Faculty of Behavioral, Management, and Social Sciences, University of Twente

Educational Science and Technology

Master Thesis

Enhancing Self-directed Learning for Frontline Workers

An Educational Design Research

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Summary

The thesis explores enhancing self-directed learning (SDL) among blue-collar workers through mobile learning (mLearning) tools, focusing on the Smart Skills platform by SwipeGuide. Blue-collar workers often face challenges with traditional training due to tight schedules, irrelevant content, and repetitive tasks. Given these issues, SDL is seen as a promising solution to empower workers to take control of their learning. This research aims to explore how the Smart Skills platform can effectively support SDL.

An Educational Design Research (EDR) approach is employed in the study. The initial phase involves a literature review and interviews with stakeholders to identify factors that influence workplace learning and SDL in blue-collar environments. The analysis highlights the importance of social support and interaction in fostering a learning culture. It also underscores the benefits and challenges of mLearning, noting its flexibility but also the technological barriers faced by some workers.

The core of the thesis is the design and construction of the Digital Mentor Program, a feature within the Smart Skills platform aimed at enhancing SDL among frontline workers. The program leverages existing workplace social structures, formalizing mentorship to provide structured guidance and personalized learning paths. It includes features like a mentorship matching system, a mentorship dashboard for managing tasks and tracking progress, and a feedback and reflection section to support continuous learning.

The thesis concludes by offering recommendations for piloting the Digital Mentor Program in real-world settings to evaluate its effectiveness. Limitations of the study are acknowledged, particularly the lack of direct input from frontline workers during the research, and the need for broader testing across different industries. Additionally, the study

emphasizes the importance of integrating evaluation and reflection mechanisms in future

research to ensure that the designed interventions are both effective and scalable.

Introduction

Initial Orientation

Learning in blue-collar workplaces is crucial but often challenging (Decius et al., 2021). To start with, time limitations prevent employers from releasing employees for additional training due to tightly scheduled work processes (Blings, 2008, as cited in Decius, 2021; Sponselee et al., 2022). Second, knowledge transfer from external training to practical work applications is often limited (Faizal et al., 2017). Lastly, blue-collar workers often view formal training programs as irrelevant or misaligned with their daily tasks, leading to low participation rates and minimal impact on job performance (Burnham & Ponton, 2021). Despite these challenges, continuous upskilling is necessary for both companies and workers to adapt to the ever-changing workplace (Sawant et al., 2022). A promising solution is integrating blue-collar workers' learning opportunities directly into the workplace (Sponselee et al., 2022).

To address these issues, SwipeGuide introduced a mobile learning platform specifically tailored to the needs of frontline workers within the broader blue-collar workforce (SwipeGuide, n.d.). This platform, SwipeGuide, delivers on-the-job training materials for standard procedures, seamlessly integrating work and learning (SwipeGuide, n.d.). However, while it addresses many challenges associated with traditional training, it does not fully resolve the issue of engaging workers in ongoing skill development, particularly when immediate job needs do not drive it. Recognizing this, SwipeGuide developed Smart Skills—a skills management platform that helps frontline workers organize their skill development and personalize their learning journeys for further career growth (SwipeGuide, n.d.). Smart Skills enables workers to track their progress, identify areas for improvement, and align their personal goals with their roles' demands.

However, the nature of blue-collar work, often characterized by low autonomy, minimal skill requirements, and repetitive tasks (Çiçek, 2013), complicates efforts to involve

these workers in learning for skill development (Saari et al., 2021). Skill development in these roles requires a higher level of autonomy and self-direction, which is not always naturally fostered in such environments (Decius et al., 2021). This is where Self-Directed Learning (SDL) becomes essential. By fostering SDL, workers are more likely to participate in workplace learning even when external regulation is absent (Decius et al., 2021).

With this focus, SwipeGuide aims to explore *how the Smart Skills platform can enhance self-directed learning (SDL) among frontline workers*. This exploration will contribute to a deeper understanding of workplace learning in blue-collar environments by identifying barriers and facilitators of SDL. Practically, the findings will provide insights for refining Smart Skills to better support self-directed learning among frontline workers.

