How to Incorporate Accessibility to Design Principles for IS Artefacts?

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Design principles are used to specify design knowledge and describe the aim of artefact instantiation. Accessibility research aims to create artefacts that can be used by all users. However, schemes for design principles lack the tools to define accessibility explicitly. This study proposes extensions to scheme design principles for accessibility-related design science research. We draw accessibility domain-specific characteristics from the literature to include accessibility in design principles for Human-Computer Interaction (HCI) instantiations. We extended the components of design principles with the following attributes: HCI Artefact Features; Contextual factors; Computer Input Modalities; Computer Output Media; Human Sensory Perception; Human Cognition; Human Functional Operations. We devised a checklist for researchers to follow the variations in accessibility. The extensions are intended to foster researchers to incorporate accessibility in producing a more accurate formulation of design principles.

Keywords:
accessibility,
design principles,
design science research,
IS artefacts,
information systems

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1 Introduction

Accessibility is a research topic often categorized as a sub-subject of the Human-Computer Interaction (HCI) discipline [1]. Accessibility research is interdisciplinary in nature and has domain-specific characteristics that are needed to address in research. In general, accessibility-related research is attempting to identify issues in the HCI within a wide spectrum of human abilities and aims to discover solutions to information and system quality that enables users' autonomy use of information and information technology (IT)[2]. Simply to say, in practice, accessibility aims to create artefacts that can be used by all users. Accessibility, therefore, represents the extent to which users with their variable abilities in perception, cognition, and action can interact and operate with a system without external assistance (secondary users or assistive technology) [2]. In contrast, the goal of HCI research is to attempt to build and evaluate new behavioural solutions with a focus on interactions that increase human capabilities to interact with information, technologies, and tasks [3,4]. HCI research is focusing advancing the knowledge base with descriptive knowledge by explaining human cognition, affect, and behaviour in interaction with technology. Secondly, HCI research is providing prescriptive knowledge for IT system design and human process and interaction artefacts presented in a form of design theories and/or design entities [4].

According to Adam et al., (2021) [3:4], Design Science Research (DSR) can support three modes of HCI research: (1) 'how to construct an HCI artefact for a given problem space.' (2) 'how individuals use the artefact in its environment,' and (3) 'building and evaluating novel composite solutions that improve synergies between technologies and human behaviour'. Mäkipää et al., (2022) [2], identified four domains in IT artefact development, the factors within them, and their roles and actions that influence the realization of accessibility. The domains are (1) user, (2) management (3) developers, and (4) features of IT artefact. The factors within these domains and the relationships between the domains should all be concerned to ensure the realization of accessibility. However, accessibility research barely uses design science as a research method even though it is promising for HCI research [5].

Gregor et al., (2020) [6] derived a schema for researchers to specify a design principle for IT-based artefacts. The schema aids researchers to formulate design principles components and define who is implementer, in what context, by what mechanisms, for what purpose, for whom, and why the instantiation is intended. The components include aim, implementer, user, context, mechanism, and rational. It clarifies the general role of the actors (implementer, users, and enactors) who are involved with the use of the design principle. In psychology and cognitive science, a schema is defined as a concept that describes a pattern of thought or behaviour that organizes categories of information and the relationships among them [7]. Schema is, in psychology, an internal model of the mental structure from the real world. People organize information into schemes and schema is used to understand added information. For example, a builder of an artefact (IT developer, researcher etc.) has a schema about the user, that is, an idea of what the user is like. This schema, however, allows the builder to identify different users as the same user type (c.f. user groups which are categorized based on certain characteristics). The schema also includes activities such as how artefacts is used by users i.e. designers' assumptions. These assumptions are needed to convert to realization by observing real-world interaction behaviour of users. In accessibility research, this means that we need to focus on user abilities. However, user ability is a variable that depends on the individuals. The nature of human abilities, severity, and their mixture is complex. Moreover, due to assistive technology, potential accessibility barriers become even more complex to understand [8]. Gregor et al., (2020) [6] addressed the lack of 'people aspect' of design principles and devised a design theory to make design principles more understandable and useful in real world design contexts. Accessibility is therefore also one criteria of reusability of design principles [9]. Addressing the lack of a more accurate description of the attributes of the components in the design principle scheme would enable accessibility researchers to incorporate accessibility to design principles. Therefore, we addressed this issue by asking: **How to incorporate accessibility to design principles for IS artefacts?**

In this paper, we continue the work and propose an extension to the scheme presented by Gregor et al., (2020) [6]. The goal of this study is to extend the scheme for design principles with attributes of human aspect factors in use of HCI artefact including: HCI artefact features; variables of the context; mechanisms in HCI; and variables in user abilities. We draw upon theories related to the components of design principles and accessibility domain specific characteristics that should be included and addressed in design principles for HCI instantiations. This paper is organized as follows. The next section describes the theoretical foundation of DRS as well as DSR in HCI research. Then, we present research methods. Finally, we propose the next steps to complement and justify the extensions.

