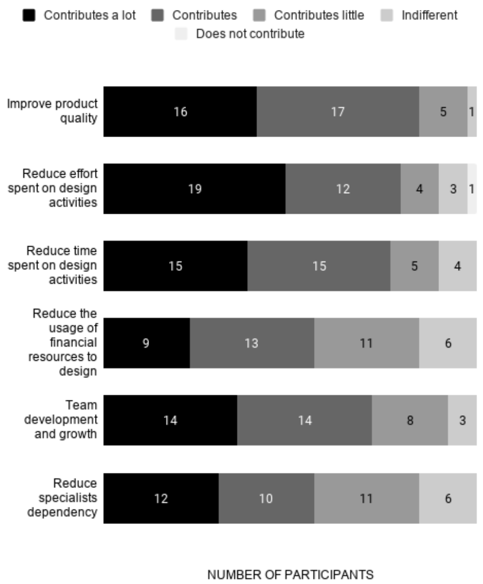

Figure 10. KM contribution to goals achievement when supporting HCI design.

According to the participants, the goals to which using KM in HCI design contributes the most are *improve product quality* (84.6% of the participants stated that KM contributes a lot or contributes to it) and *reduce effort spent on design activities* (79.5% of the participants stated that KM contributes a lot or contributes to it). On the other hand, the participants have seen less contribution of KM in HCI design to *reduce the usage of financial resources in design* and to *reduce the dependency on specialists* (43.6% of the participants stated that KM contributes little or is indifferent to both of them).

4.3 Discussion

In this section, we present some discussions about the results shown in the previous section.

By analyzing the participants' profile, we noticed that several stakeholders (20.5%) who had knowledge of and experience with HCI design did not play a role devoted to HCI design by the time of the survey execution. We believe that this reinforces the multidisciplinary nature of HCI design and corroborates with a recent finding from (Neto et al., 2020) that some professionals may choose to pursue a double background involving design and development areas.

Concerning *stakeholders* (RQ1), it can be noticed that a variety of them are involved in HCI design. Considering that the interactions usually occur in the context of projects, the results indicate that teams of HCI design projects have included designers, developers, project managers, and frequently also have involved clients and users. These stakeholders have different roles in HCI design, and thus may have different HCI design knowledge needs. For example, a developer may need to implement the design solution presented in a design artifact. For that, this artifact should present technical decisions that affect the implementation. A project manager, in turn, may need to have a broader view of several design artifacts to verify if the implemented solution satisfies the requirements agreed with the client. Hence, KM approaches must consider the needs of different stakeholders to properly support HCI design. Moreover, it may be necessary to integrate knowledge from different sources to provide a solution that integrates the needs of different stakeholders. This can be done, for example, with a knowledge management system with multiple views for each different role.

Regarding *knowledge involved in HCI design* (RQ2), by analyzing the knowledge items used and produced in HCI design practice, we can notice which knowledge has been more useful to practitioners. Most participants use knowledge items that provide design knowledge obtained from previous design experiences, such as design solutions from the organization, design solutions from outside the organization and examples. This can be a sign that new designs have been created based on previous experiences adapted to the new context. However, these knowledge items have not been much produced by the participants. This may be due to the effort required to record knowledge for future reuse. Hence, it would be important to facilitate capture, recording and retrieval of knowledge embedded in design solutions. On the other hand, two of the knowledge items produced by the highest number of participants (organizational design standards and guidelines) record general principles and practices to be followed when designing HCI solutions. This may indicate that the participants have found it easier to produce knowledge independent of specific solutions. Considering the relation between the number of knowledge items used and produced by the participants, the higher number of used items shows that, in general, the participants have acted more as knowledge consumers than knowledge producers. This may happen because either the participants do not have enough time to produce knowledge items, or the knowledge production is done by someone else. Consulting knowledge directly helps designers in the activities they were doing at that moment. In contrast, knowledge production does not seem to be immediately useful to them, although it is important at an organizational level. We believe that approaches that promote knowledge recording and storage requiring less effort could motivate designers to act as knowledge producers.

