

**Design Principles and Implementation Factors for Performance Support Systems
in Rare, Frequent, and High-Risk Work Processes: A Scoping Review**

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Abstract

The use of performance support systems in the workplace has increased in recent years. These systems can be used to enhance job performance and facilitate workplace learning. However, a lack of clear strategies or guidelines during the early design phases leaves organisations, including the Ministry of Defence, uncertain about where to begin the design process. This thesis presents a scoping review to identify design principles and implementation factors for designing long-term, technology-based performance support systems. Based on a literature search using Web of Science, Scopus, ERIC, and PsycINFO, 32 studies met the inclusion criteria. The review identifies specific design principles for frequent, rare, and high-risk work processes for low- to high-experienced users. Key principles include user-centred design, balancing support and autonomy, step-by-step instruction, and integration with familiar systems. Additionally, this thesis highlights implementation factors, including training and support familiarise with the system and system maintenance. These findings provide organisations with design principles and implementation factors to enhance job performance and workplace learning through long-term, technology-based performance support systems.

Keywords: performance support, job performance, workplace learning, design principles, implementation factors

Table of Contents

Abstract.....	2
Introduction.....	5
Context of the research	6
Theoretical Framework.....	7
Workplace Learning.....	8
Job Performance	10
Perspectives on Performance Support Systems	11
Experience Levels and Task Types.....	12
Technology and Performance Support Systems.....	13
Components of Technology-Based Performance Support Systems.....	14
Final Definition of Performance Support Systems.....	15
Research Questions	15
Methodology	16
Study Design	16
Literature Search	17
Inclusion Criteria.....	18
Identification of Studies.....	19
Data Extraction.....	20
Data Analysis.....	21
Results.....	21
Design Principles.....	23

User-Centred Design	23
Supporting Frequent Work Processes	27
Supporting Rare Work Processes	30
Supporting High-Risk Work Processes	32
Implementation Factors	35
Discussion	38
Theoretical Implications	39
Interwovenness.....	40
Formality.....	40
Directedness	40
Limitations	41
Practical Recommendations and Future Research	42
References	44
Appendix A: Search Log.....	53
Appendix C: Overview of Included Studies	57
Appendix D: Frequency Table User-Centred Design Principles.....	60
Appendix E: Frequency Table Design Principles.....	62

Introduction

In today's fast-paced work environment, driven by rapid advancements in information and communication technologies, the skills, behaviours, and knowledge required for effective job performance have become increasingly complex (Tynjälä, 2008; Van Laar et al., 2020). This complexity underscores the need to continually upskill workforce capabilities to ensure agility and sustained value (Steel, 2022). Organisations must implement solutions to meet the increasing need for learning and performance (Yakin & Yildirim, 2016). Technology-based performance support systems can help employees meet these demands while performing their tasks (Karakaya-Ozyer & Yildiz, 2022).

The term performance support systems has been conceptualised in various ways, leading to a lack of consensus regarding its precise meaning. In general, performance support systems provide employees with the necessary tools, information, and guidance precisely when needed to accomplish tasks (Gery, 1991; Reiser & Dempsey, 2017). Access to information through resources such as printed documents, computers, and mobile devices helps employees perform their work without interruption, enhancing their performance and learning with minimal external support (Noe, 2017; Van Tiem et al., 2012). Performance support systems bridge the gap between performing and learning across all career stages, ensuring employees can meet the complex job demands (Leiß et al., 2022).

The use of performance support systems in the workplace has increased in recent years (Askar, 2018). These systems are used for various stakeholders, such as undergraduate students (Sezer, 2021), HR employees (Leiß et al., 2022), instructional designers (Ugur-Erdogmus & Cagiltay, 2019), NATO employees (Dolowitz et al., 2023), and CSI officers (Yakin & Yildirim, 2016). Although various performance support systems have been introduced in different contexts, no studies have been found that assess clear strategies or guidelines for the initial design phase. This results in organisations, including the Ministry of

Defence, being uncertain of where to begin in the design process. Designers of performance support systems often prioritise technical aspects, which can overshadow the educational and didactical design components essential for enhancing performance and learning (Kalota & Hung, 2013). A structured approach in the initial design phase of performance support systems is crucial for achieving optimal learning outcomes (Carvalho, 2018).

Design principles guide the initial choices in the design process of systems (McKenney & Reeves, 2019). These principles serve as practical guidelines or heuristics, providing a structured approach to the design of learning systems (Herrington et al., 2009). However, even the most well-designed performance support systems may face challenges in adoption, if they are not effectively implemented (Sumner & Yildirim, 2015). Therefore, it is crucial to identify and understand the factors that influence the adoption of these systems in the workplace (Carvalho, 2018). Implementation factors are elements, criteria, and practical considerations which are crucial in the successful integration and use of new tools within an organisation (Lee et al., 2017). By identifying design principles and implementation factors, this thesis can assist organisations in designing effective performance support systems that enhance job performance and facilitate workplace learning for various users and tasks.

Context of the research

This project is carried out at the Netherlands Organisation for Applied Scientific Research (TNO), an institution focused on translating knowledge into practical solutions for companies and government agencies (TNO, n.d.). The research is conducted within the Defence, Security, and Safety unit, which provides innovative solutions to enhance the overall safety and security of the Ministry of Defence. TNO and the Ministry of Defence are partners in defence and security innovation. The current research being commissioned by the Ministry of Defence and conducted by TNO.

The Ministry of Defence is interested in implementing performance support systems in the workplace to efficiently train employees and ensure deployment readiness in a constantly changing environment (Ministry of Defence, 2022). The educational vision of the Ministry of Defence prioritises aligning learning and education with the employees' needs and tasks at all times (Ministry of Defence, 2016). This vision emphasises learning the right amount of information at any time and from any location (just in time, just as needed, just in place) facilitated by learning technologies (Ministry of Defence, 2022). It focuses on maintaining the employability of the workforce through increased efficiency, productivity, and motivation (Ministry of Defence, 2016). Performance support systems align with this vision by giving learners control and responsibility over their own learning (Ministry of Defence, 2022).

Given the existing uncertainty in the design process, this thesis aims to develop and provide clear design principles and implementation factors. These principles and factors, derived from the literature, will assist organisations in creating effective performance support systems. This approach seeks to enhance job performance and facilitate workplace learning, thereby addressing the initial challenges faced by organisations such as the Ministry of Defence.

Theoretical Framework

Since the definition of performance support systems varies among researchers, it is essential to clarify how the multifaceted term is constructed. The theoretical framework will help to elaborate the definition, which has been divided into six parts, each addressing a related concept. The first part deals with workplace learning, the process and outcome of performance support systems. In the second part, job performance discusses job performance, which is facilitated by performance support systems, is examined. The third part discusses the short-term and long-term perspectives of performance support systems. It will then discuss the experience levels and task types appropriate for performance support systems. The fifth

part deals with an overview of various technologies and components of performance support systems. The final part will combine all the sections and create a final definition for performance support systems.

Workplace Learning

Workplace learning is the process of upgrading skills and acquiring knowledge in the workplace, where learning and work processes are integrated (Billett, 1995). Kyndt et al. (in press) identify three aspects of workplace learning: interwovenness, formality, and directedness. Interwovenness focuses on the degree to which learning activities are integrated with work processes. Formality indicates the level of organisation and facilitation within these learning processes. Directedness involves the learner's intention towards learning, ranging from externally directed to self-directed or undirected. In the context of these three aspects, performance support systems are interwoven with the work process, self-directed, and usually take place informally.

Workplace learning encompasses a spectrum from formal to informal activities. Formal learning is structured with clear support, time, context, and objectives, often delivered as courses by a teacher (Kyndt & Baert, 2013). Traditional training, an example of formal learning, follows a systematic approach with a structured curriculum, a controlled environment, and instructor-led sessions.

In contrast, informal learning occurs spontaneously, lacking preparation and organisation regarding support, time, context, activities, and objectives, making it more self-directed (Kyndt & Baert, 2013). Performance support, a relatively recent approach compared to traditional training, often happens in informal contexts. It involves tools and systems that provide immediate, on-the-job assistance, helping learners to perform tasks without the need for prior formal instruction (Moore & Klein, 2020). Typically, performance support systems operate within informal settings, where learning happens as a byproduct of everyday

activities. However, these systems can also be adapted for formal settings, assisting learners in navigating, and adjusting to the new system during structured training.

Table 1 outlines key distinctions across various categories to highlight the differences between traditional training and performance support (Atay et al., 2022; Gal et al., 2017; Van Tiem et al., 2012).

Table 1

Comparison of Traditional Training versus Performance Support Systems

Characteristic	Traditional training	Performance Support Systems
Learning	Formal	Mainly informal; formal possible
Environment	Classroom, laboratory, or online	Workplace and on-the-job
Control	Instructor control	Employee control
Duration	One-time	Continuous process
Training materials	Function-oriented, general, and abstract	Task-oriented, specific, and concrete
Unit size	Comprehensive and lengthy	Just enough for the task on hand and modular
Focus	Knowledge and skill transfer	Job performance, with workplace learning as both the focus and outcome
Timing	Before performance	Before, during and after performance
Audience	Small and homogeneous groups	Heterogeneous groups with broad participation
Interaction	Social events and personal interaction	Individual process and human-computer interaction

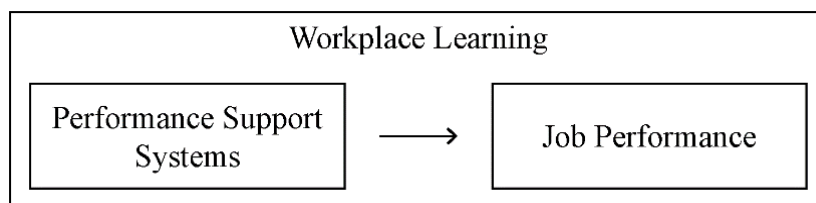
Note. Adapted from Atay et al. (2022), Gal et al. (2017) and Van Tiem et al. (2012).

