Systematic Mapping of Computational Tools for Studying Human-Computer Interaction

Ivan Leoni Vilas Boas, Universidade Federal de Itajubá,
ivanleoni18@hotmail.com, https://orcid.org/0009-0009-7887-4350
Luiz Olmes Carvalho, Universidade Federal de Itajubá,
olmes@unifei.edu.br, https://orcid.org/0000-0003-2470-3117
Phyllipe Lima, Universidade Federal de Itajubá,
phyllipe@unifei.edu.br, https://orcid.org/0000-0002-8358-4405
Simone de Sousa Borges, Universidade Federal de Itajubá,
simoneborges@unifei.edu.br, https://orcid.org/0000-0003-1767-2834
Rodrigo Duarte Seabra, Universidade Federal de Itajubá,
rodrigo@unifei.edu.br, https://orcid.org/0000-0002-7465-2963

Abstract: The systematic mapping in this research identified 18 computer tools developed for studying topics related to human-computer interaction (HCI), most of them focused on teaching design processes through case studies. The research analyzes the characteristics, objectives, and functionalities of the identified tools. The main contribution of the article is understanding the state of the art in developing computer tools for studying HCI, creating the opportunity for future research into alternative ways of using resources for that purpose. The results revealed the identification of few currently accessible tools for collaborating with the study of HCI.

Keywords: computer tools, human-computer interaction, HCI education, systematic mapping.

Mapeamento Sistemático de Ferramentas Computacionais para o Estudo da Interação Humano-Computador

Resumo: O mapeamento sistemático conduzido nesta pesquisa identificou 18 ferramentas computacionais desenvolvidas para o estudo de assuntos relacionados à interação humano-computador (IHC), com a maioria delas visando o ensino de processos de *design* por meio de estudos de caso. A pesquisa apresenta uma análise das características das ferramentas identificadas em relação aos seus objetivos e funcionalidades. A principal contribuição do artigo reside no entendimento do estado da arte do desenvolvimento de ferramentas computacionais para o estudo da IHC, criando a oportunidade para futuras investigações sobre outras formas de uso de recursos direcionados a essa finalidade. Os resultados revelaram a identificação de poucas ferramentas acessíveis atualmente para colaborar com o estudo da IHC.

Palavras-chave: ferramentas computacionais, interação humano-computador, educação em IHC, mapeamento sistemático.

1. INTRODUCTION

HCI is a multidisciplinary field of study that deals with design, evaluation, and implementation of user-centered interactive computer systems (BORYS, 2016; AVOURIS *et al*., 2018; GULL *et al*., 2018; KOUTSABASIS *et al*., 2018; DA SILVA; ZIVIANI, 2018; MUÑOZ-ARTEAGA, 2020; NGUYEN *et al*., 2020). The importance of HCI lies in computer systems being increasingly present in everyday life, from mobile applications and websites to automation systems and smart devices. According to Manresa-Yee *et al*. (2016), Dittmar (2023), Gonzalez-Gonzalez (2023), and Xu and Lai (2023), it is necessary to ensure those systems are designed to be usable, effective, and satisfactory for their users. Furthermore, HCI has been the subject of growing interest in academic circles, driven by advances in computing capabilities and the wide accessibility of technological devices and tools.

The significant scientific production in HCI (LIMA *et al*., 2024) indicates the importance and relevance of various resources to facilitate its study in different contexts (SALES *et al*., 2016; SILVEIRA, 2020; CARVALHO *et al*., 2021; KRONBAUER *et al*., 2021). This is confirmed by the increase in the diversity of methods, techniques, and approaches developed, covering a variety of objectives and methodologies, including usability evaluation (DE OLIVEIRA *et al*., 2021; MATTEDI *et al*., 2022; SANTOS *et al*., 2023), user-centered design (ALVES; MATOS, 2023), interface evaluation (LIMA *et al*., 2022; VIEIRA; SEABRA, 2022), and the investigation of interaction techniques (GOMES *et al*., 2023; ZHANG *et al*., 2024).

Given the multidisciplinarity involved in HCI, the field must be considered to synthesize theories, methods, and tools from correlated areas, such as computer science, psychology, ergonomics, and design, among others (BARBOSA; SILVA, 2010; SHARP *et al*., 2023). Consequently, educators and professionals need to consider a range of existing tools and resources to better address their works (MARTINELLI; ZAINA, 2021; MARTINS; VILLELA, 2021). Also, considering the complexity and diversity of the topics covered in HCI, there is a need to investigate which tools and means are explicitly used to support the study of the area (BOSCARIOLI, 2014; RAPP, 2020; DUARTE; BARANAUSKAS, 2022). It is essential to consider the variety of target audiences involved in the study of HCI, including students, researchers, and interested parties in general, who may have different levels of knowledge, skills, and learning preferences. This research seeks to identify which computational tools best support the educational needs of students and teachers in HCI, aiming to enhance both learning experiences and teaching practices in this evolving field. This research addresses applications, software, systems, platforms, and utilities designed to perform specific tasks with electronic devices solely to study HCI. Essentially, any program or set of programs that help users perform various tasks in a digital environment will be considered a computational tool.

This study carried out a systematic mapping study to identify computer tools used in the study of topics related to HCI. The main goal is to identify tools that allow students and educators to explore, experiment with, and practically apply HCI concepts, sharing the cognitive effort needed to understand the principles and techniques of this area more efficiently. Therefore, the purpose is to understand the state of the art in this field of research. The systematic identification of study resources, in the form of the most varied functionalities, in tools of various types and contexts of use, contributes to future work on selecting these tools, representing the main contribution of the research. In addition, the historical sharing of HCI tools identified in this study allows researchers and educators to learn about the evolution of technologies, enabling them to identify the areas covered to assist HCI education.