As for design artifacts, we noticed that the ones produced by more participants (wireframes, functional prototypes and mockups) represent abstractions of the design solution. Hence, the creation of such artifacts is part of the design solution development. On the other hand, the artifacts used by more participants (user requirements, sceneries and interaction models) provide useful information to develop the design solution (i.e., they represent inputs to design development). One-third of the participants (33.3%) considered the artifacts used or produced by them limited to meet information needs about the design solution and reported the use of complementary ways to transfer missing knowledge. When analyzing the three most cited ways, we observed that two of them (talks and meetings) are based on the conversation between team members. This can be a sign that it may be difficult to articulate certain pieces of knowledge in artifacts. This is reinforced by the high usage of annotations, which are less formal and structured, and the low usage of documentation and tools. Besides, considering that the use of more than one method of knowledge transfer is a common practice used by the participants, it is likely that they prefer to have this communication redundancy as a way of reinforcing the understanding of all stakeholders about the design. Therefore, we believe that the missing knowledge in HCI design artifacts can be transferred, for example, by performing regular meetings and by providing means to easily attach additional annotations on design artifacts.

Concerning *HCI design activities* (RQ3), 'produce design solutions' was the one that more participants (79.5%) indicated to have access to enough knowledge to perform it. This can be a sign that participants have used knowledge mainly to support the creation of design solutions. On the other hand, a high number of participants indicated that they had not had sufficient knowledge to perform the activities 'understand and specify the context of use' (23%), 'specify user requirements' (23%) and 'evaluate the design solution' (25.6%). Therefore, it is necessary to identify useful knowledge to support these activities (e.g., missing knowledge related to personas and user research data, as reported in RQ2) and provide means to represent and access it in an easy way.

As for the *approaches to support knowledge access and storage in HCI design* (RQ4), it can be observed that the most used approaches, such as brainstorming, mental models and electronic spreadsheets and documents, usually support both knowledge access and storage. This may suggest that it is easier and simpler to implement and use them. Brainstorming, for example, has the advantage of the participants sharing and obtaining knowledge at the same time. On the other hand, web-based resources, such as blogs, forums and social networks are more used to support knowledge access than knowledge storage. Probably, these resources have been used more as sources of inspiration to bring new ideas from outside the organization. In addition, the reason why these resources have been less used by practitioners to record knowledge may be a concern in not exposing organizational design knowledge on the internet. HCI design knowledge must be captured, recorded and propagated in order to be raised from the individual level to the organizational level. Hence, we believe that KM initiatives in HCI design should consider approaches such as the ones most used by practitioners to support both knowledge access and storage.

Concerning the *benefits and difficulties of using KM in HCI design* (RQ5), most participants declared to have experienced KM practices in HCI design. 41.0% followed institutionalized practices and 46.2% have performed on their own initiative. This indicates that HCI design professionals have been concerned with the need for practices that help manage knowledge and are seeking solutions by themselves when they are not provided by the organization. According to the participants, in general, using KM to support HCI design brings more benefits than difficulties. The most cited benefits were related to standardization, reuse, communication and productivity, while the most cited difficulties were related to the lack of consensus in HCI design conceptualization and to the effort of implementing, engaging the team and integrating the KM approach in the organization. Based on that, to effectively implement a KM approach, it would be interesting to convince people and the organization that the additional effort in the beginning is worth the benefits they obtain afterward.

Finally, by analyzing *goals to which the use of KM in HCI design has contributed* (RQ6), 'reduce the usage of financial resources' and 'reduce the dependency on specialists' have been considered less impacted by the use of KM in HCI design. This may be because reducing costs can be a side effect of reducing time spent on design or producing better designs, with fewer errors. Moreover, even if expert's knowledge is transferred and managed at the organizational level, user-centered design deals with people, hence there are subjective aspects that still need to be addressed by specialists. Another point to be considered is that the participants of the survey were, in the majority, HCI design experts, which could have biased their answers about the impact of using KM to reduce the dependency on HCI design experts. It is also important to note that 'reduce the effort spent on design activities' was the goal which participants believe to be most impacted by the use of KM in HCI design. By having in hand proper knowledge resources, the designer can learn from previous experiences, reuse solutions and explore more design alternatives, which can lead to designing better and more efficiently.