Research Context

Smart Skills

In addition to the company's existing mLearning product, SwipeGuide, Smart Skills places a stronger emphasis on workers' skill development and integrates SwipeGuide's standard training into practical demonstrations of skill proficiency (SwipeGuide, n.d.). It serves as a tool to facilitate upskilling for workers and enables managers to conduct more effective skill assessments. The platform offers a self-paced, online learning experience that empowers workers to enhance their skills flexibly and conveniently, addressing the time constraints of traditional training methods. Moreover, Smart Skills offers on-the-job assessments for supervisors to immediately control workers' learning process. The customized skill framework enables companies to align training with job relevance, counteracting the lack of relevance in traditional training programs. Supervisors oversee the platform, assigning practical skills required for workers to perform their jobs effectively while providing workers with autonomy in self-directing their learning paths. Unlike

traditional fixed curriculums, Smart Skills allows workers to engage in learning at their convenience, tailoring their experience to specific workplace needs.

Organizational Context

The company involved in this study operates a manufacturing plant focused on mass production, where efficiency and quality are key priorities. The production floor is divided into sections handling tasks such as brake press operations, laser cutting, and turret pressing. Workers engage in repetitive, hands-on tasks related to metal fabrication and assembly, with on-the-job training provided by experienced operators and team leads.

Supervisors and team leaders ensure adherence to standard operating procedures (SOPs) and quality standards while managing production flow across shifts. The company is a client of SwipeGuide and has implemented its product to improve training and provide instant access to work instructions at workstations. The company emphasizes safety, continuous improvement, and agility in its operations, with a flat organizational structure that empowers quick decision-making on the factory floor.

Stakeholders

Frontline Workers. Frontline workers are the primary stakeholders in this study, as the intervention seeks to identify opportunities to promote self-directed learning within their daily tasks. Frontline workers typically possess a range of educational backgrounds, with many having completed high school or vocational training, while others may have limited formal education. Having information on understanding their needs and preferences can better inform the design and implementation of effective learning interventions. The ultimate goal is to empower these workers to take charge of their own learning and skill development, leading to improved job performance and career growth.

Team leads and Supervisors. Team leads and supervisors play crucial roles in this study by providing insights into the learning context of frontline workers. Team leads, who oversee daily operations and direct interactions with workers, offer practical perspectives on immediate workplace challenges. Supervisors, responsible for broader strategic planning and decision-making, contribute insights into the feasibility and long-term integration of self-directed learning interventions. Many team leads and supervisors have risen through the ranks, often starting as frontline workers themselves. By leveraging the knowledge and experience of both roles, the study can better tailor its strategies to meet the specific needs of the workforce, thereby enhancing the overall training and development process.

SwipeGuide. SwipeGuide is a technology company dedicated to enhancing the skills of blue-collar workers through digital solutions. Their SwipeGuide platform, initially developed to assist frontline worker training, offers digital work instructions, checklists, and standard operating procedures (SOPs) to guide workers on "how-to" perform tasks effectively and safely. Additionally, SwipeGuide has introduced Smart Skills, a skills-based learning platform that focuses on "know-how" by providing skills management, a skills matrix, and self-directed learning content. This platform allows workers to track their progress, collect certificates, and manage their skills development, fostering a culture of continuous skill development and operational excellence. Smart Skills will be the main focus of this study. The study's findings may inform enhancements to self-directedness in learning and other future developments in Smart Skills, making their contributions critical to understanding and improving workforce training and development within this study.

Theoretical Framework

To understand how Smart Skills can enhance self-directed learning (SDL) among blue-collar workers, this theoretical framework examines three core concepts: workplace learning (WPL), self-directed learning, and mobile learning (mLearning). The framework begins by exploring the unique context of how blue-collar workers learn on the job, followed by an analysis of the role of SDL in this environment. It then considers the impact of mobile applications like Smart Skills on learning processes. Finally, these concepts are integrated to provide a comprehensive understanding of their interplay, offering a foundation to guide this research.

Workplace learning (WPL)

Learning during working is highly contextual and practical, focusing on immediate problem-solving and the application of skills on the job (Cerasoli, 2017), and is often referred to as " (informal) workplace learning" (Decius et al., 2021; Kankaraš, 2021). Often mistaken for work-related learning, WPL specifically focuses on learning activities within the workplace setting (Berg, 2008; Kyndt et al., 2023). Work-related learning encompasses all learning endeavors undertaken by individuals concerning their work roles, such as pursuing a degree or professional development courses outside the workplace (Kyndt et al., 2023). On the other hand, WPL emphasizes the seamless integration of learning into daily work routines, it highlights how employees develop new skills and knowledge through their everyday tasks and interactions (Kankaraš, 2021).