2 Theoretical Foundation

2.1 Design Science Research

The goal of DSR is to generate prescriptive knowledge about the design of IS artefacts like software, methods, models, and concepts [10]. The design of the artefact, its precise definition and the evaluation of its usefulness are the most central issues of DSR [11]. Design research differs from design in general by focusing more on generating and developing new knowledge, while design in general focuses on using existing knowledge [12]. Therefore, the design must combine behavioural and organizational theories to develop an understanding of business problems, context, solutions, and evaluation methods [11].

For strategies to be implemented in the business infrastructure effectively, it requires organizational designing activities as well as information system designing activities [11]. These design activities are interdependent and they reflect the most central research subjects in the field of IS. To be more precise, design activities shows the relationship of business strategies and IT strategies to the infrastructures of the organization and information systems [11]. The design activities contain a sequence of activities that produces an innovative product, i.e. an artefact. The evaluation of the artefact produces feedback, based on which both the design process and the artefact and their quality can be developed. This type of iteration between build and review is typical before the final version of the artefact is complete. In design science, one contradiction must be accepted. Design means both process and product (artefact) – in other words, design means both doing and a thing [13]. Researchers must therefore consider both the design process and the artefact itself as part of the research [11]. March and Smith (1995) [14], indicated two types of design activities (construction and evaluation), and four types of artefacts (constructs, models, methods, and instantiations) produced by design scientists in IS studies. Construction refers to the process of constructing an artefact for a specific purpose. Construction is guided by the question of whether the artefact is feasible. Thus, the artefact itself becomes a research object that must be evaluated scientifically [14]. Evaluation is the process of deciding how well an artefact performs its task [14]. Evaluation requires developing metrics and measuring the artefact against those metrics. Metrics also determine what the artefact is trying to achieve. If the metrics have not been defined or the testing was not successful, it is impossible to scientifically prove the usefulness of the artefact.

Hevner et al. (2004) [11] further emphasized that, it is important to separate routine design work from design research. Routine design refers to the utilization of existing knowledge in the solution of the organization's known problems [15]. The key distinction between routine design and design science research is that it is precisely recognized what contribution the research makes to current knowledge, both in terms of basic knowledge and the methodological part [15]. Maedche et al., (2021) [12] proposed a reference framework for design research activities to help researchers position their own work and justify the type of contribution they want to make. The framework includes two dimensions between which design-oriented research varies. The first dimension includes the researchers' explanation of their contribution to current knowledge and tells whether the explanation is prescriptive or descriptive. The second dimension comprises the role of researchers in relation to the artefact and shows whether researchers are creating a new artefact (Creation) or examining an existing artefact (Observation) [12].

2.2 Design Science in Human Computer Interaction Research

HCI research focus on producing information about how people interact with information, technology, and tasks [3,4]. Design research and HCI research streams can be seen inherently related and highly overlapping [4]. The knowledge produced in HCI research can be classified as either descriptive knowledge aimed at explaining human behaviour and cognition with technology or as prescriptive knowledge aimed at guiding how IT systems should be constructed [3].

Adam et al., (2021) [3] presented three modes that DSR can focus in HCI. First, they called 'interior mode' as such research that focuses on IT system design technically and aim to solve problems on how to build and design an interface that enhance human performance. These HCI artefact constitutes constructs, model, methods, and instantiations for an interface design. Second, 'exterior mode' focuses on the use of artefact in its environment. Researchers focus on how individuals use the artefact by observing and analysing existing real-world use cases. Researchers primarily evaluate how effectively users interact with the IT system interface basing the observations to qualitative and/or quantitative evidence to produce both prescriptive and descriptive knowledge around human behaviours [3]. Third, some research projects that integrate both interior and exterior modes Adam et al., (2021) [3] called 'gestalt mode'. Gestalt mode type of research focuses on synergistic design of human behaviour and IT systems to improve human performance. In such projects selected evaluation methods should cover both systems performance and human performance so that the improvements to the HCI application can be justified. These types of research projects contribute to guiding design theories to achieve synergies between people and systems between socio-technical systems and technical components [3].