4.4 Threats to Validity

As discussed in the context of the systematic mapping, when carrying out a study, it is necessary to consider threats to the validity of its results. In this section, we discuss some threats involved in the survey using the classification presented in (Wohlin et al., 2012).

Internal Validity: It is defined as the ability of a new study to repeat the behavior of the current study with the same participants and objects. The main threat to internal validity is communication and sharing of information among participants. To address this threat, the questionnaire was made available online, so that the participants could answer it at the time they considered most appropriate. This can minimize the threat of communication since participants were not physically close during the study and did not necessarily perform the study at the same time.

External Validity: It is related to the ability to repeat the same behavior with different groups of participants. In this sense, the limited number of participants and the fact that all of them are Brazilian professionals are also threats to the results. Moreover, some of the participants were invited based on the authors' relationship network, which may also have influenced the answers.

Construction Validity: It refers to the relationship between the study instruments, participants and the theory being tested. In this context, the main threat is the possibility that the participants have misunderstood some questions. To address this threat, we performed a pilot that allowed us to improve and clarify questions. Moreover, we provided definitions for the terms used and examples of information that should be included in the survey, so that the participants could better understand how to answer it.

Conclusion Validity: It measures the relationship between the treatments and the results and affects the ability of the study to generate conclusions. A threat to conclusion validity refers to the subjectivity in data analysis, which may reflect the authors' point of view. In addition, the results reflect the participants' personal experience, interpretation and beliefs. Hence, the answers can embed subjectivity that could not be captured through the questionnaire. These and the other threats discussed above affect the representativeness of the survey results and, thus, the results must be understood as preliminary evidence and should not be generalized.

5 Consolidated View of Findings

In this section, we present some discussions involving the systematic mapping and survey results, aiming to provide a consolidated view of the findings from both studies.

The three most cited motivations for using KM found in the systematic mapping (RQ3) are the same as the three goals most impacted by the use of KM in HCI design practice, according to survey participants (RQ6). This shows that, in general, it is expected that the use of KM in HCI design can contribute to improving product quality and reducing effort and time spent on design activities.

Considering the most reported benefits and difficulties of using KM in HCI design, the survey results provided some of them that were not observed in the literature. For example, most survey participants reported 'standardization' and 'productivity' as benefits and 'KM implementation and maintenance effort' and 'lack of consensus about HCI design conceptualization' as difficulties. This difference is not a surprise, since the mapping results showed that most proposed approaches had not been applied in the industry. We believe that to achieve success in implementing knowledge management, it is important to consider HCI design professionals' perspectives, pursuing the benefits and implementing strategies to overcome the difficulties.

There are other differences between the mapping and survey results. For example, traditional KM technologies, such as knowledge management systems, knowledge repositories and knowledge-based systems, have been the most used approaches reported in the literature, but have not been much used by HCI design professionals. The reasons why they do not use those approaches may be quite diverse, including not being aware that they exist or considering them too complex. Since 46.2% of the participants perform KM practices on their own initiative, they have likely preferred simpler approaches that can be implemented by themselves. This reinforces the gap between industry and academy perceived from the analysis of the systematic mapping results. In order to decrease this gap, KM approaches to support HCI design should be closer to approaches that professionals are already familiar with, which can contribute to simpler and easier implementation and use.

Results from both studies show that design guidelines and design solutions have been reused in HCI design. Organizational design standards, lessons learned and design component libraries have also been useful for HCI design professionals. Therefore, KM approaches to support HCI design should be able to handle these knowledge items, supporting their capture, storage and retrieval. As indicated by results from both studies, these knowledge items have probably been most used to support the activity 'produce design solutions'. This was the activity in which most approaches found in the literature use knowledge and most participants considered having sufficient knowledge support. KM approaches should also provide support to other activities such as 'understand and specify context of use', 'specify user requirements' and 'evaluate design solutions', contributing to the HCI design process as a whole.