The remainder of this paper is structured as follows. Section 2 presents the research methodology used to search, extract, and classify information from the papers analyzed. Section 3 discusses the results. Finally, Section 4 outlines the conclusions.

2. DEFINITION OF RESEARCH

This work proposes a systematic mapping study following the procedures defined by Petersen *et al*. (2015) and is structured to employ research questions, search protocols, selection criteria, classification, and data extraction. Its goal is to identify, analyze, and classify computer tools developed for the study of HCI topics and verify their accessibility and suitability for different contexts of use.

2.1 Questions of Interest

To meet the main objective of understanding the state of the art of tools designed to study topics related to HCI, three research questions were defined:

Q1: What are the tools currently available to support the study of topics related to HCI?

Q2: What are the most common features and functionalities identified in the tools?

Q3: What are the application areas of the identified tools?

The first question is the starting point to extract data from the publications, identifying the existing tools available to understand the current scenario of the field of HCI education. The second question contributes by analyzing the specific characteristics of the tools, such as their objectives and functionalities, so that interested parties can gain insights into their uses and applicability. The third question identifies usage trends, providing an understanding of the areas in which those tools have been and can be used in the study of HCI.

2.2 Research Execution

Searches were conducted in the main scientific documentation databases: *ACM Digital Library*, *CAPES*, *ERIC – Education Resource Information Center*, *IEEE Xplore*, *ScienceDirect*, *Scopus*, *Springer Link*, *Web of Science*, and *Wiley Online Library*. *Google Scholar* was also used to broaden the scope of results and minimize the risk of omissions. The search terms were defined based on the authors' decision to use simple, generic words associated with the research to minimize the risk of omissions and to maximize the number of results with the potential to answer the research questions of interest. This decision was considered to avoid bias from the resulting articles towards certain areas or topics of HCI, since the purpose of this study was precisely to obtain them as a result. A combination of search terms related to "HCI teaching" and "tool" was used with synonymous keywords associated with the research objectives. The complete search strings, adapted for each platform, can be found in Table 1.

Table 1 – Search strings in digital databases (continued). Source: The authors.

Source	Search Strings
ACM Digital Library	[[All: "teaching human-machine interaction"] OR [All: "teaching human-computer interaction"] OR [All: "teaching man-machine interaction"] OR [All: "human-machine interaction education"] OR [All: "human-computer interaction education"] OR [All: "man-machine interaction education"]] AND [[All: "tool"] OR [All: "environment"] OR [All: "application"] OR [All: "platform"]]
CAPES	("teaching human-machine interaction" OR "teaching human-computer interaction" OR "teaching man-machine interaction" OR "human-machine interaction education" OR "human-computer interaction education" OR "man-machine interaction education") AND ("tool" OR "environment" OR "application" OR "platform")
ERIC	("teaching human-machine interaction" OR "teaching human-computer interaction" OR "teaching man-machine interaction" OR "human-machine interaction education" OR "human-computer interaction education" OR "man-machine interaction education") AND ("tool" OR "environment" OR "application" OR "platform")
Google Scholar	("teaching human-machine interaction" OR "teaching human-computer interaction" OR "teaching man-machine interaction" OR "human-machine interaction education" OR "human-computer interaction education" OR "man-machine interaction education") AND ("tool" OR "environment" OR "application" OR "platform")

IEEE Xplore	(("All Metadata":"teaching human-machine interaction" OR "All Metadata":"teaching human-computer interaction" OR "All Metadata":" teaching man-machine interaction" OR "All Metadata":"human-machine interaction education" OR "All Metadata":"human-computer interaction education" OR "All Metadata":"man-machine interaction education") AND ("All Metadata":"tool" OR "All Metadata":"application" OR "All Metadata":"environment" OR "All Metadata":" platform"))
ScienceDirect	("teaching human-machine interaction" OR "teaching human-computer interaction" OR "teaching man-machine interaction" OR "human-machine interaction education" OR "human-computer interaction education" OR "man-machine interaction education")
Scopus	TITLE-ABS-KEY (("teaching human-machine interaction" OR "teaching human-computer interaction" OR "teaching man-machine interaction" OR "human-machine interaction education" OR "human-computer interaction education" OR "man-machine interaction education") AND ("tool" OR "environment" OR "application" OR "platform"))
Springer Link	("teaching human-machine interaction" OR "teaching human-computer interaction" OR "teaching man-machine interaction" OR "human-machine interaction education" OR "human-computer interaction education" OR "man-machine interaction education") AND ("tool" OR "environment" OR "application" OR "platform")
Web of Science	("teaching human-machine interaction" OR "teaching human-computer interaction" OR "teaching man-machine interaction" OR "human-machine interaction education" OR "human-computer interaction education" OR "man-machine interaction education") AND ("tool" OR "environment" OR "application" OR "platform") (Title) OR ("teaching human-machine interaction" OR "teaching human-computer interaction" OR "teaching man-machine interaction" OR "human-machine interaction education" OR "human-computer interaction education" OR "man-machine interaction education") AND ("tool" OR "environment" OR "application" OR "platform") (Abstract) OR ("teaching human-machine interaction" OR "teaching human-computer interaction" OR "teaching man-machine interaction" OR "human-machine interaction education" OR "human-computer interaction education" OR "man-machine interaction education") AND ("tool" OR "environment" OR "application" OR "platform") (Author Keywords)
Wiley Online Library	"("teaching human-machine interaction" OR "teaching human-computer interaction" OR "teaching man-machine interaction" OR "human-machine interaction education" OR "human-computer interaction education" OR "man-machine interaction education") AND ("tool" OR "environment" OR "application" OR "platform")"anywhere