The table above shows traditional training as a more structured approach to learning, whereas performance support systems offer flexibility across various dimensions. The main goal of performance support is to enhance job performance, with workplace learning serving as both the means and the end. Workplace learning describes how learning occurs within the work environment and reflects both the process and the outcome of performance support systems (Tynjälä, 2013). Figure 1 illustrates the connection between workplace learning and

job performance, emphasising how learning activities within the workplace contribute to improved job performance.

Figure 1

Relation among Performance Support Systems, Job Performance, and Workplace Learning



Job Performance

Job performance refers to the individual actions and behaviours that employees participate in that are related to and contribute to organisational goals (Viswesvaran & Ones, 2000). Understanding job performance is crucial for evaluating the effectiveness of performance support systems, as these systems help to enhance employees' task performance and overall contribution to organisational success. Job performance consists of three dimensions: task performance, organisational citizenship behaviour, and counterproductive behaviours (Viswesvaran & Ones, 2000). The present study focuses on task performance, which can be defined as how well employees carry out their prescribed job tasks (Koopmans et al., 2011). Performance support systems are designed to enhance these job tasks, thereby improving the overall task performance. Key aspects of task performance include work quantity and quality, job skills, and job knowledge (Rotundo & Sackett, 2002). Job performance has a direct influence on the success and growth of an organisation (Campbell & Wiernik, 2015). Thus, the overall definition of performance support systems should include job performance and workplace learning as objectives.

Perspectives on Performance Support Systems

Given the importance of integrating job performance and workplace learning into the definition of performance support systems, it is essential to recognize that definitions can vary among researchers. Two perspectives on performance support systems can be identified. On one hand, performance support systems can be viewed as an external information storage, serving as a substitute for the user's memory (Gal et al., 2017). Since the system relates to the current performance only and learning is not the intention, Van Schaik (2010) refers to this perspective as a short-term system. Principles such as product assurance or safety may support the use of short-term systems. A well-known example is the assembly manuals of IKEA, which will help the user assemble the product without the intention to learn.

On the other hand, the long-term perspective views performance support systems as a performance and learning tool, often referred to as performance and learning support (Gal & Nachmias, 2011). The user can use the system to see how to perform a task and learn from it. The goal is to provide guidance which enhances job performance and facilitates learning, which will help to make the employee less reliant on the guidance of other employees (Bragg & Brunskill., 2019). Van Schaik (2010) refers to this approach as a long-term system that helps to gain knowledge and skills needed for future performance. Learning at the workplace occurs as a byproduct or consequence of performance, whether ideal or not, in the long-term system (Leiß et al., 2022). An example of a long-term support system is a spelling and grammar tool. This tool provides the user with feedback on spelling and grammar, immediately improving the user's performance. The user is expected to learn through explanations of why a correction is suggested.

Throughout this thesis, the focus is on the long-term performance support systems, which facilitate learning at the workplace and result in higher job performance.

Experience Levels and Task Types

Long-term performance support systems can be used to enhance job performance with workplace learning as a byproduct (Leiß et al., 2022). Moreover, the success level of the system can be influenced by the user's experience level and the task type (Gal & Nachmias, 2011). In this way, performance support systems can ensure that minimal support is needed from other employees to guide a job task. Zaguri and Gal (2016) and Van Tiem et al. (2012) developed a model to determine whether performance support systems are useful based on the user's experience level and task type. The model distinguished between three experience levels: zero (no experience inside the organisation or task), low to medium (experience inside the organisation and with similar tasks), and high (experience within the organisation and with the task). Furthermore, the model identified three task types: frequent, rare, and high-risk. In Table 2, the model defines performance training as formal training that involves learning how to use the performance support system.

Table 2

System Selection Model

Task type	Experience level		
	Zero	Low to Medium	High
Frequent	Performance Training	Performance Support	No Intervention
Rare	No Intervention	Performance Support	Performance Support
High-risk	Performance Training	Performance Training	Performance Support

Note. Adapted from Van Tiem et al. (2012) and Zaguri and Gal (2016).

Prior knowledge influences the effectiveness of performance support systems (Nguyen, 2009). For low-experienced users, providing performance training to familiarise them with a performance support system can be beneficial. In contrast, for high-experienced users, these systems can provide redundant support to refresh their knowledge (Nguyen,

2009). However, for high-experienced users performing frequent tasks, these systems might become counterproductive, causing an expertise-reversal effect (Nguyen, 2006). This effect occurs when detailed support leads to cognitive overload, making systems that help novices ineffective or harmful to experts (Kalyuga, 2007). Performance support systems can still be beneficial for medium- and for high-experienced users performing rare or high-risk tasks.

Therefore, it is important to consider the task type and user experience level when designing a long-term performance support system (Nguyen, 2006). Effective use of these systems can increase productivity, reduce errors, and improve work quality (Gal et al., 2017; Sumner & Yildirim, 2015). As shown in Table 2, performance support systems can be effective for low- to medium-experienced users in frequent, rare, and high-risk tasks and for high-experienced users in rare and high-risk tasks.

Thus, this thesis will focus on low- to medium-experienced users for frequent, rare, and high-risk tasks, ensuring that performance support systems are applied where they can have the most significant impact, enhancing overall productivity and reducing errors.

Technology and Performance Support Systems

Performance support systems have evolved across various technologies. Initially, paper-based job aids replaced formal training to save costs and improve performance (Duncan, 1985). In the 1990s, Gloria Gery introduced Electronic Performance Support Systems (EPSS), integrating computer-based guidance into the work environment (Gery, 1991). EPSS enhance the functionality of traditional job aids by integrating computer-based systems into the work environment to give interactive, dynamic guidance at the moment of need (Gery, 1991). With the increasing popularity of wearable and mobile devices in the workplace, mobile performance support systems (MPSS) emerged, with the advantage of being carried out easily (Huang & Klein, 2023). This thesis focuses on technology-based

performance support systems, broadly using the term performance support systems for electronic and mobile systems.

Components of Technology-Based Performance Support Systems

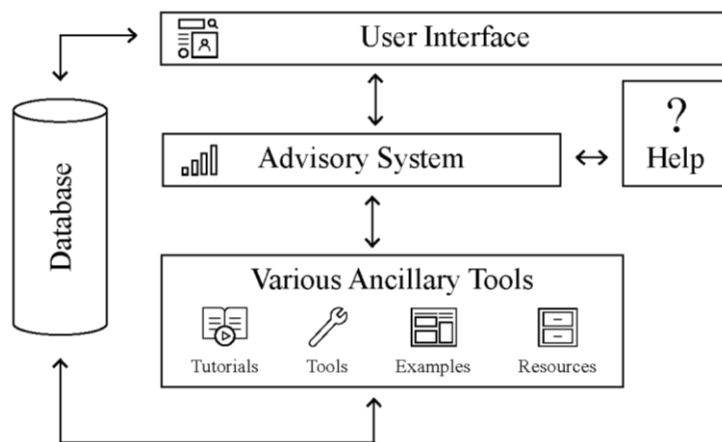
The literature on performance support systems identifies four essential components that all technology-based systems must include (Alparslan et al., 2008; Karakaya-Ozyer & Yildiz, 2022; Sezer, 2021).

- (1) An advisory system guides users and provides real-time guidance and scaffolding. It ensures seamless navigation across the system.
- (2) A database is the central location where all the information is stored.
- (3) The ancillary tools consist of various applications and tools to enhance performance improvement and facilitate learning.
- (4) The online help guides users in using the system and offers practical recommendations for optimal use.

The user interface is the linchpin of the four components, enabling users to access all necessary components and easily navigate through them (Hung et al., 2010; Ugur-Erdogmus & Cagiltay., 2019). Figure 2 shows a visual representation of the connections between the components.

Figure 2

Overview of the Component Structure within a Performance Support System



Note. Adapted from Alparslan et al. (2008) and Ugur-Erdogmus and Cagiltay (2019)

Final Definition of Performance Support Systems

The term performance support systems has been interpreted differently among researchers over time. These systems can take various forms and use various technologies to support the user in performing job tasks. In this thesis, performance support systems will specifically refer to long-term, technology-based performance support systems. To align with this focus, the following definition synthesises key elements from existing definitions:

Long-term technology-based performance support systems provide steps, procedures, and relevant information accessible through various technologies to give employees the right task-specific information precisely when needed. These systems are designed to be part of the real work environment to improve performance and learning with minimal support from others (Gery, 1991; Leiß et al., 2022; Noe, 2017; Van Tiem et al., 2012).

Research Questions

The thesis will explore the design principles and implementation factors for creating effective long-term technology-based performance support systems. To achieve this aim, the study will perform a scoping review guided by the following two research questions:

- (1) What design principles identified in the literature for designing effective long-term technology-based performance support systems for frequent, rare, and high-risk work processes?
- (2) What implementation factors identified in the literature for implementing effective long-term technology-based performance support systems?