6 Conclusion

In this paper, we presented an investigation about the use of knowledge management in the HCI design context. To investigate the state of the art, we performed a systematic mapping. After that, we carried out a survey with 39 Brazilian professionals who work on HCI design. As the main result of the studies, we provided a panorama of research related to the topic and identified gaps and opportunities for improvements to organizations interested in applying KM initiatives in the HCI design context.

We noticed that, although HCI design is a favorable area to apply knowledge management, there have been only a few publications exploring this research topic. Due to the increasing importance of interactive systems and the diversity of interfaces that have been made available for people's use, we believe that there are many challenges and questions to be addressed in future research. For example: (i) The lack of a common conceptualization of HCI design (pointed out in #01 and #02 in the mapping study and also by 35.9% of the survey participants) leads to communication problems between the different actors involved in the HCI design process. We believe that the use of ontologies to establish this common conceptualization could help in this matter. However, since ontologies are not much familiar to practitioners (survey RQ4 results), ontology-based KM approaches in HCI design should abstract the ontology to final users (e.g., using the ontology to derive the conceptual model of a knowledge-based system). (ii) The gap between theory and practice (systematic mapping RQ2 results) shows that it is necessary to take KM solutions to practical HCI design environments. The survey results show that HCI design professionals are familiar with more robust KM approaches (such as knowledge management systems), but prefer to use simpler ways to deal with knowledge, such as brainstorming sessions and electronic spreadsheets and documents. Therefore, lightweight technologies and a divide and conquer strategy to reduce the complexity of the conception, implementation and evaluation of a KM approach might be useful, allowing to provide results for the organizations in smaller periods of time and increasing benefits as the approach evolves. (iii) Other aspects besides usability (e.g., user experience, communicability and accessibility) should be explored in KM initiatives to improve HCI design. (iv) The benefits and difficulties identified in the mapping (RQ7) and reported by the survey participants (RQ5) indicate issues that can be investigated in future research. For example, case studies can be carried out in organizations to evaluate the use of KM approaches in the HCI design context.

Concerning related works, we did not find any study investigating the use of KM in the HCI design context. A work that can be related to ours is (Stephanidis & Akoumianakis, 2001), consisting of a literature review about categories of computer-aided HCI design tools and a proposal of a new category to address the knowledge complexity involved in HCI design. However, the study focused on computational tools, not investigating how other kinds of KM approaches can help in the HCI design process.

As future work, concerning the systematic mapping, new studies can be conducted to better understand the state of the art of KM in HCI design and improve the use of KM in this context. For example, the results obtained in our mapping study could be compared with results from other studies investigating KM use in other domains (e.g., requirements engineering). Moreover, KM solutions proposed in other domains can inspire new proposals to support HCI design by using KM. As for the survey, it can be extended to include more participants from different countries and also to investigate other aspects. Considering the studies' results, which showed us a gap between the HCI design professionals and the approaches proposed in the literature, we have worked on the development of a tool to support KM in the context of HCI design of interactive systems (Castro et al., 2021). By making use of the information provided by this study, we aim to reduce the gap between academy and industry by proposing a tool able to meet the needs of HCI design professionals.

References

Bjørnson, F. O., & Dingsøyr, T. (2008). Knowledge management in software engineering: A systematic review of studied concepts, findings and research methods used. *Information and Software Technology*, *50*(11), 1055–1068.

Bouwmeester, N. (1999). A Knowledge Management Tool for Speech Interfaces (Poster Abstract). *Proceedings of the 22Nd Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*, 293–294. https://doi.org/10.1145/312624.312721

Carroll, J. M. (2014). Human Computer Interaction (HCI). In M. Soegaard & R. F. Dam (Eds.), *The Encyclopedia of Human-Computer Interaction* (2nd ed., pp. 21–61). The Interaction Design Foundation.