Hevner and Zhang, (2011) [4] indicated that it is crucial to identify what constitute an HCI artefact in design research. They categorized examples of HCI artefacts within DSR artefact types: construct, model, method, or instantiations [14]. Constructs in HCI are defined as 'vocabulary and symbols used to define design problems and solutions that provide a means to represent design ideas' [4:58]. Examples of construct-type HCI artefacts included metaphors, constructs of interaction, visualization, and organization (layouts of HCI). Models in HCI are '…sensemaking arrangements of constructs that allow exploration of abstract design' [4:58]. Examples of these type of HCI artefacts are such as graphical models, card stacks, 3D models, cognitive maps, etc. [4]. Methods-type HCI artefacts are defined as 'processes that provide guidance on how to solve problems and exploit opportunities' [4:58]. Examples of these types of HCI artefacts are well-established participatory design, collaboration processes, human-centred design, and value sensitive design [4]. Lastly, instantiations in HCI represents the 'implementation of an artefact in a working system,' 'demonstrates feasibility and value,' or 'provides ability to study uses and impacts on embedded system' [4:58]. Instantiation-type of artefacts in HCI are websites, user interfaces, input/output devices, avatars, etc. [4].

2.3 Accessibility Domain Specific Characteristics in Design Activities

The domain of accessibility contains basically three points of knowledge of accessibility that can be considered as field specific characteristics that are required for successfully design an accessible HCI artefact: (1) assumptions about users' abilities, that is developers should consider human senses one by one and assume that users may lack one of abilities; (2) users' actual need, that is developers should elicit users' requirements related to task and context of HCI artefact that is a target of development. (3) factors in value chain that are related to management and development of the artefact and have influence to accessibility [2].

Assumptions about users' abilities contain the mindset that user lack some human abilities therefore multimodal interaction should be provided. Users' actual needs are detected in the collaboration with users. Collaboration with users is the process of planning a partnership. Since its introduction, the method has been adapted and extended in the field of HCI. Similarly, the participatory design approach consists of a set of theories, practices, and studies related to end-user participation in technology development and design [16]. User participation and experimental research are also getting increasingly important in IS research to study decision-making processes and user behaviour [17]. Overall, user participation as an approach contains several methods that can be used in various parts of the value chain such as brainstorming, direct observation, activity diaries, cultural probes, surveys and questionnaires, interviews, group discussion, empathic modelling, user trials, scenarios and personas, prototyping, cooperative and participatory design, etc. [16]. To achieve a diverse view of users' needs, user participation should be including users with different disabilities as a representative. However, some of the user participation methods have limitations to adopted into user requirements elicitation with certain users [16]. From these methods and techniques direct observation, scenarios, personas, and prototyping are evaluated to be appropriate as such for use with user groups with motion, vision, hearing, or cognitive and communication disabilities [16]. However, the information derived from observation, scenarios, and personas is mostly produced by the researcher, which means that only the use of a prototype can be classified as one that produces user-oriented information and can be used with users with disabilities without adjustment. Factors in the value chain refer to the accessibility implementation process that includes different stakeholders and their input to the realisation of accessibility.

3 Design Science Methodology

We designed our study based on design science research process model by Peffers et al. (2007) [18] (see Figure 1.). Present study focus on extending a scheme for design principles proposed by Gregor et al. (2020) [6]. Thus, we started with the objective-centred solution entry point [18]. We aimed to improve [15] existing scheme [6] with the relevance that makes the scheme more accurate and adaptable for accessibility-related DSR. Therefore, we first defined objectives of a solution.

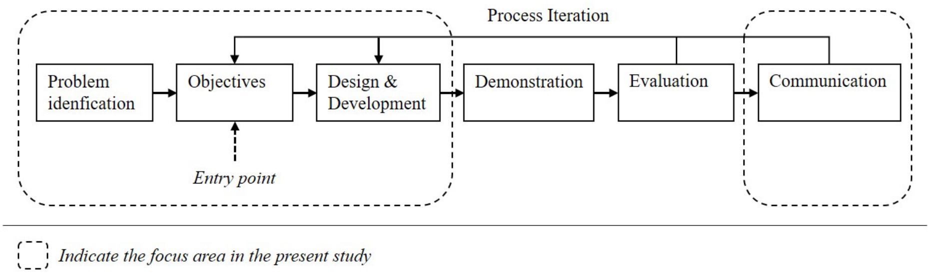

Figure 1: Research Process Model
Source: Adopted from [18].