The authors of the present study performed searches with the definitive strings in March 2024, and the result totaled 1237 artifacts, considering all the sources: *ACM Digital Library* – 82; *CAPES* – 20; *ERIC* – 6; *IEEE Xplore* – 28; *Google Scholar* – 916; *ScienceDirect* – 29; *Scopus* – 36; *Springer Link* – 112; *Web of Science* – 4; *Wiley Online Library* – 4. After this process, duplicate works (247) were eliminated. Next, 947 papers were excluded based on the established exclusion criteria (Table 2), resulting in 43 studies. The remaining studies were analyzed in the complete reading phase to find information that could answer the research questions. From them, only 16 remained and the others were excluded because they did not directly addressed computer tools developed for studying HCI topics or because they only superficially portrayed the tools mentioned in the papers.

Table 2 – Inclusion (IC) and exclusion (EC) criteria. Source: The authors.

Criteria	Description
IC-01	Research that addresses the use, development, evaluation, and discussion of computational tools related to the study of HCI topics.
IC-02	Articles, theses, and dissertations that provide substantial information on tools and resources related to the study of HCI topics.
IC-03	Ensure that all relevant works are included, regardless of when they were published.
IC-04	Studies were carried out in different geographical regions to ensure a global perspective on the subject, broadening the diversity and representativeness of the work identified.
EC-01	Studies that do not directly address computer tools developed for studying HCI topics.
EC-02	Studies that appear in multiple instances in different databases.
EC-03	Studies that are not available exclusively in Portuguese and English.
EC-04	Technical reports, conference abstracts, or other publications that do not provide detailed or sufficient information for complete analysis.
EC-05	Systematic reviews, meta-analyses, or narrative reviews.
EC-06	Studies are not available for open access or require payment to read.
EC-07	Studies that only superficially mention computational tools without presenting sufficient characteristics, functions, or information for detailed analysis and discussion.

During the entire reading task, the works by Kay and Kummerfeld (1998) and Schedlbauer and Pastel (2007) stood out for their research into computer tools in the field of HCI. Based on these, a snowballing process was performed, which increased the number of studies included in the analysis. In this new process, two additional articles were found accessible and included to the selected ones, increasing the total number of articles and tools to 18 and 21, respectively. Also, at this stage, it was found that three of the 18 articles presented two tools each: Berry (2004), Xiao *et al*. (2008), and Youngblood (2013). However, Berry (2004) also uses the same tool as Rosson *et al*. (2004). In addition, the articles by Alnuaim *et al*. (2016) and MacKenzie and Buxton (1993) also presented the same tools, respectively, as the works by Alnuaim (2015) and Soukoreff and MacKenzie (1995). We chose to use the latter works because they describe the tools in more detail. As a result, out of the 21 tools identified, only 18 were unique.

The importance of the research protocol is highlighted, as observed by Dornelas *et al*. (2022), who emphasize validation as an indication of the robustness of the results, ensuring their integrity to the researchers. During the protocol, concerns were identified about the credibility and comprehensiveness of the data, given the interpretative nature of the authors of this research on the tools under analysis. To ensure the quality of the results, the following additional measures were adopted: (i) a concise data extraction form was implemented, using an online Google Sheets tool to assist with systematic mapping; (ii) the data extraction process was documented in detail to enable replication and verification by the researchers; (iii) the option "undefined" was added to the extraction items to reflect the lack of information in the categorization of the tools, minimizing the subjectivity of the extraction process; (iv) total citations and references of the selected studies were included to ensure transparency and traceability of the sources used.

3. RESULTS AND DISCUSSION

The works identified in the mapping were analyzed to answer the research questions proposed in the article. Regarding the first research question – ***Q1: What are the tools currently available to support the study of topics related to HCI?***, 18 computer tools developed for the study of HCI were identified. Table 3 includes the complete reference of each work and an identifier (ID) to facilitate reference in the discussion of the results.

Table 3 – Catalog of the tools identified (continued). Source: The authors.

ID	Tool	Reference
F1	The Generalized Fitts' Law Model Builder	SOUKOREFF, R. W.; MACKENZIE, I. S. Generalized Fitts' law model builder. In: Conference Companion on Human Factors in Computing Systems, p. 113-114, 1995.
F2	GraphApp	PATRICK, L. J. GraphApp: A high-level toolkit for building prototype user interfaces. In: Human-Computer Interaction INTERACT'97: IFIP TC13 International Conference on Human-Computer Interaction, Sydney, Australia. Springer US, p. 606-607, 1997.
F3	Guidelines for Usability through Interface Development Experiences (GUIDE)	HENNINGER, S. A methodology and tools for applying context-specific usability guidelines to interface design. Interacting with Computers, v. 12, n. 3, p. 225-243, 2000.
F4	Visualizing a Development Record (VaDeR)	BERRY, B. VaDeR: Visualizing a development record: A study of claims-centric scenario-based design. PhD Thesis, Virginia Tech, 2004.
F5	Case Study Browser	ROSSON, M. B. *et al.* Case studies for teaching usability engineering. ACM SIGCSE Bulletin, v. 36, n. 1, p. 36-40, 2004.
F6	Movement Time Evaluator (MTE)	SCHEDLBAUER, M.; PASTEL, R. A tool for enabling scientific exploration of human performance models in HCI education. In: Proceedings of HCI Educators 2007, p. 116-121, 2007.
F7	vELAP	DEBEVC, M. *et al*. Examples of using technology in teaching human-computer interaction according to the Bologna process. In: ITI 2008-30th International Conference on Information Technology Interfaces. IEEE, p. 489-494, 2008.
F8	Collaborative Case Commenting Tool	XIAO, L. *et al*. Support of case-based authentic learning activities: A collaborative case commenting tool and a collaborative case builder. In: Proceedings of the 41st Annual Hawaii International Conference on System Sciences (HICSS 2008). IEEE, p. 6-6, 2008.