Castro, M. V. H. B., Barcellos, M. P., Falbo, R. de A., & Costa, S. D. (2021). Using Ontologies to aid Knowledge Sharing in HCI Design. *XX Brazilian Symposium on Human Factors in Computing Systems (IHC'21)*. https://doi.org/10.1145/3472301.3484327

Castro, M. V. H. B., Costa, S. D., Barcellos, M. P., & Falbo, R. de A. (2020). Knowledge management in human-computer interaction design: A mapping study. *23rd Iberoamerican Conference on Software Engineering, CIbSE 2020*.

Chammas, A., Quaresma, M., & Mont'Alvão, C. (2015). A Closer Look on the User Centred Design. *Procedia Manufacturing*, *3*, 5397–5404. https://doi.org/https://doi.org/10.1016/j.promfg.2015.07.656

Chewar, C. M., Bachetti, E., McCrickard, D. S., & Booker, J. E. (2004). Automating a Design Reuse Facility with Critical Parameters. In R. J. K. Jacob, Q. Limbourg, & J. Vanderdonckt (Eds.), *Computer-Aided Design of User Interfaces IV* (pp. 235–246). Springer Netherlands.

Chewar, C. M., & McCrickard, D. S. (2005). Links for a Human-Centered Science of Design: Integrated Design Knowledge Environments for a Software Development Process. *Proceedings of the 38th Annual Hawaii International Conference on System Sciences*, 256c-256c. https://doi.org/10.1109/HICSS.2005.390

De Souza, C. S. (2005). The Semiotic Engineering of Human-Computer (Acting with Technology). In B. A. Nardi, V. Kaptelinin, & K. A. Foot (Eds.), *Technology*. The MIT Press. https://doi.org/10.1017/CBO9781107415324.004

Gabriel, I. J. (2007). An Expert System for Usability Evaluations of Business-to-Consumer E-Commerce Sites. *Proceedings of the 6th Annual ISOnEworld Conference, Las Vegas, NV*.

Henninger, S., Haynes, K., & Reith, M. W. (1995). A Framework for Developing

Experience-based Usability Guidelines. *Proceedings of the 1st Conference on Designing Interactive Systems: Processes, Practices, Methods, & Techniques*, 43–53. https://doi.org/10.1145/225434.225440

Hughes, M. (2006). A Pattern Language Approach to Usability Knowledge Management. *J. Usability Studies*, *1*(2), 76–90.

ISO. (2019). ISO 9241-210:2019(en) - Ergonomics of human-system interaction - Part 210: Human-centred design for interactive systems. In *Int. Organization for Standardization*.

Kitchenham, B. A., & Charters, S. (2007). *Guidelines for performing Systematic Literature Reviews in Software Engineering* (Vol. 2).

Mafra, S. N., & Travassos, G. H. (2006). Estudos Primários e Secundários apoiando a busca por Evidência em Engenharia de Software. *Relatório Técnico, RT-ES*, *687*(06).

Mohamed, M. A., Chakraborty, J., & Dehlinger, J. (2017). Trading off Usability and Security in User Interface Design Through Mental Models. *Behav. Inf. Technol.*, *36*(5), 493–516. https://doi.org/10.1080/0144929X.2016.1262897

Neto, E. H., van Amstel, F. M. C., Binder, F. V., Reinehr, S. dos S., & Malucelli, A. (2020). Trajectory and traits of devigners: a qualitative study about transdisciplinarity in a software studio. *2020 IEEE 32nd Conference on Software Engineering Education and Training (CSEE\&T)*, 1–9.

O'Leary, D. E. (1998). Enterprise Knowledge Management. *Computer*, *31*(3), 54–61. https://doi.org/10.1109/2.660190

Petersen, K., Vakkalanka, S., & Kuzniarz, L. (2015). Guidelines for conducting systematic mapping studies in software engineering: An update. *Information and Software Technology*, *64*, 1–18. https://doi.org/https://doi.org/10.1016/j.infsof.2015.03.007

Pfleeger, S. L. (1994). Design and analysis in software engineering: the language of case studies and formal experiments. *ACM SIGSOFT Software Engineering Notes*, *19*(4), 16–20.