To define objectives, we performed a literature search to draw accessibility domain specific characteristics that should be included and addressed in design principles for HCI instantiations. We adopted kernel theories such as the International Classification of Functioning, Disability and Health (ICF) agreed upon by the World Health Assembly [19], which helped us to identify variations in human abilities. ICF is commonly used by disability experts in governments and other sectors [20]. Then, we based the search within the lens of the following components of the design principle scheme [6]: instantiation, context, mechanism, enactor, and user. We reasoned and drawn attributes related to the interaction with an HCI artefact. In this paper, we conducted three first step in design science research process: problem identification; definition of objectives; and design and development [18]. We adopted existing knowledge [11], and the construction of the first version of the extensions. We also included the communication phase to the present study as we plan to develop the first proposal based on peer-reviewing process [18]. In Demonstration, and Evaluation phase, we will apply and demonstrate the results with focus group including accessibility researchers and evaluate the feasibility by interviewing accessibility researchers.

4 Theoretical Extensions to the Scheme for Formulating Design Principles in Accessibility-Related DSR

In this section we illustrate the extensions to a scheme for design principles. The extensions are intended for accessibility-related research to incorporate accessibility to produce more accurate design principles. Figure 2. illustrate the components of design principles [6] and indicates our proposed attributes of these components that should be specified in a case of accessibility-related research.

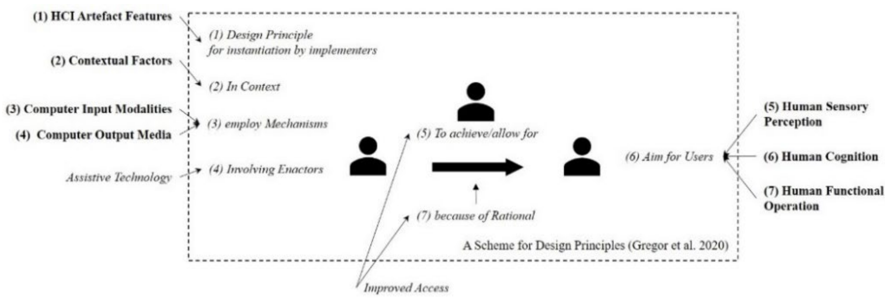

Figure 2: Extensions for Components for Design Principles
Source: Area inside the dotted line is adopted from [6].

The knowledge i.e. building blocks are draw from the following kernel theories: Studies [21,22] related to HCI artefact features; [23–27] related to Contextual factors; [6,28] related to Computer Input Modalities; [28] related to Computer Output Media; [20,28,29] related to Human Sensory Perception; and [29–33] related to Human Cognition. Component numbers four and seven in the original scheme for design principles [6] are extended with the considerations of assistive technology as one part of enactors, and "Improved Access" as a goal of design principles related to accessibility. As follow, extensions for the components for design principles are described:

(1) HCI Artefact Features: HCI artefact instantiations such as websites and user interfaces can be sorted into specific features, where users interact with the artefact trough the content, presentation style, functionality, interaction style, and structure

[21,22]. Users construct their own conceptual version of the nature of an artefact with their personal judgment. This judgment is influenced by emotional consequences such as pleasure, satisfaction, etc. as well as behavioural consequences, such as the time spend with artefact [21].

(2) Contextual factors: The context of use can affect users' abilities. The context of use may vary due to environmental factors, including users' emotional state, sociocultural factors, socio-technical factors, whereby cultural, political, sociological, and historical aspect of context [23–26]. Moreover, user expectations of artefact behaviour often rely on past experiences, prejudice, evoked memories, unmet expectation, and conviction that strongly influences how users perceive and experience the accessibility [27]. Furthermore, the expectations are related to the history of context and the emotional state.

(3) Computer Input Modalities: Mechanisms, such as acts, activities, and processes [6] in a case of HCI artefact relate to mechanisms how user interact with the HCI artefact. Referring to basic model of HCI by [28], mechanisms include modalities that user can provide input for HCI artefact: movements, force, sound, images [28].

(4) Computer Output Media: After the computer has received input from a user, it processes the data and provide an output for the user with modalities such as visual, auditive, tactile, olfactory, gustatory, or vestibular [28].