Methodology

Study Design

This literature review employed a scoping method to address the research questions. A scoping review systematically discovers and maps characteristics or factors related to a specific concept (Munn et al., 2018). This method helps to determine the key concepts underlying a research area, the main sources, and the forms of evidence accessible (Arksey & O'Malley, 2005). In this thesis, the scoping review sought to summarise the current research in this field to derive design principles and implementation factors for long-term technology-based performance support systems.

Scoping reviews are broad and aim to cover the full spectrum of a topic. The expected outcomes of a scoping review include a comprehensive overview of the existing literature, identification of research gaps, and recommendations for further research (Munn et al., 2018). Unlike systematic reviews, scoping reviews do not assess the quality of individual studies but map the evidence to inform future research (Arksey & O'Malley, 2005). The scoping review mapped evidence by identifying themes and trends, guiding where further high-quality research is needed.

The scoping review followed guidelines proposed by Levac et al. (2010) to review the included studies. The phases and the prescribed reporting guidelines aim to enhance the replicability and overall quality of the scoping review process. The phases are as follows:

- (1) Identify the research question: Define the scope and objectives.

- (2) Identify relevant studies across several databases: Conduct database searches.
- (3) Select studies based on inclusion criteria: Filter studies according to PRISMA-ScR guidelines.
- (4) Chart data: Extract and organise information.
- (5) Summarise and report findings.

To ensure a systematic selection of studies, this thesis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines for selecting studies (Tricco et al., 2018). These guidelines align with the steps outlined by Levac et al. (2010) and provide a detailed framework for the selection process. The PRISMA-ScR guidelines have four phases:

- (1) Identification: Relevant studies are found using keywords and database searches.
- (2) Screening: Studies are selected based on predetermined criteria.
- (3) Eligibility: Studies are reviewed to ensure they meet the inclusion criteria.
- (4) Inclusion: The remaining studies are evaluated.

Literature Search

Three approaches were used to identify relevant studies, including a comprehensive search strategy to arrive at relevant literature. First, the various electronic databases were consulted (see Table 3). In addition, the first hundred hits on Google Scholar were searched for grey literature that may have been overlooked.

Table 3*Databases Used for the Scoping Review*

Database	Reason
Scopus	Multidisciplinary research
Web of Science	Multidisciplinary research
ERIC	Wide range of educational research
PsycINFO	Wide range of psychology and behavioural research
Google Scholar	First 100 hits for grey literature

A scoping search was performed to identify the keywords, see Appendix A for the search log. The scoping search assisted in refining the terms, using the correct Boolean operators, and included extra key terms. The following search string was used:

(“Performance support” OR “job aid*” OR “job performance aid*” OR “mobile performance support*” OR “electronic performance support*”) AND (“performance” OR “learning”) NOT (“sport*” OR “high performance support” OR “vector machine*” OR “vector regression” OR “carbon*” OR “nano*” OR “cataly*” OR “retrospective”)

Second, a manual search was conducted in two journals, Performance Improvement Quarterly and Performance Improvement Journal due to their unique focus on performance improvement and many relevant articles. Third, the snowball technique was used to look for literature within previously discovered literature. The snowball technique involves utilising the reference list or citations of the relevant studies to locate additional studies that were missed in the initial search (Wohlin, 2014).

Inclusion Criteria

This study used seven inclusion criteria. When a publication did not fulfil one of the specified criteria, it was excluded from the data collection process. The eligibility criteria for the literature review were that the study:

- (1) was published in English.
- (2) was published in a peer-reviewed journal or conference paper.

(3) was available to the author in full-text format.

(4) focused on a technology-based performance support system.

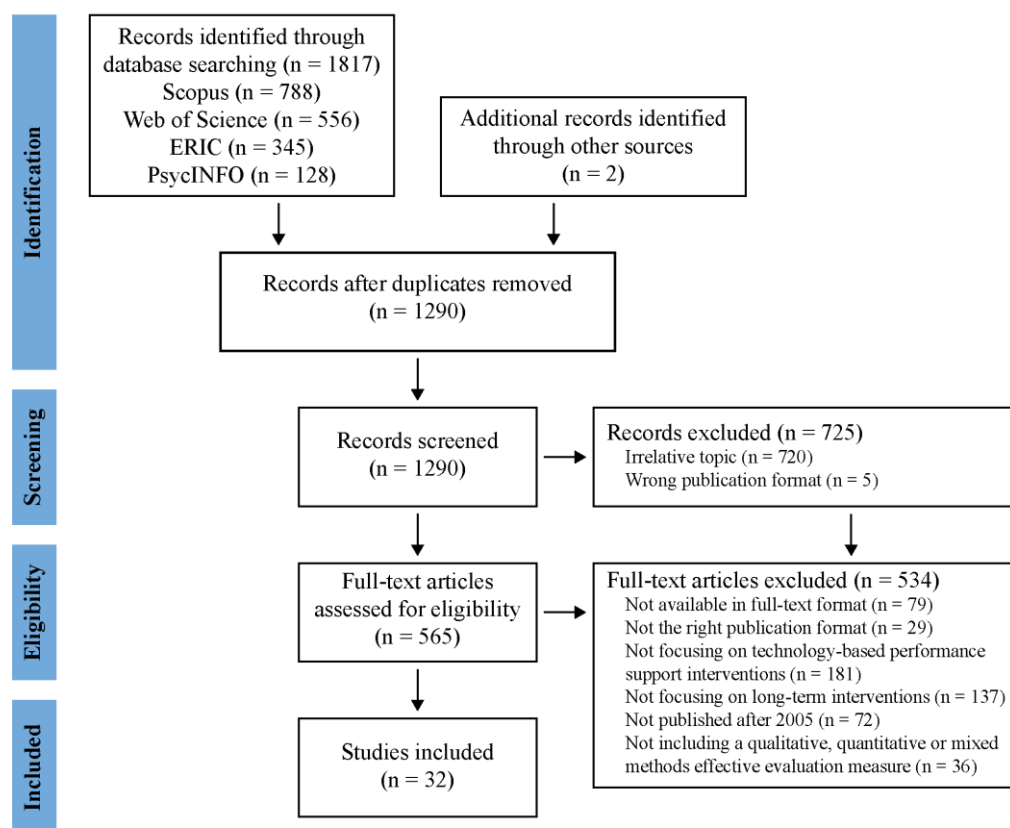
(5) focused on the long-term system perspective of performance support systems, where the performance support systems aid in performance and learning improvement.

(6) included qualitative, quantitative, or mixed methods evaluation of the performance support systems.

(7) was published after 2005. The year 2005 is chosen as a cutoff point due to significant technological advancements that have influenced the design and functionality of performance support systems. Major developments such as the emergence of Web 2.0 technologies, the rise of mobile devices at the workplace, and the adoption of cloud computing have all transformed in the design and implementation of performance support systems.

Identification of Studies

For the identification of studies, Rayan software was used, serve as a central tool for the entire review process. Rayan offers a user-friendly interface and helpful features for screening studies (Ouzzani et al., 2016). During the identification phase, duplicate studies were removed. Additionally, some studies were included through manual journal searches and the snowballing technique. In the screening phase, abstracts were evaluated, and publications that did not meet the aim of the study were excluded. During the eligibility phase, the full texts of the remaining studies were scanned and removed if they did not meet the inclusion criteria. All studies that remained after the screening were included in the review. The four phases of the PRISMA-ScR guidelines for selecting studies in this scoping review are shown in Figure 3.

Figure 3*Overview of the PRISMA Guidelines*

Note. Adapted from Tricco et al. (2018).

Data Extraction

The selected studies were examined to extract relevant data and understand their contents to answer the two research questions. The results of the scoping review were managed using a data extraction form that included the following categories: general information, research design, performance support system, design and implementation, and findings. Table 4 displays the extracted elements for each category, this extraction form is explained in more detail in Appendix B.

Table 4*Data Extraction Form*

Category	Extracted elements
General information	First author, title of publication, publication year, journal
Research design	Type of research, data sources, domain, target users
Performance support system	Experience level, task type, system explanation
Design and implementation	Design process, principles, challenges, and recommendations
Findings	Main results, other considerations

Data Analysis

The data analysis was guided by the framework of Arksey and O'Malley (2005) and Levac et al. (2010). This framework ensures a systematic approach to the data extraction and analysis with both numerical and thematic analysis (Arksey & O'Malley, 2005). First, a numerical analysis of the included studies was conducted, detailing the number of studies, publication years, research types, task types, experience levels, and study characteristics to provide an overview of the literature.

Afterwards, a thematic analysis was presented, outlining the design principles for various task types and implementation factors. This analysis involves examining the text, determining how it relates to the research questions, and creating a code (label) that reflects the text. The data extraction form, which provides an overview of all the principles, characteristics, and other findings, was then used to organize these codes and identify patterns among them (Levac et al., 2010). After the thematic analysis, the results were summarised and reported.

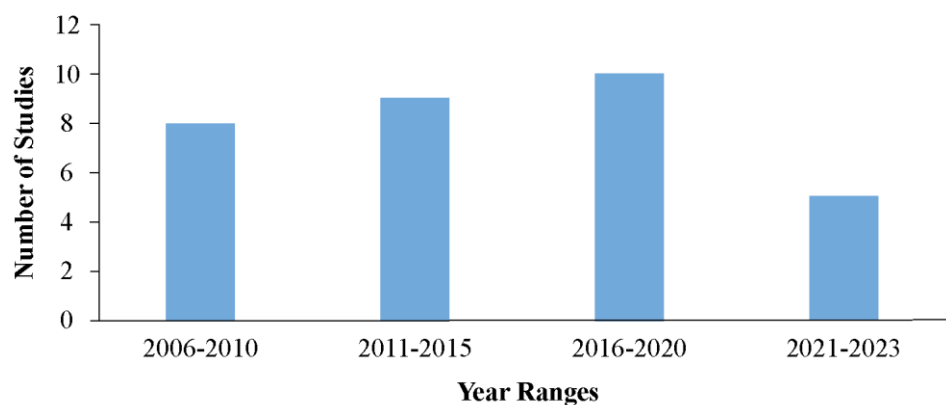
Results

Thirty-two studies that met the inclusion criteria were identified through a systematic search and screening process guided by PRISMA-ScR guidelines. An overview of the numerical analysis of the included studies is provided in Appendix B. Figure 4 shows an

overview of the publication years of the included studies, which were published between 2006 and 2023.