Rogers, Y., Sharp, H., & Preece, J. (2011). *Interaction Design: Beyond Human-Computer Interaction* (3rd ed.). John Wiley & Sons.

Rus, I., & Lindvall, M. (2002). Knowledge management in software engineering. *IEEE Software*, *19*(3), 26–38. https://doi.org/10.1109/MS.2002.1003450

Schneider, K. (2009). *Experience and Knowledge Management in Software Engineering* (1st ed.). Springer Publishing Company, Incorporated.

Sikorski, M., Garnik, I., Ludwiszewski, B., & Wyrwiński, J. (2011). Knowledge Management Challenges in Collaborative Design of a Virtual Call Centre. *Knowlege-Based and Intelligent Information and Engineering Systems*, 657–666.

Smith, A., & Dunckley, L. (2002). Prototype evaluation and redesign: structuring the design space through contextual techniques. *Interacting with Computers*, *14*(6), 821–843. https://doi.org/10.1016/S0953-5438(02)00031-0

Smith, J. L., Bohner, S. . A., & McCrickard, D. S. (2005). Toward introducing notification technology into distributed project teams. *12th IEEE International Conference and Workshops on the Engineering of Computer-Based Systems (ECBS'05)*, 349–356. https://doi.org/10.1109/ECBS.2005.69

Stephanidis, C., & Akoumianakis, D. (2001). Knowledge Management in HCI Design. In W. Karwowski (Ed.), *International Encyclopedia of Ergonomics and Human Factors* (Vol. 1, pp. 705–710). Taylor & Francis.

Still, K. (2006). Exploring Knowledge Processes in User-Centered Design Process. *The 7th European Conference on Knowledge Management*, 533.

Suàrez, P. R., Jùnior, B. L., & de Barros, M. A. (2004). Applying knowledge management in UI design process. In P. Slavik & P. Palanque (Eds.), *Proceedings of the 3rd annual conference on Task models and diagrams - TAMODIA '04* (pp. 113–120). ACM Press. https://doi.org/10.1145/1045446.1045468

Sutcliffe, A. G. (2014). Requirements Engineering from an HCI Perspective. In M. Soegaard & R. F. Dam (Eds.), *The Encyclopedia of Human-Computer Interaction* (2nd ed., pp. 707–760). The Interaction Design Foundation.

Valaski, J., Malucelli, A., & Reinehr, S. (2012). Review: Ontologies Application in Organizational Learning: A Literature Review. *Expert System with Applications: An International Journal*, *39*(8), 7555–7561. https://doi.org/10.1016/j.eswa.2012.01.075

Wahid, S. (2006). Investigating Design Knowledge Reuse for Interface Development. *Proceedings of the 6th Conference on Designing Interactive Systems*, 354–356. https://doi.org/10.1145/1142405.1142462

Wahid, S., Smith, J. L., Berry, B., Chewar, C. M., & McCrickard, D. S. (2004). Visualization of design knowledge component relationships to facilitate reuse. *Proceedings of the 2004 IEEE International Conference on Information Reuse and Integration, 2004. IRI 2004.*, 414–419. https://doi.org/10.1109/IRI.2004.1431496

Wieringa, R., Maiden, N., Mead, N., & Rolland, C. (2005). Requirements Engineering Paper Classification and Evaluation Criteria: A Proposal and a Discussion. *Requir. Eng.*, *11*(1), 102–107. https://doi.org/10.1007/s00766-005-0021-6

Wilson, P., & Borras, J. (1998). Lessons learnt from an HCI repository. *International Journal of Industrial Ergonomics*, *22*(4), 389–396. https://doi.org/https://doi.org/10.1016/S0169-8141(97)00093-0

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B., & Wesslén, A. (2012). *Experimentation in software engineering*. Springer.