F9	Case Builder Tool or BRIDGE	XIAO, L. *et al*. Support of case-based authentic learning activities: A collaborative case commenting tool and a collaborative case builder. In: Proceedings of the 41st Annual Hawaii International Conference on System Sciences (HICSS 2008). IEEE, p. 6-6, 2008.
F10	Second Life	PERERA, I. *et al*. Towards successful 3D virtual learning – A case study on teaching human computer interaction. In: 2009 International Conference for Internet Technology and Secured Transactions (ICITST). IEEE, p. 1-6, 2009.
F11	MDAT	HUSSEIN, I. *et al*. A method in applying psychology to multimedia design and HCI education. International Journal of Computer Science and Network Security, v. 9, n. 12, p. 134, 2009.
F12	T-InterMod	LOSADA, B. *et al*. The InterMod methodology: An interface engineering process linked with software engineering stages. New Trends on Human-Computer Interaction: Research, Development, New Tools and Methods, p. 53-63, 2009.
F13	FANGS	YOUNGBLOOD, S. A. Communicating web accessibility to the novice developer: From user experience to application. Journal of Business and Technical Communication, v. 27, n. 2, p. 209-232, 2013.
F14	WAVE	YOUNGBLOOD, S. A. Communicating web accessibility to the novice developer: From user experience to application. Journal of Business and Technical Communication, v. 27, n. 2, p. 209-232, 2013.
F15	sLearn	ALNUAIM, A. Designing and evaluating a contextual mobile learning application to support situated learning. PhD Thesis. University of the West of England, Bristol, 2015.
F16	Continuous User Understanding (CUU)	JOHANSSEN, J. O. *et al.* A syllabus for usability engineering in multi-project courses. In: SEUH, p. 133-144, 2019.
F17	Plataforma web de apresentação autônoma	NGUYEN, H. N. *et al*. Interface design for HCI classroom: from learners' perspective. In: International Symposium on Visual Computing. Cham: Springer International Publishing, p. 545-557, 2020.
F18	ChatGPT	BARAMBONES, J. *et al*. ChatGPT for learning HCI techniques: A case study on interviews for personas. IEEE Transactions on Learning Technologies, v. 17, p. 1486-1501, 2024.

Notice that even without applying restrictions as to the year of publication of the searches in the repositories, only three tools were used to support the study of HCI in the last five years. Considering the period from 1981 to 2024 (43 years), there were only 18 unique ones. Most of them were academic prototypes, which are no longer widely available or accessible. The extraction process enabled two thematic analyses of the selected tools. The first analysis classified them according to the primary purpose of use portrayed by their authors. As Table 4 shows, the same tool can serve different purposes.

Table 4 – Classification of tools by purpose. Source: The authors.

Purpose	ID	Purpose	ID
Modeling and simulating	F1 and F6	Case studies	F4, F5, F8 and F9
Interface development and prototyping	F2 and F12	Usability	F3, F10 and F16
Guidelines	F3, F11 and F14	Evaluation	F14, F16 and F17
Visualization and navigation	F4, F5 and F8	Contextual investigation	F15
Accessibility	F7, F13 and F14	Creating personas and interviews	F18
Collaboration	F8 and F9	Educational presentation	F7 and F17

Considering the different purposes, the (i) **modeling and simulating** category tools (SOUKOREFF; MACKENZIE, 1995; SCHEDLBAUER; PASTEL, 2007) facilitate for students to create virtual representations of interactive systems and to understand complex processes. For example, by applying Fitts' Law, which relates movement time to distance and target size, students can optimize the efficiency of interactive designs, providing a solid basis for creating intuitive and efficient interfaces. The (ii) **interface development and prototyping** tools (PATRICK, 1997; LOSADA, 2009) allow students to develop interactive interface designs quickly. Those tools are crucial for experimenting with layouts, interactions, and user flows, facilitating continuous design refinement based on feedback and iterative testing. **(iii) Guidelines-based tools** offer guidelines and best practices for user-centered interface design. They help students to understand and apply principles of usability, accessibility, and user experience to their projects, promoting more effective designs (HENNINGER, 2000; HUSSEIN *et al*., 2009; YOUNGBLOOD, 2013). In the (iv) **visualization and**

navigation category (BERRY, 2004; ROSSON *et al*., 2004; XIAO *et al*., 2008), the tools allow users to explore and understand complex information in systems projects. Intuitive and efficient navigation makes it easier for students to explore the case studies, assimilate the theoretical concepts, and apply the examples to real projects. The tools in the (v) **accessibility** category (YOUNGBLOOD, 2013; NGUYEN *et al*., 2020) help students design interfaces accessible to all users, including people with disabilities. These tools adjust designs to meet accessibility standards and promote digital inclusion. The (vi) **collaboration** category covers tools that enable students to collaborate on HCI activities and projects. Those tools facilitate communication between team members and the sharing of ideas, promoting a more cooperative environment (XIAO *et al*., 2008).