Blue-collar WPL: The moderated 3P model

In blue-collar workplaces, opportunities to learn new skills and acquire knowledge are often embedded in the workflow, whether through learning a new machine, attending onboarding sessions, or correcting errors (Decius et al., 2021). To better understand what

blue-collar WPL is like, Tynjälä's (2013) moderated 3P model provides a comprehensive framework. This model builds upon John Biggs' original 3P model (1999), which is widely used in educational psychology to describe the learning process in academic settings. Tynjälä's (2013) adaptation refines Biggs' framework by adding nuances that address the unique characteristics and demands of workplace learning.

While originally tailored to workplace learning environments in general and not specifically to blue-collar contexts, the model demonstrates the process of blue-collar WPL in a structured manner. Additional literature was consulted to connect these phases and blue-collar workers' specific learning needs and conditions, ensuring the model's relevance and applicability (Decius et al., 2021). The moderated 3P model encompasses four interconnected phases: Presage, Interpretation, Process, and Product.

Presage Phase. Before the learning experience begins, factors such as individual learner characteristics and workplace context come into play. Decius (2021) identifies traits like curiosity, learning goal orientation, and self-directed learning orientation as essential for blue-collar workers to participate in WPL. Additionally, contextual factors like social support from supervisors and coworkers, an error-friendly learning climate, and manageable time pressure create a conducive learning environment (Decius et al., 2021; Sponselee, 2022).

Interpretation Phase. This phase shows a distinction from Bigg's (1999) original 3P model by adding a factor between the presage and process components (Tynjälä, 2013). Learners' previous knowledge and skills do not determine their learning alone, instead, determining factors are how they see themselves as workers and learners, as well as how they perceive their workplace environment (Tynjälä, 2013). This is supported by Burnham (2021), who found that blue-collar workers' beliefs about their self-efficacy significantly influenced their engagement in learning activities.

Process Phase. The process phase involves the actual learning activities and interactions during the experience, shaped by individual actions and workplace conditions (Tynjälä, 2013). In blue-collar settings, learning often happens through hands-on engagement with job tasks, peer observation, and problem-solving (Decius et al., 2021). Workers typically learn by doing—acquiring skills as they tackle real-world challenges on the job (Decius et al., 2021). Effective WPL for blue-collar workers involves active engagement with learning activities, supported by feedback and reflection opportunities (Decius, 2021).

Product Phase. The outcomes of WPL, as captured in the product phase, typically include the development of job-specific skills and enhanced knowledge, leading to improved job performance and increased job satisfaction (Kankaraš, 2021; Decius, 2021), which potentially motivate workers to engage more in learning (Cerasoli, 2017). For instance, Kankaraš (2021) found that continuous learning programs led to significant improvements in technical competencies among workers. Behavioral changes, such as increased organizational citizenship behavior, are also possible. Burnham (2021) observed that workers who overcome educational barriers are more likely to support colleagues and contribute positively to the organization.

Self-directed Learning (SDL)

In a blue-collar workplace, the skills acquired through workplace learning are mostly need-based, addressing immediate job requirements and practical challenges (Decius et al., 2021). The focus on task-specific learning leaves little room for developing broader competencies, such as soft skills like communication and leadership, which require proactive, self-directed efforts beyond daily tasks (Decius et al., 2021; Kruszelnicki, 2020). Therefore, fostering a culture of continuous learning in these environments necessitates the implementation of Self-Directed Learning (SDL).

SDL is a foundational concept in adult education, where learners actively take charge of their own learning processes (Loeng, 2020). As Knowles (1975) describes, SDL involves individuals diagnosing their learning needs, setting goals, identifying resources, choosing and implementing strategies, and evaluating outcomes. This approach shifts the responsibility from the educator to the learner, emphasizing autonomy, initiative, and self-direction in the learning journey (Schweder & Raufelder, 2021).