Figure 4

Overview of Publication Years



In addition to publication years, the domains of the performance support systems were examined since they have the potential to be effective in a variety of contexts. Table 5 summarises the various domains and target users considered in this scoping review. Some studies target both professionals and students, which results in overlapping counts.

Table 5

Domains of Included Studies

Domain	Target users		Total
	Professionals	Students	
Education	7	12	15
Health Care	1	3	3
Security and Defence	6	1	7
Industry and Engineering	4	0	4
Information Technology and Telecommunications	3	0	3
Total	21	16	32

The included studies in this scoping review examine performance support systems across various work domains. The education domain has the highest number of studies due to the ease of conducting research in educational settings and the broad applicability of educational research. In domains such as healthcare, security and defence, industry and engineering, and information and telecommunications, most studies focus on professionals. However, there were too few studies exclusively within the professional workplace learning context, necessitating the inclusion of research targeting students. Including students and the educational domain ensures a broad overview and a balanced perspective on the topics studied within performance support systems. Detailed descriptions of the target users and the descriptions of the systems can be found in Appendix B.

Design Principles

The following sections introduce the design principles for frequent, rare, and high-risk work processes identified through a scoping review of the literature. These principles represent a synthesis of findings from various studies. To answer the first research question, the general design principle of the user-centred design approach will be first explained. This approach, supported by extensive research, is recognised for its effectiveness in enhancing usability and user satisfaction by focusing the entire process around the user (Van Schaik et al., 2007; Sumuer & Yildirim, 2015).

User-Centred Design

To design effective performance support systems, it is essential to employ a User-Centred Design (UCD) approach throughout the design process (Dolowitz et al., 2023; Lee et al., 2017). UCD serves as a fundamental design principle that should guide the design process for performance support systems across all task types and experience levels.

A crucial aspect of UCD is prioritising users' needs through extensive analysis (Oestreich et al., 2019; Peters et al., 2019; Ugur-Erdogmus & Cagiltay, 2019). This involves

understanding the specific needs, contexts, and challenges faced by users and ensuring the system is tailored to meet these needs effectively (Lee et al., 2017). Furthermore, active user involvement helps to resolve usability issues by allowing users to share their experiences, preferences, and suggestions throughout the process (Dabbagh & Fake, 2017; Sezer, 2021). This process ensures that the system closely aligns with user needs and preferences, leading to more effective and user-friendly systems (Hung et al., 2010; Lee et al., 2017).

Another key aspect of UCD is iterative design, which requires designers to continuously refine the system based on user feedback (Dabbagh & Fake, 2017; Hung et al., 2010). Pilot testing, a part of this process, provides valuable insights into the system's performance in real-world scenarios, highlighting areas for improvement (Stoyanova et al., 2008). Conducting a prototyping phase early in the process allows designers to address issues before full-scale implementation, ensuring the final system is optimised for user needs (Bollen et al., 2015; Colley et al., 2014).

Table 6 provides an overview of general principles of user-centred design to consider when designing a performance support system. Not all these general principles need to be included in a performance support system, however, it is highly recommended that they are considered during the design process (Alparslan et al., 2008). It may be useful to prioritise the principles of user focus and usability, which are foundational to effective user-centred design. In Appendix C, a frequency table shows each user-centred design principle and the studies from the scoping review in which it appeared.

Table 6*General Principles of User-Centred Design*

Category	Principle
User Focus	Analyse user needs and context
User Involvement	Involve users actively throughout the process
Usability	Ensure ease of use
	Maintain a consistent interface and experience
	Provide task-specific information
	Deliver just-in-time support when needed
	Design with modularity
User Experience	Make the system learner-controlled
	Incorporate multimedia
	Adaptable to various experience levels
Iterative Design	Continuously refine and improve based on user feedback
	Conduct a prototyping phase

A UCD approach involves design principles that prioritise usability and adaptability. An inclusive and accessible design ensures that the system can be used by individuals with various experience levels (Alparslan et al., 2008; Van Schaik et al., 2007; Yakin & Yildirim, 2016). The design of the system must be adaptable, offering various layers of complexity to meet the needs of each user (Van Schaik et al., 2007).

The system should provide task-specific information, which ensures that users receive the support they need at the right moment without cognitive overload (Bollen et al., 2015). Within this task-specific information, it is helpful to use independent modular components (Dolowitz et al., 2023). Modularity facilitates easy updates or scaling, ensuring the user experience remains uninterrupted (Bollen et al., 2015). Each module should function as an independent unit which could easily integrate with others (Dolowitz et al., 2023). This modularity allows users to interact with the system in a non-linear way, accessing only the modules relevant to their specific tasks. Users can control their own learning paths and access the information just-in-time when they need it (Dolowitz et al., 2023; Stoyanova-Petrova et

al., 2012). Ideally, each module should be designed to be five minutes or less with a clear learning objective (Dolowitz et al., 2023).

Consistency in visual design and fixed positioning throughout the system helps the user to navigate easily and access information at the moment of need (Bollen et al., 2015). Immediate access to information is crucial, as it reduces the time users spend searching for necessary resources, thereby enhancing their productivity and satisfaction (Karakaya-Ozyer & Yildiz, 2022; Nguyen, 2009). Since the system is self-directed, non-linear, and learner-controlled, the role of the instructor changes from teaching to support the learning process (Alparslan et al., 2008; Gal et al., 2017).

Incorporating various forms of multimedia can enhance the effectiveness and reduce cognitive load (Mitchem et al., 2013; Stoyanova et al., 2008). Multimedia elements, such as videos, animations, and interactive simulations, can present information in more engaging and understandable formats, providing multiple ways to access and process information (Stoyanova et al., 2008).

A straightforward and easy-to-use user interface is necessary to maintain all the user-centred principles within a system (Hung et al., 2010; McKenney, 2008; Ugur-Erdogmus & Cagiltay, 2019; Van Schaik et al., 2007). Since the user interface is the initial encounter of the performance support systems and the linchpin for the rest of the information (Hung et al., 2010). Therefore, a well-designed user interface is essential to ensure user acceptance (Ugur-Erdogmus & Cagiltay, 2019). Simple and consistent interfaces facilitate user familiarity with frequently used features and enable seamless navigation across system components (Van Schaik et al., 2007).

Prioritising frequently used functions in the user interface is crucial, relegating fewer common functions to secondary positions (Van Schaik et al., 2007). McKenney (2008) emphasises that the performance support system should prioritise recognition over recall by

incorporating search capabilities and maintaining user progress and navigation histories.

Search and help functions should be easily accessible throughout the performance support system (Ugur-Erdogmus & Cagiltay, 2019). By minimising cognitive load, a well-designed user interface with search functionality enhances performance support systems' overall functionality and usability (Sumuer & Yildirim, 2015).

Since performance support systems may not be equally beneficial for all experience levels and task types, it is crucial to differentiate design principles for high-risk, frequent, and rare work processes (Nguyen, 2009).

Supporting Frequent Work Processes

Frequent work processes include activities that occur every day and form the core of the job responsibilities (Zaguri & Gal, 2016). Of the 32 included studies, 23 can be labelled as studies on performance support systems for frequent work processes. Table 7 shows the two principles that are specific to frequent work processes, and Appendix E presents a frequency table that shows the studies in which the design principles are involved.

Table 7

Principles for Frequency Work Processes

Design principle	Description
Balance support and autonomy	The system should provide guidance to novice users and reducing support as the experience increases to foster autonomy and minimise cognitive overload.
Integrate with familiar system	The system should ensure that performance support systems integrate with familiar systems, which increases the ease of use.

Performance support systems for frequent work processes are useful for novice users with low to medium experience (Zaguri & Gal, 2016). In contrast, high-experienced users can experience the support offered by the system as cognitive overload or redundant (Gal &

Nachmias, 2011). The section below discusses the relevant design principles to consider when designing performance support systems for frequent work processes.

Balance Support and Autonomy

The first important design principle when designing systems supporting frequent work processes is balancing support and autonomy. This principle is well-supported and mentioned by 15 of the 23 frequency work processes studies (see Appendix E). The goal is to support the learning process without hindering learner development by overwhelming with detailed instructions. However, this is one of the most challenging aspects of developing performance support systems (Bollen et al., 2015). As a result, the system should be engaging and challenging, provide just enough task-specific knowledge, and be adaptable to the user's experience level. According to Martínez-Mediano and Losada (2017), students' level of control should be adapted to their prior knowledge while encouraging them to apply new knowledge. Support levels should decrease as experience and autonomy increase (Stoyanova et al., 2008). This phenomenon is introduced in the literature as scaffolding and can help balance support and autonomy. Scaffolding assists in guiding users through the learning activities (Ugur-Erdogmus & Cagiltay, 2019). As the user's knowledge and proficient increase, the environment fades away the instructional support, allowing for greater autonomy (Hung et al., 2010; Van Schaik et al., 2006).