The tools included in the (vii) **case studies** category (BERRY, 2004; ROSSON *et al*., 2004; XIAO *et al*., 2008) allow learners to analyze and explore real examples of interactive interface design, helping them understand HCI design processes. These tools provide valuable insights for developing practical skills and assimilating theoretical knowledge. Furthermore, in the (viii) **usability** category (HENNINGER, 2000; PERERA *et al*., 2009; JOHANSSEN *et al*., 2019), the tools allow students to evaluate the ease of use of interactive interfaces, provide usability guidelines, and identify design problems to improve them, contributing to developing more intuitive interfaces. The (ix) **evaluation** category allows students to test and analyze interactive interfaces based on predefined criteria. They offer methods for collecting or providing user feedback, conducting tests or interpreting results, and providing continuous design improvements (YOUNGBLOOD, 2013; JOHANSSEN *et al*., 2019; NGUYEN *et al*., 2020). The tool in the (x) **contextual investigation** category (ALNUAIM, 2015) allows students to conduct field studies and analyze real contexts in which interactive interfaces are used. It makes easier to understand the needs and behaviors of users in the environment in which the interfaces will be used, guiding more informed, user-centered design decisions. (xi) **Persona creation and interview** tools enable students to develop fictional user profiles based on accurate data and conduct interviews to understand the needs and expectations of end users. It helps train students to interview real users and create interface designs that more accurately meet user demands, improving the overall experience (BARAMBONES, 2024). Finally, (xii) **educational presentation** tools (DEBEVC *et al*., 2008; NGUYEN *et al*., 2020) support effective communication of HCI concepts, facilitating the creation of interactive presentations that illustrate design processes, decisions, and results.

Among the tools identified, only F10, F14, F16, and F18 are currently accessible online. The first two and the last one are accessible online, while the third makes its code available on the “GitHub” platform. Note that although tools F1, F3, F5, and F6 include access links in their respective works, they are currently “broken”, highlighting the need to update and maintain those resources. The small number of tools available corroborates the points made by Lazem (2019) and Muñoz-Arteaga (2020) about the difficulty in accessing computer resources for teaching HCI. This lack represents an obstacle to academic and professional development in the area, highlighting the urgent need for investments and efforts to develop and improve those resources.

In addition to the general scarcity of tools, there is a notable deficiency in specific resources designed to address ethical issues in HCI, as discussed by Sin *et al*. (2022) and Krauß *et al*. (2023), contrasts with comprehensive and applied teaching. This can result in a support gap for designers, who must consider all relevant ethical aspects, including interaction with a wider circle of stakeholders and environmental and situational factors.

About the second research question – ***Q2: What are the most common features and functionalities identified in the tools?***, the F1 and F6 tools play essential roles in HCI modeling and simulation. F1 allows adjusting task parameters, such as amplitude and target size, and configuring the behavior of the input equipment. It also has a user-friendly interface for configuration, with settings executed via text file or graphical interface. F6 is based on object-oriented design, allowing new models and task types to be added. The tool offers an interactive platform for customized experiment configuration, multi-platform and plotting with scatter and distribution plots, export to advanced packages such as R, detailed visualizations, remote connectivity via TCP/IP, and the ability to save and share data in XML or CSV. The F2 and F12 tools are designed for user interface development and prototyping. F2 is a multi-platform toolkit focused on developing graphical user interfaces (GUI), notable for its ease of learning and efficiency in prototyping. In turn, F12 adopts an approach based on the "InterMod" methodology, which ensures that interfaces are adaptable, centered on user needs, and integrates good software engineering practices. Integration with the User Interface Markup Language (UIML) makes documenting and reusing the design in different environments easier.

The F3, F11, and F14 tools have distinct and complementary roles in teaching and applying usability, design, and accessibility via guidelines. F3 helps students integrate usability guidelines into software projects by offering a structured and personalized approach with a relational database for organized access to information. F11 improves the understanding of cognitive psychology by providing guidelines for multimedia systems, helping to choose suitable media, and avoiding cognitive overload. F14 verifies the compliance of web pages with the Web Content Accessibility Guidelines (WCAG). As to visualization and navigation (F4, F5, and F8) and collaboration (F8 and F9) via case studies, the tools that stand out are those that promote an interactive and easy-to-use approach. F4 stands out for its interactive and sequential visualization of data, using a timeline and colored icons to represent design phases, which makes it easier to understand processes and artifacts. F5, in turn, organizes usability documents in a hierarchical and phased manner, offering detailed and comparative access to the case studies. F8 also provides a hierarchical structure for intuitive document navigation but supports HTML, PDF, and Word and facilitates collaborative comments. F9 facilitates the creation of cases by collaboration on design projects. Although some users may face an initial learning curve, the tool is valued for its effectiveness in organization and communication, promoting a collaborative learning environment.

When integrated, the F7, F13, and F14 tools provide comprehensive approaches to teaching and applying accessibility principles. F7 is an educational tool for managing and streaming online videos proposed for development by students to improve accessibility through subtitles, videos in sign language, and other adaptive features, and allowing the interface to be customized to meet the needs of users with disabilities. F13 is an extension to the "Firefox" browser that simulates a screen reader's output, offering a textual representation of web browsing for visually impaired users. The F3, F10, and F16 tools offer unique approaches to teaching usability. While F3 provides a guided, personalized framework for applying usability via guidelines, F10 offers a robust 3D virtual environment that encourages hands-on experimentation and creative collaboration, allowing for deep immersion in usability concepts. F16 stands out for helping to continuously understand user behavior to integrate usability test techniques during development, offering practical insights into actual interaction with the software. F17 can also be used for assessments, being a web platform designed for interactive presentations of interaction design projects, allowing real-time feedback by students and teachers. The F15 tool is a mobile application designed to enrich contextual investigation and situated learning in educational environments. It facilitates the collection and organization of data during practical activities, allowing detailed and contextually relevant observations to be recorded. F18 is an advanced conversational artificial intelligence platform that stands out for its capabilities in creating personas and conducting simulated interviews.