SDL is highly situational and context-dependent, meaning it is not a one-size-fits-all approach (Loeng, 2020). A learner's ability to engage in self-directed learning can vary depending on the environment and specific circumstances (Pratt, 1993, as cited in Loeng, 2020). Grow's Stages of Self-Direction Model (1991) suggests that learners at different stages of self-direction require varying levels of support, ranging from directive guidance for less self-directed learners to more autonomous learning environments for those with higher levels of self-direction. This adaptability is crucial for effectively implementing SDL across various learning contexts, ensuring that learners receive the appropriate level of guidance to maximize their self-directed efforts (Loeng, 2020). In the context of adult education, SDL is central to fostering independence, critical thinking, and lifelong learning (Schweder & Raufelder, 2021). It empowers learners to take control of their educational journeys, which is essential for personal and professional growth (Loeng, 2020). Recognizing that learners exhibit varying levels of self-direction, learning support should be tailored to enhance SDL effectively (Grow, 1991; Loeng, 2020). By doing so, learners can be better equipped with the skills and mindset needed to navigate and succeed in complex, ever-changing environments (Schweder & Raufelder, 2021).

In the context of blue-collar workers, SDL is particularly valuable as workplace learning often lacks the structured guidance found in formal education (Decius et al., 2021). Self-Directed Learning Orientation (SDLO) enables workers to identify and pursue informal

learning opportunities within their daily routines (Decius et al., 2021). By taking the initiative to learn, blue-collar workers can continuously improve their skills, enhance job performance, and advance their careers (Raemdonck, 2012). SDL thus empowers workers to adapt to changes, solve problems independently, and thrive in their roles, making it a critical component of success in blue-collar settings (Decius et al., 2021).

Mobile Learning (mLearning)

Considering the barriers blue-collar workers face in their traditional training methods, such as limited access to training materials, rigid schedules, and a lack of contextual learning opportunities (Decius, 2021; Sponselee et al., 2022; Faizal et al., 2017; Burnham & Ponton, 2021), Smart Skills emerges as a viable solution. Smart Skills leverages mobile learning (mLearning) to provide flexible, on-the-job training that integrates seamlessly into the daily routines of blue-collar workers (Lang & Palat, 2012).

Mobile learning (mLearning) utilizes mobile devices such as smartphones, tablets, and other portable gadgets to facilitate learning anytime and anywhere (Pimmer et al., 2014). The popularity of mobile devices, particularly smartphones and tablets, has increased due to their versatility and multifunctionality (Pimmer et al., 2014). They offer advantages such as usability, portability, and adaptability, which are beneficial for educational purposes (Moreira et al., 2017). mLearning has found significant applications in workplace settings, providing employees with the ability to learn and access information right on-site (Moreira et al., 2017).

mLearning in blue-collar workplace

In blue-collar workplaces, where workers are often engaged in manual and field-based tasks, mLearning seamlessly integrates learning with daily work tasks (Decius et al., 2021; Pimmer et al., 2014). Workers can access instructional videos, safety guidelines, and

troubleshooting guides directly at the point of need, facilitating on-the-job learning without disrupting their workflow (Pimmer et al., 2014).

mLearning also bridges the gap between formality and informality in learning (Pimmer et al., 2014). It supports formal learning through structured training modules and courses that workers can access during breaks or downtime, providing a flexible alternative to rigid training schedules (Pimmer et al., 2014). At the same time, mLearning enhances informal learning by allowing workers to engage in spontaneous, unstructured learning activities as they encounter challenges and solve problems in real time (Decius et al., 2021).

Furthermore, mLearning accommodates both deliberate, planned learning and reactive, need-based learning (Pimmer et al., 2014). Workers can follow personalized learning paths and scheduled courses for career development at their own pace, while also accessing immediate resources for specific tasks or issues they encounter on the job (Kyndt et al., 2023).

Integrated Framework: WPL, SDL, and mLearning

This integrated framework brings together Workplace Learning (WPL), Self-Directed Learning (SDL), and Mobile Learning (mLearning) to offer a comprehensive understanding of how these elements interact to enhance learning in blue-collar environments (Figure 1).

SDL and WPL Foster Continuous Learning

The interaction between SDL and WPL forms a continuous learning cycle that is naturally integrated into the work process. SDL encourages blue-collar workers to independently seek out learning opportunities within their work context (Loeng, 2020), thereby reducing the reliance on external regulation traditionally associated with blue-collar training methods (Decius et al., 2021). WPL, in turn, supports this process by providing practical, hands-on experiences that reinforce learning (Raemdonck, 2012; Decius et al.,