Stoyanova et al. (2008) illustrated a system that balances support and autonomy through scaffolding. In the engineering education system, instructional support decreased as students progressed. The system is adapted based on students' input and learning preferences, reflecting their knowledge level. Furthermore, it provided feedback informing users how well they had performed and what the next step was. It also provided recommendations based on learners' progress and learning preferences.

Incorporating scaffolding principles in performance support systems empowers learners with instructional support while fostering independence and autonomy.

Integration with Familiar Systems

The second important design principle for designing systems supporting frequent work processes is the integration with familiar systems. This principle is well-supported and mentioned by 16 of the 23 frequency work process studies (see Appendix E).

Van Schaik et al. (2007) highlighted that a common problem faced by students was the lack of awareness regarding library services and their potential to get assistance with it. To address this, strategically placing a performance support system in a familiar IT system can foster success (Read & Morasch, 2016). In higher education, this often involves a learning management system (LMS) which supports students throughout their academic journey by providing course materials, assignments, and communication channels (Van Schaik et al., 2007). Martínez-Mediano and Losada (2017) argued that performance support systems gain significant strength through integration with LMSs. By linking performance support systems directly to an LMS and strategically placing them into the system, learners can access relevant sources without leaving their familiar learning environment (Sezer, 2021).

An example is the study of Read and Morasch (2016), who designed an EPSS for information literacy instruction for university students. After placing the performance support system in a strategic position close to the course assignments within the learning management system, the usage increased significantly from 13 views per month to an average of 104 views. Read and Morasch show that the closer the link between the course assignments and the instructional support, the greater the likelihood that students will access the instructional support.

Integrating performance support systems with familiar IT systems benefits users by minimising disruptions, enhancing learning experiences, and fostering autonomy (Bollen et al., 2015).

Supporting Rare Work Processes

Rare work processes include activities that are infrequently performed during the workday, leading to the skills and knowledge required for them being easily forgotten (Zaguri & Gal, 2016). Of the 32 included studies, 5 can be labelled as studies on performance support systems for rare work processes. Notably, all five studies are classified as high-risk and rare. Table 8 shows the principle that are specific for rare work processes, and Appendix E presents a frequency table that shows the design principles and the studies in which they are involved.

Table 8

Principles for Rare Work Processes

Design principle	Description
Simulation-based environments	For rare work processes, simulation-based environments can offer real-world applications with real-time, interactive guidance which helps to improve task accuracy and efficiency.

Performance support systems for rare work processes are valuable for users at all experience levels, from low to high (Zaguri & Gal, 2016). Even when designing performance support systems specifically for rare work processes, it is essential to apply the same design principles used for frequent processes, which include balancing support and autonomy and integrating within familiar systems. The section below discusses the relevant design principle to consider when designing performance support systems for rare work processes.

Simulation-Based Environments

The design principle that is important when designing systems supporting rare work processes is simulation-based environments. This principle is well-supported and mentioned

by 5 of the 5 rare work process studies (see Appendix E). Simulation-based environments are designed to replicate real-world tasks and conditions as accurately as possible (Gal et al., 2017). These systems allow learners to experience tasks in a controlled, risk-free environment (Sezer, 2023). The focus is on realism and the direct transfer of knowledge to real-world situations (Rios et al., 2013).

Simulation-based environments prepare learners for specific, high-risk tasks by exposing them to various realistic scenarios that might not encounter during standard procedures (Rios et al., 2013). These environments are particularly relevant for rare work processes, where the opportunity to practice in real life is limited, and the consequences of errors can be significant (Rios et al., 2013; Sezer, 2023). By simulating realistic conditions, learners can enhance their skills and knowledge, leading to improved performance during actual tasks (Sezer, 2023). This is especially important in fields where precision and safety are crucial, such as aviation, medicine, and maintenance.

The focus of simulation-based environments is on accuracy and realism (Gal et al., 2017). The environments are designed to mirror the actual physical and operational contexts in which tasks take place. In the study of Rios et al. (2013), an AR-enhanced simulation replicated the exact procedures and challenges technicians faced in the maintenance of the Boeing 737 engine system. The environment ensured that the trainees were fully prepared for real-world maintenance. The AR performance support system provided real-time, interactive guidance, which helped to reduce errors and improved the quality and speed of the job tasks. The study found that AR-based training resulted in a 17% reduction in task completion time and a 24% increase in task quality compared to traditional methods.

Simulation-based environments are essential for preparing learners to perform rare and often high-risk tasks with precision and confidence. Many rare work processes involve high-risk elements, where simulation-based environments can be beneficial. When designing a

simulation-based performance support system, the physical context in which the real tasks take place must look like the authentic environment (Gal et al., 2017). Typically used in high-stakes fields such as aviation, medicine, and maintenance, where the accuracy and transferability of the skills are critical. For example, a flight simulator for pilots or a medical simulation for surgeons. The outcome is skill development and performance enhancement, with a strong emphasis on error reduction, safety, and efficiency in real-world tasks.

Supporting High-Risk Work Processes

High-risk work processes include activities where the cost of a mistake is significant due to potential impacts on safety, health, and performance (Zaguri & Gal, 2016). Of the 32 included studies, 8 can be labelled as studies on performance support systems for high-risk work processes. Five of the high-risk studies focus on human contact, where errors directly affect patient health or critical forensic outcomes (Colley et al., 2014; Peters et al., 2019; Sezer, 2023; Sumuer & Yildirim, 2015; Yakin & Yildirim, 2016). The three other studies examine mechanics, where high criticality arises from the need for precise and accurate performance in environments where mistakes can impact the operation of machinery (Gal et al., 2017; Lacontora & Mendonça, 2010; Oestreich et al., 2019). Table 9 shows the principles that are specific for high-risk work processes, and Appendix E presents a frequency table that shows the design principles and the studies in which they are involved.

Table 9*Principles for High-Risk Work Processes*

Design principle	Description
Preparation and refresher	The system should provide support before and after high-risk tasks to boost confidence and reduce errors. The support can function as preparation or as a refresher.
Step-by-step instructions	The system should offer clear, structured guidance through step-by-step instructions, ensuring accurate and efficient task performance. This approach helps users visualise each step, reduces errors, and improves safety in high-risk situations.

Performance support systems for high-risk work processes are valuable for high-experienced users since these processes require job knowledge and involve responsibility (Zaguri & Gal, 2016). As for the high-risk processes, the principle integration with familiar systems can be helpful for high-risk processes since it will help the user with a familiar layout and structure. Moreover, five of the high-risk studies involve rare work processes where the simulation-based environments can be helpful. The section below discusses the relevant design principles when designing performance support systems for high-risk work processes.

Preparation and Refresher

The first design principle that is important when designing for high-risk work processes is the unique timing of the system. This principle is well-supported and mentioned by 6 of the 8 high-risk work process studies (see Appendix E). When dealing with patient contact or high-critical safety measures, pausing the work process to get just-in-time support is challenging or not possible (Colley et al., 2014; Sezer, 2023). Therefore, having support both before and after the work process becomes crucial.

An example is the study of Lacontora and Mendonça (2010), who designed a mobile performance support system for US military automotive maintenance technicians to learn how to maintain the engines of military vehicles. The app assists in conducting engine diagnostics

in a military setting, especially under time constraints or other stressors (e.g. resource shortages). This system occurs during the preparation and reflection phases, allowing users to handle tasks more effectively within limited time constraints.

Another example is the performance support system of Peters et al. (2019), which provided practice-based information to help bridge the gap between classroom information and clinical practice for medical students. However, during patient contact, there is not much time to search for information; therefore, the support is used to refresh the competencies before the contact when a student is anxious about making mistakes or perceived weakness in the practice. Sometimes, the performance is checked afterwards to check if it was performed correctly. Peters et al. (2019) stated that the support systems helped to clarify uncertainties and gave the students more self-confidence.

In situations with high criticality due to patient contact or safety measures, the performance support systems function as a preparation or a refresher. This is especially important in the domain of health care and defence.

Step-by-step instructions

The second important design principle when designing high-risk work processes is providing step-by-step instructions. This principle is well-supported and mentioned by 7 of the 8 high-risk work process studies (see Appendix E). In high-risk situations, providing step-by-step instructions in the support system is important because it allows individuals to envision each step of practice through detailed explanations and animations (Sezer, 2023). The step-by-step instruction ensures that crucial details, such as the correct compression depth in cardiac massage, are remembered and executed effectively (Sezer, 2023).

Step-by-step instructions offer clear and structured guidance for high-risk tasks, which allows users to perform the tasks accurately and efficiently. A step-by-step instruction can

include warnings about forgotten steps, an overview of the to be followed steps, and troubleshooting tips (Gal et al., 2017; Yakin & Yildirim, 2016).

An example that included step-by-step instruction is the study of Gal et al. (2017), who designed a tablet-based performance support system for training Israeli Air Force helicopter engine technicians. The system includes step-by-step instructions accompanied by tutorial videos and troubleshooting tips, allowing users to visualise and practice complex procedures in a simulated environment. The system guides users in selecting the correct tools, referencing technical literature, and watching tutorial clips that demonstrate each procedure. This structured approach allows trainees to work more independently, improving their practical skills in a controlled, and realistic environment.

By providing clear, structured guidance, these instructions help users perform tasks accurately and efficiently, reducing the likelihood of errors that could lead to severe consequences (Rios et al., 2013). Overall, the step-by-step instructions structure the task and help to improve safety, consistency, and overall task execution in high-risk work processes (Yakin & Yildirim, 2016).