To support the answer to the third research question – ***Q3: What are the application areas of the identified tools?*** – a second categorization of the tools was proposed based on the work by Barbosa and Silva (2010), as shown in Table 5. This book was selected because it is the reference book in most HCI syllabuses in undergraduate courses in Brazil.

Table 5 – Classification of tools by topics. Source: The authors.

Topics	**ID**	**Subtopics**	**ID**
Basic concepts	F7, F10 and F13	Quality in HCI (Accessibility)	F7 and F13
		Quality in HCI (Usability and user experience)	F10
HCI theoretical approaches	F1, F6 and F11	Applied cognitive psychology (Human information processor)	F11
		Experimental psychology (Fitts' Law)	F1 and F6
HCI design processes	F4, F5, F8 and F9	Scenario-based design	F4, F5, F8 and F9
Identification of user needs and HCI requirements	F15 and F18	Contextual investigation	F15
		Interview	F18
Organization of the problem space	F18	Creating personas	F18
HCI design	F2 and F12	Interface design (user interface representations)	F2 and F12
Principles and guidelines for HCI design	F3 and F14	General principles and guidelines	F3 and F14
HCI evaluation planning	F16	How to evaluate? (Data collection)	F16
HCI evaluation methods	F16 and F17	HCI evaluation through observation (Usability testing)	F16
		HCI evaluation through inspection	F17

The data in Table 5 allow observing that at least one tool could be used to teach HCI. However, not every subtopic in the book has a specific tool associated to it, and some may cover more than one topic or subtopic. This research question revealed that the issues least covered by the tools were "Organization of the problem space" and "HCI evaluation planning." Several factors can explain the reason for this lower emphasis: (i) HCI teaching tools generally prioritize topics with direct practical application, which makes those topics less obvious, as they involve preparatory or theoretical activities; (ii) the inherent complexity of those concepts can also contribute to their being approached more synthetically to avoid overloading students with theory to the detriment of practice; (iii) because they are interdisciplinary, those topics are often integrated into other stages of the HCI design process, which reduces their visibility as independent areas of study; (iv) the pedagogical preferences of educators and students tend to emphasize "doing" over "planning" and "organizing," especially in practice-oriented subjects; (v) students' perception of the value of those topics influences their emphasis on teaching tools once more tangible and directly applicable topics tend to be more attractive, as indicated by Boskovic *et al*. (2020).

Most of the tools found aims at teaching the topic of "HCI design processes" and the subtopic "Scenario-based design." This distribution can be attributed to a few reasons. Firstly, the continuous evolution of the technology and the diversification of digital platforms have broadened the scope of HCI (NGUYEN *et al*., 2020), requiring more sophisticated and adaptive approaches to its teaching, as concluded by Lai (2008). As devices become more varied and contexts of use more complex, tools need to support a range of scenarios and interactions to ensure that design solutions meet users' expectations in different conditions (LAZEM, 2019). Secondly, there is a need for effective collaboration and communication between interdisciplinary teams for HCI training, increasing the demand for tools supporting documentation, sharing, and reviewing design scenarios (DITTMAR, 2023). Furthermore, as argued by Krauß *et al*. (2023), with the growing number of stakeholders involved in HCI projects, from designers and developers to direct and indirect end users, as well as environmental and situational actors, the ability to collaboratively create, revise and iterate design scenarios becomes crucial. Therefore, the increase in computing resources for those topics reflects the need to adapt to a dynamic technological environment, the demand for efficient collaboration, and the complexity of design processes, highlighting the importance of these tools for teaching and learning.

Finally, the authors emphasize a few issues that threaten the validity of this research: the selection of scientific databases and the manual search for papers. In the first case, although ten renowned databases for primary research studies were selected, other publication outlets could have been included, allowing more relevant work to be identified. In the second case, although the searches were well planned and executed, some work related to the topic may not have been included due to human error. To mitigate the latter, the authors of this research reviewed the identified works to resolve possible discrepancies. In addition, the research restriction of focusing only on tools developed for an educational context is a limitation of this study, reducing the number of papers selected.

4. FINAL CONSIDERATIONS

The present study conducted a systematic mapping of computer tools used to study HCI. The research began with a comprehensive search in 10 digital databases, analyzing 1237 publications. From these, 18 were selected for detailed analysis, leading to the identification of 21 tools, of which only 18 were unique.

In alignment with the primary objective of the research and answering the specific questions delineated, the findings suggest that the HCI community should prioritize making the tools developed more accessible to students and teachers in the field. Among the main functions of the tools analyzed, those aimed at teaching using case studies stand out, as they enrich the learning experience by integrating interactive visualization, structured organization, collaboration, and real-time documentation.

Note that the scope of this study was limited to computational tools for studying HCI, focusing only on Portuguese and English resources. This restriction narrows the breadth of the research considered. Further research could expand the analysis to include other languages and forms of resources, not only computer tools. Additionally, different methodologies, such as problem-based learning, projects, cases, scenarios, learner-centered methodologies, and educational methods focused on experience, should be explored. Exploring and integrating those alternative methodologies will expand pedagogical possibilities, fostering more diverse and effective educational experiences that cater to various learning styles and contexts. This will ultimately contribute to more meaningful learning outcomes for HCI students.

REFERENCES

ALNUAIM, A. Designing and evaluating a contextual mobile learning application to support situated learning. **PhD Thesis**. University of the West of England, Bristol, 2015.