2021). The presage factors and process activities within WPL can be leveraged to create customized learning strategies tailored to different levels of SDL (Tynjälä, 2013). For instance, blue-collar workers with higher autonomy may require less guidance, while those with lower self-directed learning abilities benefit from more structured support (Grow, 1991). This interplay ensures that learning is not only continuous but also contextually relevant and immediately applicable (Raemdonck, 2012; Decius et al., 2021). Therefore, SDL drives effective WPL, which in turn further supports SDL development, creating a continuous learning cycle.

mLearning as a Facilitator for SDL and WPL

mLearning plays a crucial role in supporting both SDL and WPL by offering accessible, just-in-time learning resources that are seamlessly integrated into the work environment (Pimmer et al., 2014). For SDL, mLearning provides the tools necessary for blue-collar workers to independently manage their learning, accessing content that is tailored to their needs and context (Raemdonck, 2012; Pimmer et al., 2014). In the realm of WPL, mLearning enhances the integration of learning with work routines, making it easier for workers to engage with learning materials without disrupting their workflow (Kyndt et al., 2023; Pimmer et al., 2014). By offering resources that are both relevant and easily accessible, mLearning supports workers in navigating the situational demands of their learning environment, thereby enhancing the overall effectiveness of both SDL and WPL.

In summary, SDL drives continuous and effective WPL by empowering blue-collar workers to take charge of their learning, while WPL supports the development of SDL through various levels of support. mLearning serves as a vital tool in this process by providing flexible, integrated learning opportunities that enhance both SDL and WPL. Together, these components create a robust framework that fosters ongoing skill development and adaptability in blue-collar workplaces.

Figure 1

The integrated framework
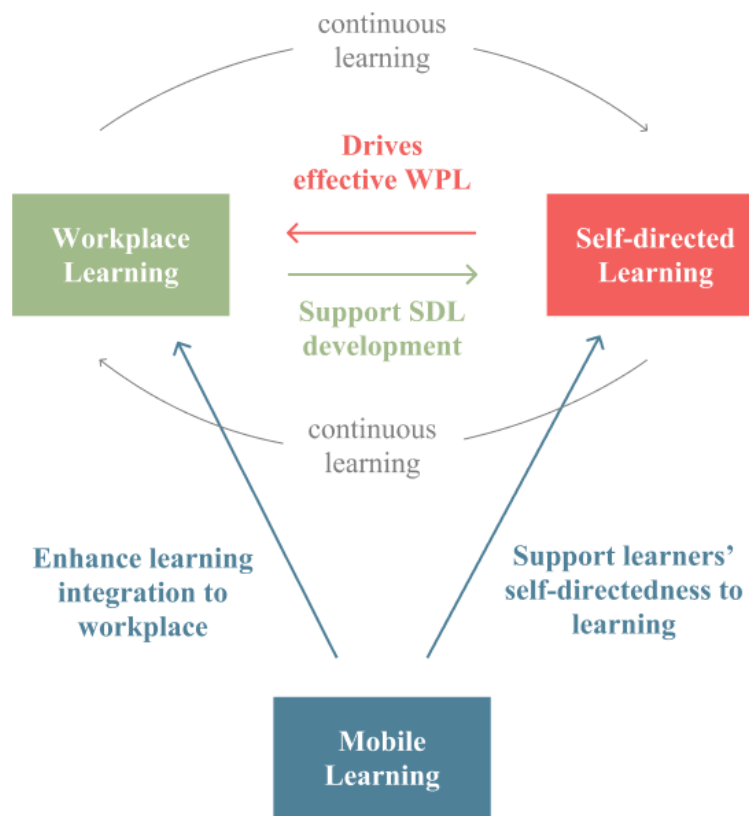
An Educational Design Research

An Educational Design Research (EDR) approach (McKenney & Reeves, 2012) is opted for in this project. Unlike traditional experimental approaches, EDR is particularly suited to addressing complex, real-world educational challenges (McKenney & Reeves, 2012). It aims to develop solutions that are both theoretically grounded and practically relevant, ensuring that the interventions designed are applicable in actual learning environments. This approach is ideal for the goals of this study, as it focuses on crafting interventions that enhance self-directed learning among frontline workers, a group that operates within unique and challenging conditions.