Implementation Factors

After the design of the performance support system, the final challenge to overcome is the acceptance of users for its use in everyday environments (Rios et al., 2013). Well-designed performance support systems are not automatically accepted and effectively implemented (Sumner & Yildirim, 2015). Several factors influence the adoption of a system in the workplace, all of which are helpful to identify and understand before implementation (Carvalho, 2018).

The following section introduces the implementation factors for performance support systems, identified through a scoping review of the literature, to answer the second research question. The factors represent a synthesis of findings from various studies. The

implementation factors are helpful for all the work processes including frequent, rare, and high-risk work processes. Table 10 shows the implementation factors, and Appendix E presents a frequency table that shows the factors and the studies in which they are involved.

Table 10

Implementation Factors

Implementation Factors	Description
Training and support	The organisation should offer training to users to get familiar with the performance support system to improve familiarity.
System maintenance	The organisation should have a plan to maintain and update the content of the performance support system to ensure ongoing relevance and effectiveness.

The following section discusses these two implementation factors crucial for performance support systems in all work processes.

Training and Support

The first implementation factor that is important to identify and consider before implementation is training and support. This principle is well-supported and mentioned by 18 of the 32 included studies (see Appendix E). Effective training programs are crucial for the successful implementation of support systems. Offering users a training session can significantly improve their familiarity with the system and reduce trial and error (Lee et al., 2017). The type of training depends on the complexity of the system. For more complex systems, the organisation should provide training sessions, while for simpler systems, a handbook may be sufficient (Lee et al., 2017). Hung et al. (2010) demonstrated that even a 30-minute training session before implementation can make a difference. Similarly, Nguyen (2009) showed that participants who received training and access to a performance support system exhibited more positive attitudes than those who only had access to the system. The

combination of training and EPSS helps people to be confident in the work process and provides the opportunity to refresh and validate their knowledge (Nguyen, 2009).

Mitchem et al. (2013) emphasised the need for comprehensive training sessions for teachers using a performance support system to assist secondary students with disabilities. The study highlighted that ongoing training and support significantly improved academic and behavioural outcomes (Mitchem et al., 2013). Similarly, Kalota and Hung (2010) found that pre-service and in-service teachers benefited from training to get familiar with the performance support system, which helped them integrate technology into their instruction more effectively. Kalota and Hung (2013) suggested that even though EPSS aims for a “performance from day one” attitude, allowing additional time for users to acclimate to the interface and functionality is recommended.

Training and support before the full-scale implementation can increase employees' familiarity with the system and reduce trial and error (Lee et al., 2017). The successful implementation of performance support systems requires a multifaceted approach that includes comprehensive training before implementation and continuous support during implementation. By adhering to these principles, organisations can enhance the effectiveness of these systems, leading to improved learning outcomes and job performance.

System Maintenance

System maintenance is the second important implementation factor to identify and consider before implementation. This principle is well-supported and mentioned by 22 of the 32 included studies (see Appendix E).

A key characteristic of a performance support system is that it should be easy to update and maintain (Alparslan et al., 2008; Bollen et al., 2015). Regular updates are necessary to address system issues, enhance existing tools, and keep the system relevant (Sumner & Yildirim, 2015). Without frequent updates, a performance support system can

become outdated and forgotten by employees (Lee et al., 2017). To prevent this, it is beneficial to review and refresh the content every few months to ensure it meets user needs and removes outdated information (Lee et al., 2017). Gal and Nachmias (2012) recommend planning evaluation cycles to review the system and implement updates based on these evaluations. The collection of user feedback through evaluation cycles can help to identify with areas for improvements and ensure the system continues to meet user needs (Sumuer & Yildirim, 2015). Incorporating user feedback in the updates increases the user satisfaction of a system (Sumuer & Yildirim, 2015).

Leiß et al. (2022) identified that the biggest challenge in implementing and effectively using a performance support system is the lack of resources to produce and maintain the content. To address this challenge, it is helpful to develop a plan for system maintenance and regular updates, including designating a person or team responsible for these tasks (Leiß et al., 2022). This will help the organisation to ensure that the system remains functional and useful over time.

In conclusion, effective system maintenance requires user feedback, regular updates, robust infrastructure, and continuous monitoring. Thus, creating a plan for maintenance and regular updates within the design phase is essential for the long-term success of the system.

Discussion

This thesis aims to identify the design principles and implementation factors to design effective long-term technology-based performance support systems tailored for low- to high-experienced users across various task types. By conducting a scoping review of 32 studies, the thesis helps to guide the initial design phase of performance support systems to ensure that such systems effectively enhance job performance and facilitate workplace learning. This includes addressing gaps in current strategies, offering practical insights for organisations

such as the Ministry of Defence, and contributing to the broader understanding and development of performance support systems in various professional contexts.

Theoretical Implications

In this thesis, the scoping review summarised the current research in this field to derive design principles and implementation factors for long-term technology-based performance support systems. Zaguri and Gal (2016) and Van Tiem et al. (2012) developed a model to determine whether performance support systems are useful based on the user's experience level and task type (frequent, rare, or high-risk work processes). This scoping review has used the model of Zaguri and Gal (2016) and Van Tiem et al. (2012) as structure to frame the design principles for various task types for frequent, rare, and high-risk work processes.

The main goal of a performance support system is to enhance job performance, with workplace learning serving as both the means and the end. Workplace learning characterises the process underlying job performance by describing how learning takes place in the workplace. It reflects both process and outcome of performance support systems (Tynjälä, 2013) and leads to job performance. Workplace learning, as defined by Kyndt et al. (in press), includes learning that is integrated into work processes (interwovenness), ranging from formal to informal (formality), and varies in the degree to which it is directed by the individual or external factors (directedness). The design principles and implementation factors identified in this review emphasise the need for performance support systems. These systems should be specifically designed to support learning that is interwoven with daily work tasks, accommodates varying degrees of formality, and facilitates both self-directed and externally directed learning.

Interwovenness

Effective performance support systems must seamlessly integrate into the workflow, providing support without interrupting the work process. To achieve seamless integration, the system should actively involve user throughout the design phase and continuously refine based on their feedback. For frequent tasks, the system should balance support and autonomy, ensuring that the system is integrated into a familiar system. For rare and high-risk tasks, simulation-based environments and preparation tools help integrate learning into the workflow by providing risk-free practice environments and refresher training.

Formality

Performance support systems are designed to support users exactly when and where needed by combining formal and informal learning elements. Formal learning includes structured elements like modular components, step-by-step instruction, or simulation-based environments, which are useful for tasks that require in-depth understanding. On the other hand, informal learning involves task-specific support at the moment of need, which is crucial when a user needs a quick reference or encounters an unexpected problem. By combining formal and informal elements, performance support systems provide the support that is both comprehensive and flexible. This flexibility ensures that users with various experience levels can perform tasks efficiently and effectively.

Directedness

Performance support systems should support varying degrees of directedness, which involve the learner's intention towards learning, ranging from externally directed to self-directed or undirected. This means the system should be flexible enough to accommodate to different levels of guidance, allowing for both self-directed learning opportunities and more structured support. The performance support systems should incorporate various forms of multimedia, be learner-controlled, and allow for self-directed, non-linear navigation.

However, when it comes to high-risk tasks with preparatory and refresher tools, structured guidance through step-by-step instruction is essential to ensure safety and performance.

In summary, an effective performance support system must balance the autonomy to support self-directed learning with the necessary support for high-risk tasks, depending on the user's needs and context.

Limitations

This thesis has several limitations that should be acknowledged. The major limitation of this study is the potential bias derived from the study being conducted by a single reader. Following the suggestion of Stoll et al. (2019), future research should involve multiple independent readers for screening and data extraction to enhance reliability and minimise errors.

Another limitation of this study is the variability in terminology to describe performance support systems. Terms such as 'performance support', 'job aid', 'digital job performance aid', and 'EPSS' are used interchangeably, leading to inconsistencies, and potentially missed relevant studies. Following the recommendation of Levac et al. (2010), further studies should aim to expand their search strategies by incorporating a broader range of synonyms, alternative spellings, and by searching across a wider range of databases. Inconsistencies in terminology can lead to confusion in literature reviews and potential in the retrieved data.

A limitation of this study is that many of the included studies focus on a performance support system specifically designed for students. This might skew the results, given a limited number of studies focusing on professionals in the context of workplace learning and performance support systems. The inclusion of students may affect the generalisability of the findings to actual workplace settings. Future research should aim to include a higher number of studies focusing on professional settings to ensure more relevant and applicable results.

Finally, this study found limited research on rare and high-risk work processes compared to studies on frequent work processes. This imbalance could skew the findings and limit their relevance to rare and high-risk contexts. Future research should strive to include a broader range of study types to better address the needs of rare and high-risk contexts. However, if more studies are not available, future research should consider exploring sources beyond peer-reviewed studies.

Practical Recommendations and Future Research

The insights from this thesis can guide the design of performance support systems to enhance job performance and facilitate workplace learning. Organisations can use the design principles and implementation factors in the initial design phase to create a well-designed system easily adopted and implemented by the users. For organisations with existing systems, these principles and factors provide valuable insights for improvements, leading to more beneficial systems. While these principles and factors provide a strong foundation, it is advisable to develop a practical guide or toolkit that organisations can use to apply these concepts more effectively. This guide should offer concise and actionable steps for designing and implementing performance support systems, making it easier for practitioners to put these recommendations into practice.