ALNUAIM, A. *et al*. Enhancing student learning of human-computer interaction using a contextual mobile application. In: **Proceedings of the 2016 SAI Computing Conference (SAI)**. IEEE, p. 952-959, 2016.

ALVES, D. D.; MATOS, E. S. User involvement in interaction design in the context of distributed software development: An interview study. In: **Simpósio Brasileiro sobre Fatores Humanos em Sistemas Computacionais (IHC)**, Sociedade Brasileira de Computação, 2023.

AVOURIS, N. *et al*. Studying human-computer interaction for social good: The case of digital government evaluation and re-design project. In: **Proceedings of the 22nd Pan-Hellenic Conference on Informatics**, p. 230-235, 2018.

BARAMBONES, J. *et al*. ChatGPT for learning HCI techniques: A case study on interviews for personas. **IEEE Transactions on Learning Technologies**, v. 17, p. 1486-1501, 2024.

BARBOSA, S. D. J; SILVA, B. S. **Interação Humano-Computador**. Elsevier, 2010.

BERRY, B. VaDeR: Visualizing a development record: A study of claims-centric scenario-based design. **PhD Thesis**, Virginia Tech, 2004.

BORYS, M. Teaching software usability engineering: Classroom experience. In: **10th International Technology, Education and Development Conference**, p. 2712-2717, 2016.

BOSCARIOLI, C. *et al*. Currículos de IHC no Brasil: Panorama atual e perspectivas. In: **XXII Workshop sobre Educação em Computação**, p. 1294-1303, 2014.

BOSKOVIC, D. *et al*. Stimulating entrepreneurship in teaching human computer interaction. **arXiv preprint arXiv:2011.09001**, 2020.

CARVALHO, F. *et al*. Rota de Ada: Desenvolvimento de um jogo para ensino de atributos de usabilidade utilizando metodologias de design. **RENOTE**, v. 19, n. 1, p. 278-287, 2021.

DA SILVA, E. J.; ZIVIANI, H. E. Desenho e música no ensino de IHC: Relato de experiência de uma aula sobre conceitos básicos da engenharia semiótica. In: **Anais Estendidos do XVII Simpósio Brasileiro sobre Fatores Humanos em Sistemas Computacionais**, SBC, 2018.

DEBEVC, M. *et al*. Examples of using technology in teaching human-computer interaction according to the Bologna process. In: **ITI 2008-30th International Conference on Information Technology Interfaces**. IEEE, p. 489-494, 2008.

DE OLIVEIRA, M. *et al*. Usability evaluation model of an application with emphasis on collaborative security: An approach from social dimensions. **Journal of the Brazilian Computer Society**, v. 27, p. 1-32, 2021.

DITTMAR, A. Moments of surprise: Preparing technology-oriented students for interdisciplinary work. In: **Proceedings of the European Conference on Cognitive Ergonomics 2023**, p. 1-8, 2023.

DORNELAS, I. F. *et al*. Systematic mapping of technologies for supporting choreographic composition. **Journal on Interactive Systems**, v. 13, p. 232-242, 2022.

DUARTE, E. F.; BARANAUSKAS, M. C. C. Experience-based constructionism as a basis for HCI education: A case study. **International Journal of Human–Computer Interaction**, v. 40, n. 3, p. 680–700, 2022.

GOMES, P. R. I. *et al*. Gesture recognition methods using sensors integrated into smartwatches: Results of a systematic literature review. In: **Simpósio Brasileiro sobre Fatores Humanos em Sistemas Computacionais (IHC)**, Sociedade Brasileira de Computação, 2023.

GONZALEZ-GONZÁLEZ, C. S. Introducing speculative design, gender, and AI in lean UX for HCI education. In: **Proceedings of the XXIII International Conference on Human Computer Interaction**, p. 1-6, 2023.

GULL, H. *et al*. Reflections on teaching human computer interaction course to undergraduate students. In: **2018 International Conference on Computational Science and Computational Intelligence (CSCI)**, IEEE, p. 659-662, 2018.

HENNINGER, S. A methodology and tools for applying context-specific usability guidelines to interface design. **Interacting with Computers**, v. 12, n. 3, p. 225-243, 2000.

HUSSEIN, I. *et al*. A method in applying psychology to multimedia design and HCI education. **International Journal of Computer Science and Network Security**, v. 9, n. 12, p. 134, 2009.

JOHANSSEN, J. O. *et al*. A syllabus for usability engineering in multi-project courses. In: **SEUH**, p. 133-144, 2019.

KAY, J.; KUMMERFELD, B. User interface design and programming for computer science majors. In: **Proceedings of the 3rd Australasian Conference on Computer Science Education**, p. 121-126, 1998.

KOUTSABASIS, P. *et al*. Teaching HCI with a studio approach: Lessons learnt. In: **Proceedings of the 22nd Pan-Hellenic Conference on Informatics**, p. 282-287, 2018.

KRAUß, V. *et al*. Beyond well-intentioned: An HCI students' ethical assessment of their own XR designs. In: **2023 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)**. IEEE, p. 59-68, 2023.

KRONBAUER, A. H. *et al*. Relatos da estruturação de aulas remotas com a utilização de metodologias ativas. **RENOTE**, v. 19, n. 2, p. 21-30, 2021.

LAZEM, S. Championing HCI education to CS undergraduates at a grassroots level: A case study in Egypt. **Journal of Usability Studies**, v. 15, n. 1, p. 8-22, 2019.