The EDR process typically involves multiple iterative cycles across three main phases: Analysis and Exploration, Design and Construction, and Evaluation and Reflection. However, due to the scope of this master's thesis, the research primarily focuses on the first two phases, concluding with recommendations for future evaluation. Below is a detailed overview of the phases (Figure 2):

Figure 2

Overview of the EDR project

Analysis & Exploration Phase	Design & Construction Phase
↻	↻
One empirical micro-cycle	One generative micro-cycle
Analysis	**Design**
RQ1: What factors contribute to blue-collar workers' engagement in self-directed learning (SDL)?	**RQ4:** What feature can be implemented in the Smart Skills platform to enhance frontline workers' self-directedness in WPL?
Method: Literature Anaylsis	**Proecess:** Exploring and mapping solutions
RQ2: What are the factors facilitating or hindering SDL in a blue-collar workplace?	**Activities:** Idea generation, idea consideration and idea checking, and refining propositions, and making a skeleton design
RQ3: How is mobile learning (mLearning) used in workplace learning among blue-collar workers?	
Method: Problem Analysis	
Exploration	**Construction**
Method: Professional Meetings	**Method:** Constructing high fidelity prototype of the learning intervention
Products: Problem Definition, Long-range Goal, Partial Design Requirements, Initial Design Propositions	**Products:** Prototype of the intervention

Meso-cycle

Phase 1: Analysis and Exploration

The first phase, Analysis and Exploration, aims to understand the problem and identify opportunities for intervention (McKenney & Reeves, 2012). This phase focuses on identifying factors that influence self-directed learning (SDL) among frontline workers. To start with, I conducted a literature inquiry focused on self-directed learning (SDL) among blue-collar workers to answer: *What factors contribute to blue-collar workers' engagement in self-directed WPL?*

Following this, a problem analysis is conducted through interviews with team leads, supervisors, and experts. These interviews explore: *What factors help or hinder frontline workers' WPL, and how can these be used to support SDL?* Additionally, since mLearning

tool like SwipeGuide is already in use, the interviews also address: *What are the benefits and challenges of mLearning in WPL?* The purpose here is to leverage what works well and what doesn't in mLearning to inform the design of new interventions. The insights from the literature review and the interview data are then integrated to locate factors that facilitate SDL and are either present or feasible in a frontline workplace setting. This integration also examines how mLearning can support these factors within the workplace context. The analysis from this phase will help refine the problem and establish the initial design requirements for the Smart Skills platform.

Phase 2: Design and Construction

Building on the findings from the first phase, the Design and Construction phase focuses on developing a practical intervention. The goal is to translate the insights from the analysis into a tangible solution that can be tested and refined (McKenney & Reeves, 2012). This phase addresses the question: *What feature can be implemented in the Smart Skills platform to enhance frontline workers' self-directedness in WPL?* The design process includes constructing and refining the intervention to ensure it meets the specific needs of frontline workers and is both technically feasible and scalable. The outcome of this phase is a high-fidelity prototype in Figma ready for further testing.

Phase 3: Evaluation and Reflection

Finally, while the Evaluation and Reflection phase typically involves assessing the effectiveness of the design and reflecting on its impact (McKenney & Reeves, 2012), it will not be conducted in this project to fit the scope of a master thesis. Instead, this phase will provide recommendations for future evaluation and implementation, ensuring the designed feature aligns with the needs of frontline workers and leverages the full capabilities of the Smart Skills platform.

Analysis and Exploration: Literature Inquiry

A literature inquiry was conducted to explore factors that facilitate and hinder self-directed learning (SDL) in blue-collar workplace learning (WPL) and contribute to building a foundational basis for the subsequent problem analysis. Guided by the research question, *What factors contribute to blue-collar workers' engagement in self-directed WPL?*, the inquiry followed a structured, multi-stage approach.

Procedure

I first defined the research question and identified relevant keywords related to SDL in workplace learning and blue-collar workplace. Specific inclusion and exclusion criteria were established to ensure the relevance and quality of the literature, with the detailed search terms and criteria presented in Table 1. The search was conducted across major academic databases, including Google Scholar, Scopus, and the Education Resources Information Center (ERIC). After the initial search, results were manually filtered based on publication years, fields of study, and relevance to the research question, leading to the selection of 10 key articles. These articles were then read thoroughly, with annotations made to capture key insights. This systematic inquiry ensured that the literature search was thorough, relevant, and directly applicable to the research focus on enhancing SDL in blue-collar workplace environments.