However, while all principles and factors mentioned in this thesis are important, some are particularly essential. For example, prioritising the user-centred principles of user focus and usability is foundational for effective user-centred design. Furthermore, balancing autonomy and support is crucial in frequent work processes, while step-by-step instructions are highly recommended for high-risk work processes. Additionally, during the implementation phase, system maintenance is the most important factor.

While these design principles and implementation factors are crucial for designing an effective performance support system, their success depends on how well they are integrated,

used, and maintained in real-world settings. Despite these practical applications, this thesis has identified several gaps in the literature. There is a need to evaluate the quality and effectiveness of the design principles and implementation factors in real-world professional settings. While these principles are based on literature, practical evaluation is needed, especially since few studies were focused on professional settings.

Future research should focus on longitudinal studies to assess the long-term impact of these systems on workplace learning. Additionally, exploring the specific needs of various stakeholders based on different task types, particularly in workplace learning settings, is essential. Future research should aim to provide a deeper understanding of how performance support systems can be optimized to meet diverse professional needs and improve overall job performance and workplace learning.

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Appendix A: Search Log

First research question: What are the design principles identified in the literature for designing effective long-term technology-based performance support systems for frequent, rare, and high-risk work processes?

Second research question: What are the implementation factors identified in the literature for implementing effective long-term technology-based performance support systems?

Search notes: NOT Boolean operator is not working in Scopus, use the AND NOT

Database filters: English and studies, conference papers

For all the key terms that are excluded with the NOT Boolean operator, there is checked together with the first part of the key string if there are studies missing. If there were no studies missing, the NOT Boolean operator is included.

The following databases are conducted:

- Scopus is a general database by the academic publisher Elsevier
- Web of Science is a general database from Clarivate
- ERIC covers a range of education-related literature
- PsycINFO covers a range of psychological, behavioural, social and health sciences research

Table A1*Search Log of the Scoping Review*

Database	Search Strategy	# Results	Notes
Web of Science	“Performance support” OR “job aid”	695	Include EPSS and MPSS and include * for plural forms
Web of Science	“Performance support” OR “job aid*” OR “mobile performance support*” OR “electronic performance support*”	860	Include job performance aid
Web of Science	(“Performance support” OR “job aid*” OR “job performance aid*” OR “mobile performance support*” OR “electronic performance support*”)	868	Intervention(s), tool(s), and system(s), but same search results on multiple databases
Include performance and learning			
Web of Science	(“Performance support” OR “job aid*” OR “job performance aid*” OR “mobile performance support*” OR “electronic performance support*”) AND (“performance” OR “learning”)	707	41 Studies on performance support staff in sport
Web of Science	(“Performance support” OR “job aid*” OR “job performance aid*” OR “mobile performance support*” OR “electronic performance support*”) AND (“performance” OR “learning”) NOT sport*	666	40 Studies that explain the material support is of high performance referred to as ‘high performance support’
Web of Science	(“Performance support” OR “job aid*” OR “job performance aid*” OR “mobile performance support*” OR “electronic performance support*”) AND (“performance”	626	36 Studies on performance support vector machines or vector regressions within the machine learning

	OR “learning”) NOT sport* NOT “high performance support”		
Web of Science	“Performance support” OR “job aid*” OR “job performance aid*” OR “mobile performance support*” OR “electronic performance support*”) AND (“performance” OR “learning”) NOT sport* NOT “high performance support” NOT “vector machine*” NOT “vector regression”	590	21 Studies on chemical materials, therefore, exclude nano*, carbon* and cataly*
Web of Science	“Performance support” OR “job aid*” OR “job performance aid*” OR “mobile performance support*” OR “electronic performance support*”) AND (“performance” OR “learning”) NOT sport* NOT “high performance support” NOT “vector machine*” NOT “vector regression” NOT “carbon*” NOT “nano*” NOT “cataly*”	569	14 Studies that contain a retrospective cohort study
Web of Science	(“Performance support” OR “job aid*” OR “job performance aid*” OR “mobile performance support*” OR “electronic performance support*”) AND (“performance” OR “learning”) NOT (“sport*” OR “high performance support” OR “vector machine*” OR “vector regression” OR “carbon*” OR “nano*” OR “cataly*” OR “retrospective”)	556	
Scopus	“job performance aid*” OR “mobile performance support*” OR “electronic performance support*”) AND (“performance” OR “learning”) NOT (“sport*” OR “high performance support” OR “vector machine*” OR “vector regression” OR “carbon*” OR “nano*” OR “cataly*” OR “retrospective”)	788	
ERIC	performance support*”) AND (“performance” OR “learning”) NOT (“sport*” OR “high performance support” OR “vector machine*” OR “vector regression” OR “carbon*” OR “nano*” OR “cataly*” OR “retrospective”)	345	
PsycINFO	performance support*”) AND (“performance” OR “learning”) NOT (“sport*” OR “high performance support” OR “vector machine*” OR “vector regression” OR “carbon*” OR “nano*” OR “cataly*” OR “retrospective”)	128	

Appendix B: Detailed Data Extraction Form

Category	Extracted elements	Description
General information	First author	The full last name of the first author of the study.
	Title of publication	The full title of the publication as written.
	Publication year	The year in which the study was published, written as a four-digit number.
	Journal	The full name of the journal where the study was published.
Research design	Research type	The methodological approach used in the study, such as qualitative, quantitative, or mixed methods.
	Data sources	The methods used to collect data, including interviews, performance metrics, questionnaires, system logs, usability testing, and user feedback.
	Domain	The specific field or industry where the performance support system is applied, such as education, healthcare, industry and engineering, information technology and telecommunications, or security and defence.
	Target users	The specific group of users intended to use the performance support system, including their profession or educational level (e.g., students, healthcare professionals).
Performance support system	Experience level	The level of experience users have with the job tasks, categorised as zero, low to medium, or high.
	Task type	The type of tasks the performance support system is designed to support, categorized by frequency and criticality (e.g., frequent, rare, high-risk).
	System explanation	A detailed description of what users are expected to learn or achieve through the performance support system, and what their interactions with the system involve.
Design and implementation	Design process	A detailed explanation of the design decisions and steps taken during the creation of the performance support system.
	Principles	The fundamental principles guiding the design of the performance support system, such as usability, accessibility, and adaptability.
	Challenges	Specific issues or obstacles encountered during the design and implementation of the performance support system, such as technical difficulties, user resistance, and integration issues.
	Recommendations	Suggestions or guidelines for improving the design and implementation of performance support systems, based on the study's findings.
Findings	Main results	The key outcomes and results of the study, including any statistical findings related to the research questions.
	Other considerations	Additional noteworthy points discussed in the study, such as limitations of the research or suggestions for future studies.

Appendix C: Overview of Included Studies

Reference	Contribution ^a	Domain ^b	Target users ^c	Exper. Lvl ^d	Task Type ^e	Data sources ^f	EvalMethod	Summary
Alparslan et al. (2008)	D	E	S, P	1	R	F, Q	Mixed Methods	The study discusses the design of an EPSS for students, technicians, and engineers using remote lab equipment. It aims to improve accessibility to expensive lab equipment and optimize educational efficiency.
Bollen et al. (2015)	D	E	S	1	F	F, Q, S	Mixed Methods	The study discusses the design of an EPSS to aid university psychology students with design tasks.
Carvalho (2018)	I	I	P	1	F	F, I, Q, S	Mixed Methods	The study discusses the implementation and adoption of an EPSS designed for Portuguese organisations.
Colley et al. (2014)	D, E	S	P	2	HR	F, Q, S	Mixed Methods	The study discusses the design and evaluation of a MPSS, designed to provide learning resources and tools for US military personnel in emergencies or crises.
Dabbagh & Fake (2017)	D, E	E	S, P	1	F	F, I, Q	Mixed Methods	The study discusses the design and evaluation of a MPSS to assist just-in-time decision support for instructional designers by aligning instructional strategies with appropriate learning technologies.
Dolowitz et al. (2023)	D, E	S	P	1	F	F, Q, S	Mixed Methods	The study discusses the design and evaluation of a MPSS designed to improve performance and support for NATO employees. The app features short, targeted learning modules aimed at enhancing knowledge retention and work performance.
Gal & Nachmias (2011)	E	IT	P	1	F	F, P, Q	Mixed Methods	The study discusses the evaluation of an EPSS for service representatives in a large telecommunications company.
Gal & Nachmias (2012)	E	IT	P	1	F	F, Q	Mixed Methods	The study discusses the evaluation of user attitudes towards an EPSS for service representatives in a telecommunications firm.
Gal et al. (2017)	D, E	S	P	2	HR, R	F, P, Q	Mixed Methods	The study discusses the design and evaluation of a MPSS for training helicopter engine technicians. The application provided support videos and illustrations for maintenance routines.
Hung et al. (2010)	D, E	E	P	1	F	F, I, Q	Mixed Methods	The study discusses the design and evaluation of an EPSS for classroom behaviour management, finding it aids teachers in quickly developing intervention strategies. The system includes modules for quick reference, knowledge database, skill building, and collaboration
Kalota & Hung (2013)	D, E	E	P	1	F	F, P, Q	Mixed Methods	The study discusses the design and evaluation of an EPSS for preservice teachers with technology integration in their classrooms.