LIMA, A. L. S. *et al*. Automated assessment of visual aesthetics of Android user interfaces with deep learning. In: **Simpósio Brasileiro sobre Fatores Humanos em Sistemas Computacionais (IHC)**, Sociedade Brasileira de Computação, 2022.

LIMA, F. M. da C. *et al*. An analysis of the authorship and co-authorship networks of the Brazilian Human-Computer Interaction Conference. **Journal on Interactive Systems**, v. 15, n. 1, p. 265–293, 2024.

LOSADA, B. *et al*. The InterMod methodology: An interface engineering process linked with software engineering stages. **New Trends on Human-Computer Interaction: Research, Development, New Tools and Methods**, p. 53-63, 2009.

MACKENZIE, I. S.; BUXTON, W. A tool for the rapid evaluation of input devices using Fitts' law models. **ACM SIGCHI Bulletin**, v. 25, n. 3, p. 58-63, 1993.

MANRESA-YEE, C. *et al*. Repository for exchanging activities and examples in usability-related courses. In: **ICERI2016 Proceedings**. IATED, p. 1473-1480, 2016.

MARTINELLI, S. R.; ZAINA, L. A. M. Learning HCI from a virtual flipped classroom: Improving the students' experience in times of COVID-19. In: **Proceedings of the XX Brazilian Symposium on Human Factors in Computing Systems**, p. 1-11, 2021.

MARTINS, D. S.; VILLELA, M. L. B. Panorama do ensino de IHC no Brasil: uma análise dos anais do WEIHC de 2016 a 2020. In: **Workshop sobre Educação em IHC – Simpósio Brasileiro de Fatores Humanos em Sistemas Computacionais (IHC)**, p. 79-84, 2021.

MATTEDI, A. P. *et al*. Um estudo de usabilidade do ambiente cultural virtual do Museu de Sant'Ana. **RENOTE**, v. 20, n. 1, p. 21–30, 2022.

MUÑOZ-ARTEAGA, J. Collaborative production model of educational resources for human-computer interaction community in Latino America. In: **Human 4.0-From Biology to Cybernetic**, IntechOpen, 2020.

NGUYEN, H. N. *et al*. Interface design for HCI classroom: from learners' perspective. In: **International Symposium on Visual Computing**. Cham: Springer International Publishing, p. 545-557, 2020.

PATRICK, L. J. GraphApp: A high-level toolkit for building prototype user interfaces. In: **Human-Computer Interaction INTERACT'97: IFIP TC13 International Conference on Human-Computer Interaction**, Sydney, Australia. Springer US, p. 606-607, 1997.

PERERA, I. *et al*. Towards successful 3D virtual learning – A case study on teaching human computer interaction. In: **2009 International Conference for Internet Technology and Secured Transactions (ICITST)**. IEEE, p. 1-6, 2009.

PETERSEN, K. *et al*. Guidelines for conducting systematic mapping studies in software engineering: an update. **Information and Software Technology**, v. 64, p. 1-18, 2015.

RAPP, A. Design fictions for learning: A method for supporting students in reflecting on technology in Human-Computer Interaction courses. **Computers & Education**, v. 145, p. 103725, 2020.

ROSSON, M. B. *et al*. Case studies for teaching usability engineering. **ACM SIGCSE Bulletin**, v. 36, n. 1, p. 36-40, 2004.

SALES, A. B. *et al*. Jogos sérios em interação humano-computador: Uma revisão sistemática de literatura. **RENOTE**, v. 14, n. 1, 2016.

SANTOS, S. O. *et al*. Usability evaluation of mobile banking applications in the context of the elderly in a city of Ceará. In: **Simpósio Brasileiro sobre Fatores Humanos em Sistemas Computacionais (IHC)**, Sociedade Brasileira de Computação, 2023.

SCHEDLBAUER, M.; PASTEL, R. A tool for enabling scientific exploration of human performance models in HCI education. In: **Proceedings of HCI Educators 2007**, p. 116-121, 2007.

SHARP, H. *et al*. **Interaction design: Beyond human-computer interaction**. 6th ed. John Wiley & Sons, Inc., 2023.

SILVEIRA, M. S. Exploring creativity and learning through the construction of (non-digital) board games in HCI courses. In: **Proceedings of the 2020 ACM Conference on Innovation and Technology in Computer Science Education (ITiCSE '20)**, Association for Computing Machinery, p. 246–251, 2020.

SIN, J. *et al*. Uncovering inclusivity gaps in design pedagogy through the digital design marginalization framework. **Frontiers in Computer Science**, v. 4, p. 822090, 2022.

SOUKOREFF, R. W.; MACKENZIE, I. S. Generalized Fitts' law model builder. In: **Conference Companion on Human Factors in Computing Systems**, p. 113-114, 1995.

VIEIRA, R. A. ; SEABRA, R. D. Avaliação da usabilidade de interfaces gráficas para distribuições Linux. **RENOTE**, v. 20, n. 2, p. 104-113, 2022.

XIAO, L. *et al*. Support of case-based authentic learning activities: A collaborative case commenting tool and a collaborative case builder. In: **Proceedings of the 41st Annual Hawaii International Conference on System Sciences (HICSS 2008)**, IEEE, p. 6-6, 2008.

XU, S.; LAI, S. Integrating HCI in web technologies course. In: **Proceedings of the 24th Annual Conference on Information Technology Education**, p. 164-168, 2023.

YOUNGBLOOD, S. A. Communicating web accessibility to the novice developer: From user experience to application. **Journal of Business and Technical Communication**, v. 27, n. 2, p. 209-232, 2013.

ZHANG, X. Evaluating target expansion for eye pointing tasks. **Interacting with Computers**, v. 36, n. 4, p. 209–223, 2024.