Table 1

Search terms and selection criteria

Research Question	
What factors contribute to blue-collar workers' engagement in self-directed WPL?	
Search Terms	
Core Concepts	self-directed learning, workplace learning, workplace training, blue-collar workplace, blue-collar worker, employee development

Broad Concepts	adult learning, learning autonomy, learning motivation, skill development

Note: The search terms were combined using Boolean operators (e.g., 'AND') during the literature search to ensure focused and relevant results. Additionally, synonyms and related terms were used to capture a broader range of literature on each topic.

Inclusion Criteria

- Field of study: Social Science, Business & Management, and/or relevant fields
- Published within the last 10 years were prioritized
- Foundational literature that introduced key concepts, theories, or frameworks relevant to the study
- Open access and/or accessible via UT library

Exclusion Criteria

- Focused solely on formal education or academic settings
- Studies that are not in English

Results

The results from the literature inquiry aimed at identifying factors that influence continuous self-directed learning (SDL) among blue-collar workers. Although the aim was to focus on blue-collar settings, much of the existing research is centered on healthcare professions or educational environments. Therefore, the connection to blue-collar contexts was often indirect or loosely connected. This gap in the literature underscores the need for further investigation into how these factors manifest in blue-collar environments practically.

Individual Factor: Motivation

Blue-collar workplaces are often characterized by highly repetitive and routine tasks, which can result in limited opportunities for learning and development (Decius et al., 2021). The nature of this work typically offers few stimuli that encourage learning or the need to excel beyond the basic requirements of the job (Decius et al., 2021). Consequently, for blue-collar workers to upskill themselves—whether to adapt to the ongoing digital transformation or to pursue career advancement—they often need to take the initiative to invest in continuous learning on their own (Decius et al., 2021). Motivation is a key factor driving this

initiative (Cerasoli, 2017; Decius et al., 2021), which can be broadly categorized into intrinsic motivation and extrinsic motivation (Deci & Ryan, 2000).

Intrinsic Motivation. According to Deci and Ryan's (2000) Self-Determination Theory (SDT), intrinsic motivation is fueled by the fulfillment of three basic psychological needs: autonomy, competence, and relatedness.

Autonomy. When learners have control over their learning processes, including setting their own goals, selecting resources, and determining strategies, they are more intrinsically motivated (Deci & Ryan, 2000). In a blue-collar context, this means that workers feel they have some control and choice over their learning activities (Decius et al., 2021). Providing opportunities for blue-collar workers to take initiative and make decisions about their learning can significantly enhance their intrinsic motivation and engagement (Hampel et al., 2022). This sense of ownership and self-direction fosters a deeper engagement with the learning material (Raemdonck et al., 2012). With an environment fostering autonomy, companies can significantly improve both the motivation and learning outcomes of their employees, leading to better job performance and satisfaction (Lemmetty & Collin, 2020).

Competence. The feeling of being effective in one's interactions with the environment and experiencing opportunities to exercise and express one's capacities is crucial (Deci & Ryan, 2000). In blue-collar workplaces, the need for competence drives workers to master their job tasks and improve their skills (Decius et al., 2021). When learners perceive that they are developing their skills and gaining mastery, their intrinsic motivation and willingness to continue learning are significantly enhanced (Bandura, 1997).

Relatedness. Relatedness involves feeling connected to others and having supportive relationships. In blue-collar environments, this need is often satisfied through teamwork, mentorship, and peer support (Jolly, 2020). Collaborative learning activities, such as group problem-solving tasks or peer-led training sessions, can foster a sense of community and

mutual support among workers. When blue-collar workers feel that they belong and are supported by their peers and supervisors, they are more likely to stay motivated and engaged in their learning activities (Jolly, 2020). The presence of a strong social support network can also facilitate the sharing of best practices and the development of a learning culture within the workplace (Deci & Ryan, 2000).

Extrinsic Motivation. In contrast, extrinsic motivation is driven by external rewards or recognition, such as career advancement opportunities, financial rewards, or supervisor recognition (Deci & Ryan, 2000). In blue-collar workplaces, extrinsic factors that drive learning include avoiding mistakes or an obligation to fulfill under supervision (Decius et al., 2021).

In blue-collar workplaces, both types of motivation play significant roles (Decius et al., 2021). Workers driven by intrinsic motivation may engage in SDL to improve their skills and job performance out of personal interest, while those influenced by extrinsic factors might be motivated by career advancement opportunities, financial rewards, or recognition from supervisors (Boyer et al., 2014; Decius et al., 2021). Studies have also shown that extrinsic drivers can be categorized into job expectations, positive reinforcement, and negative consequences, all of which can influence intrinsic motivation and SDL engagement (Boyer et al., 2014; Baber et al., 2023).