Reference	Contribution ^a	Domain ^b	Target users ^c	Exper. Lvl ^d	Task Type ^e	Data sources ^f	EvalMethod	Summary
Lacontora & Mendonça (2010)	E	S	S	2	HR, R	F, P, Q	Mixed Methods	The study discusses the evaluation of an EPSS for military vehicle maintenance technicians focusing on engine diagnostics in a military setting.
Lee et al. (2017)	I	I	P	1	F	I	Qualitative	The study discusses the implementation of various EPSS systems to identify critical success factors for adoption, aiming to guide decision-makers and professionals in effectively integrating EPSS.
Leiß et al. (2022)	E	IT	P	1	F	Q	Qualitative	The study discusses the evaluation of an EPSS on problem-solving and learning among HR employees and ERP users in office settings.
Martínez-Mediano et al. (2017)	E	E	S	1	F	F, P, Q	Mixed Methods	The study discusses the evaluation of a MPSS to aid university students and faculty in accessing educational resources and support on-the-go.
McKenney (2008)	D, E	E	P	1	F	F, I, Q	Mixed Methods	The study discusses the design and evaluation of an EPSS aiding secondary science teachers with curriculum development and professional growth.
Mitchem & Fitzgerald (2013)	E	E	S, P	1	F	F, I, P, Q	Mixed Methods	The study discusses the evaluation of an EPSS on the academic performance for students with high-incidence disabilities and special education teachers.
Nguyen (2009)	E	I	P	1	F	I, P, Q	Mixed Methods	The study discusses the evaluation of an EPSS and instructor-led training for employees in the corporate industry, focusing on corporate employees' learning outcomes.
Oestreich et al. (2019)	E	I	P	1	F	F, P, Q	Mixed Methods	The study discusses the evaluation of EPSS for assembly workers in an industrial setting.
Peters et al. (2019)	E	H	S	1, 2	HR	F, I, P, Q	Mixed Methods	The study discusses the evaluation of an EPSS for first-year medical students during patient encounters, aiming to bridge the gap between workplace learning and medical school.
Read & Morasch (2016)	D, E	E	S	1	F	F, Q	Mixed Methods	The study discusses the design and evaluation of an EPSS designed to enhance information literacy and research skills for online graduate students.
Ríos et al. (2013)	D, E	S	P	2	HR, R	F, Q, P	Mixed Methods	The study discusses the design and evaluation of a MPSS to enhance training and execution of troubleshooting techniques for aviation technicians who maintain the Engine Air Bleed System on Boeing 737.
Sezer (2021)	D, E	H	S	1	F	I, Q	Mixed Methods	The study discusses the design and evaluation of an EPSS to enhance students' academic performance, particularly in the topic of scientific research methods for medical students.
Sezer (2023)	D, E	H	S, P	1	HR, R	F, I, P, Q	Mixed Methods	The study discusses the design and evaluation of an EPSS for undergraduate medical students to improve performance in practising Basic Life Support (BLS).

Reference	Contribution ^a	Domain ^b	Target users ^c	Exper. Lvl ^d	Task Type ^e	Data sources ^f	EvalMethod	Summary
Stoyanova et al. (2008)	D, E	E	S	1	F	F, Q, P	Mixed Methods	The study discusses the design and evaluation of a MPSS for physics students to enhance the problem-solving abilities for complex engineering tasks, bridging the gap between academic learning and practical application.
Stoyanova-Petrova et al. (2012)	D, E	E	S	1	F	F, Q, P	Mixed Methods	The study discusses the design and evaluation of a MPSS to enhance fieldwork education for engineering students, enabling them to receive interactive support and access to a knowledge database during field visits to manufacturing plants.
Sumuer & Yildirim (2015)	E	S	P	2	HR	F, I, Q	Mixed Methods	The study discusses the evaluation of an EPSS designed to support police officers in the Crime Scene Investigation and Identification Units.
Ugur-Erdogmus & Cagiltay (2019)	D, E	E	S	1	F	Q, U, S	Mixed Methods	The study discusses the design and evaluation of an EPSS designed for undergraduate students in the instructional design process.
Van Schaik et al. (2006)	D, E	E	S	1	F	Q, U, S	Mixed Methods	The study discusses the design and evaluation of an EPSS to assist university students in understanding and utilizing academic libraries. The system includes a tutorial and interactive games, which were found to be useful and increased user confidence.
Van Schaik et al. (2007)	D, E	E	S	1	F	Q, U, S	Mixed Methods	The study discusses the design and evaluation of an EPSS in academic libraries, demonstrating improved task performance and efficiency among users. The EPSS provided context-sensitive help and step-by-step procedures, significantly aiding library users.
Yakin & Yildirim (2016)	E	S	P	2	HR	F, I, Q, S	Mixed Methods	The study discusses the evaluation of an EPSS designed for CSI officers by providing task guidance, automating report generation, and establishing standardized procedures.

^a D = Design/Development; E = Evaluation; I = Implementation.

^b E = Education; H = Health Care; I = Industry and Engineering; IT = Information Technology and Telecommunications; S = Security and Defence.

^c P = Professionals; S = Students.

^d 1 = low to medium; 2 = high.

^e F = Frequent; R = Rare; HR = High-risk.

^f F = User Feedback; I = Interviews; L = Literature Review; P = Performance metrics; Q = Questionnaires; S = System logs; U = Usability Testing.

Appendix D: Frequency Table User-Centred Design Principles

[illegible]

Reference	User Focus	User Involvement			Usability			User Experience			Iterative Design
	Needs and Context Analysis	Involve users throughout the process	Easy to use	Modular components	Just-in-time	Consistent	Task-specific information	Learner-controlled	Use of multimedia	Adaptable to various experience levels	Prototyping / Beta testing
Read & Morasch (2016)	•	•	•	•	•			•	•	•	•
Rios et al. (2013)	•	•	•				•	•	•	•	•
Sezer (2021)	•	•	•	•	•	•		•	•		•
Sezer (2023)	•		•	•	•	•	•	•	•		•
Stoyanova et al. (2008)		•	•	•	•	•	•	•	•	•	•
Stoyanova-Petrova et al. (2012)	•		•	•	•	•	•	•	•		•
Sumuer & Yildirim (2015)	•	•	•	•	•	•	•	•			
Ugur-Erdogmus & Cagiltay (2019)	•	•	•		•	•	•	•	•	•	•
Van Schaik et al. (2006)	•		•		•			•	•	•	•
Van Schaik et al. (2007)	•	•	•		•	•	•	•		•	•
Yakin & Yildirim (2016)	•		•	•	•		•	•	•		

Note: A dot (•) indicates the presence of the principle in the study.

Appendix E: Frequency Table Design Principles

Reference	Task Type	Frequency		Rare	High-Risk		Implementation Factors	
		Balance support and autonomy	Integrate with familiar system	Simulation-based	Preparation and refresher	Step-by-step	Training and Support	System Maintenance
Alparslan et al. (2008)	R	•	•	•	n/a	n/a		•
Bollen et al. (2015)	F	•	•	n/a	n/a	n/a	•	•
Carvalho (2018)	F		•	n/a	n/a	n/a	•	•
Colley et al. (2014)	HR		•		•		•	•
Dabbagh & Fake (2017)	F	•		n/a	n/a	n/a		•
Dolowitz et al. (2023)	F		•	n/a	n/a	n/a	•	
Gal & Nachmias (2011)	F	•	•	n/a	n/a	n/a	•	•
Gal & Nachmias (2012)	F		•	n/a	n/a	n/a	•	•
Gal et al. (2017)	HR, R	•		•		•	•	•
Hung et al. (2010)	F	•		n/a	n/a	n/a	•	
Kalota & Hung (2013)	F	•		n/a	n/a	n/a	•	•
Karakaya-Ozyer & Yildiz (2022)	F	•	•	n/a	n/a	n/a	•	
Lacontora & Mendonça (2010)	HR, R		•	•	•	•		•
Lee et al. (2017)	F	•		n/a	n/a	n/a	•	•
Leiß et al. (2022)	F	•	•	n/a	n/a	n/a		•
Martínez-Mediano et al. (2017)	F	•	•	n/a	n/a	n/a		•
McKenney (2008)	F	•		n/a	n/a	n/a		
Mitchem & Fitzgerald (2013)	F	•	•	n/a	n/a	n/a	•	•
Nguyen (2009)	F		•	n/a	n/a	n/a	•	
Oestreich et al. (2019)	F	•	•	n/a	n/a	n/a		•
Peters et al. (2019)	HR				•	•		•
Read & Morasch (2016)	F	•	•	n/a	n/a	n/a		•
Rios et al. (2013)	HR, R		•	•			•	•
Sezer (2021)	F		•	n/a	n/a	n/a		•
Sezer (2023)	HR, R		•	•	•	•	•	
Stoyanova et al. (2008)	F	•	•	n/a	n/a	n/a		•
Stoyanova-Petrova et al. (2012)	F		•	n/a	n/a	n/a		•

Reference	Task Type	Frequency		Rare	High-Risk		Implementation Factors	
		Balance support and autonomy	Integrate with familiar system	Simulation-based	Preparation and refresher	Step-by-step	Training and Support	System Maintenance
Sumuer & Yildirim (2015)	HR		•		•	•	•	•
Ugur-Erdogmus & Cagiltay (2019)	F	•		n/a	n/a	n/a	•	
Van Schaik et al. (2006)	F	•	•	n/a	n/a	n/a	•	
Van Schaik et al. (2007)	F	•	•	n/a	n/a	n/a		
Yakin & Yildirim (2016)	HR		•		•	•		

Note: A dot (•) indicates the presence of the principle in the study. "n/a" signifies that the corresponding principle is not applicable to the task type in the study.