(5) Human Sensory Perception: Human sensory perceptions can differ in terms of abilities in sight, hearing, touch, smell, taste, and balance [20,28,29].

(6) Human Cognition: Cognitive ability are different for everyone [32,33]. It is therefore necessary to consider each specific cognitive deficit rather than considering cognitive matters as a whole [33]. Cognitive abilities includes possible variations in focusing attention, memory, thinking and speed of processing, reading and writing, mental functions of language, calculating and quantitative knowledge, solving problems, making decisions and reaction speed, psychomotor functions and sequencing complex movements and speed, emotional functions, perceptual functions, higher-level cognitive functions and domain specific knowledge, experience of self and time functions, and comprehension-knowledge [29–31]. The awareness of individuals' cognitive abilities to perform tasks in HCI artefact and the adoption of this knowledge into the design activities are crucial for creating a successful interaction.

(7) Human Functional Operations: Human outputs for HCI artefacts , such as typing with a keyboard and using pointing devices, touch screens and others, require at least one human functional ability [34]. Human functional abilities can be classified as follows: voice and speech functions (voice functions, articulation functions, fluency and rhythm of speech functions, alternative vocalisation functions) and neuromusculoskeletal and movement-related functions (functions of the joint and bones, muscle functions, movement functions) [29]. As the interaction with HCI artefact can also be considered social interactions [35], factors related to human abilities for social interaction, such as abilities for interpersonal interactions, relationships, and communication (receiving and producing, conversation, and use of communication devices and techniques) should be considered in designing for accessibility [29].

Summing up the extensions, we devised demonstration of a checklist for researchers to incorporate accessibility in design principles (Table 1.).

Table 1: A Checklist to Incorporate Accessibility in Design Principles

HCI Artefact Features	**Context**	**Computer Input Modalities**	**Computer Output Media**	**Human Sensory Perception**	**Cognition**	**Human Functional Operation**
What feature are you addressing?	What are contextual factors influencing your target?	In what way the computer will take the input from user?	How is the information presented?	With what sense the user receives the information?	What human cognitive abilities are addressed?	How the user performs the action?
☐ Content ☐ Presentational style ☐ Functionality ☐ Interactional style ☐ Structure ☐ other…	☐ Environmental ☐ User's emotional state ☐ Socio-cultural ☐ Socio-technical ☐ Cultural ☐ Political ☐ Sociological ☐ Historical ☐ other…	☐ Movements ☐ Force ☐ Sound ☐ Images ☐ other…	☐ Text ☐ Image ☐ Video ☐ Graphs ☐ Tables ☐ Sound ☐ other…	☐ Sight ☐ Hearing ☐ Touch ☐ Smell ☐ Taste ☐ Balance	☐ Focusing attention ☐ Memory ☐ Thinking and speed of processing ☐ Reading and writing ☐ Mental functions of language ☐ Calculating and quantitative knowledge ☐ Solving problems ☐ Making decisions and reaction speed ☐ Psychomotor functions and sequencing complex movements and speed ☐ Emotional functions ☐ Perceptual functions ☐ Higher-level cognitive functions and domain specific knowledge ☐ Experience of self and time functions ☐ Comprehension-knowledge	☐ Movement ☐ Voice ☐ Sight

The checklist in Table 1. is not, however, comprehensive. The checklist does not separate different severity levels in human abilities. Moreover, all variables in computer input modalities, computer output media, and in contexts are not presented. However, the checklist is intended for researchers in accessibility-related research to incorporate a wide aspect of accessibility and improve accuracy by identifying attributes relate to context, human abilities, and interaction. For example, studies exploring IT use of blind individuals often ignore the fact that these same individuals may have variations in cognitive abilities. The checklist therefore helps to specify more accurately what human factors the design principles intend to cover.

5 Conclusion and Next Phases

In this paper, we presented a tentative illustration of the extensions to a scheme for design principles. Our extensions are intended for accessibility-related research to incorporate accessibility to produce a more accurate formulation of design principles. We aim to contribute improvements to a scheme for design principles presented by [6] so that they are more adaptable to accessibility-related DSR. We provided seven attributes to extend the components of design principles and devised a checklist for researchers to incorporate accessibility in design principles. We conducted three first step of design science research process: problem identification; definition of objectives; and design and development. Next, we will conduct the evaluation of proposed extensions. We will apply the Demonstration, and Evaluation phase [18], and include accessibility researchers to evaluate the usefulness of the extensions.

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