Contextual and Environmental Factors

While motivation is crucial for SDL, several contextual and environmental factors also play a significant role in enhancing and supporting the overall SDL process:

Job-related factors. Job-related factors influence how blue-collar workers engage in self-directed learning (SDL) by providing the context and challenges that drive learning efforts. These factors include the nature of the job and task complexity (Gijbels, 2010).

Nature of the Job. Jobs that require continuous learning and adaptation to new tools, technologies, or processes naturally encourage SDL (Gijbels, Raemdonck, & Vervecken, 2010). These jobs often present opportunities for employees to acquire new skills and knowledge, which can enhance their performance and career growth. Conversely, highly routine jobs may not provide as many opportunities for SDL, as they do not demand frequent learning or adaptation (Decius et al., 2021).

Task Complexity. Complex and challenging tasks can motivate learners to engage in SDL to acquire the necessary skills and knowledge to perform their jobs effectively (Gijbels, Raemdonck, & Vervecken, 2010). When tasks are varied and require problem-solving, employees are more likely to seek out learning opportunities to meet these challenges, thereby enhancing their self-directed learning efforts (Gijbels, Raemdonck, & Vervecken, 2010).

Supportive Learning Environment. A supportive learning environment is essential for fostering continuous SDL. This environment can be shaped by organizational culture, available resources, and social interactions.

Organizational Culture. An organizational culture that values and encourages learning can significantly impact SDL. When organizations prioritize learning and provide the necessary support and resources, employees are more likely to engage in SDL (Kyndt et al., 2023).

Access to Resources. Providing access to a variety of learning resources, such as training programs, online courses, and learning communities, is crucial. These resources offer learners multiple pathways to acquire new skills and knowledge (Hampel et al., 2022).

Social Interactions. While SDL emphasizes autonomy and personal initiative, the role of social interactions in the learning process cannot be overlooked, especially in blue-collar environments (Decius et al., 2021). Learning in these settings often involves interacting

with peers, mentors, and supervisors, who provide critical feedback, support, and insights that are invaluable to the learning process (Jolly, 2020). These social interactions are integral to SDL as they help to create a collaborative learning environment where workers can share knowledge, learn from each other's experiences, and receive guidance that may not be available through formal channels (Jolly, 2020).

Analysis and Exploration: Problem Analysis

Following the literature review, a problem analysis was conducted to explore the current state of workplace learning (WPL) and mobile learning (mLearning) among the target audience of Smart Skills, the frontline workers. This analysis focused on identifying factors that influence WPL in a frontline work environment and determining which of these factors can foster SDL through leveraging the literature findings. The research question guiding this section was:

RQ2: What are the factors affecting frontline workers' WPL, and which of these factors can be used to foster SDL among frontline workers?

Furthermore, the interviews examined the current usage of mLearning within an actual blue-collar workplace. Since the Smart Skills platform was not yet implemented, the data collected on mLearning usage specifically focused on the currently utilized SwipeGuide app. This analysis aimed to identify both mLearning's advantages and challenges. The insights gained from this investigation were intended to inform the design of the Smart Skills platform. Therefore, another research question guiding this section was:

RQ3: What are the benefits and disadvantages of mLearning in frontline WPL?

Respondents

Respondents for the semi-structured interviews were selected using a purposive sampling technique (Tongco, 2007). This approach ensured that respondents were chosen

based on specific characteristics relevant to the research, such as their roles and experience in the workplace. While the original plan included interviewing blue-collar workers directly, this was not feasible due to their tight work schedules. Consequently, the interviews focused on those in supervisory and expert roles who could provide valuable insights into the learning processes and challenges faced by blue-collar workers.

The final sample consisted of 9 participants: 3 team leads, 3 supervisors, and 3 field experts. To minimize interference with work schedules, the company paired up the team leads and supervisors into groups during the interviews. This arrangement allowed the participants to share their insights while ensuring minimal disruption to their work responsibilities.

Respondent Criteria

Respondents selected for the interviews had to meet the following criteria:

- Ability to participate in the interview in English.

- Experience in using or researching mobile technology for learning purposes.

Team Leads and Supervisors

The team leads and supervisors interviewed are key members of a production line team focusing on the brake press process. These individuals typically have extensive hands-on experience and were often frontline workers themselves before being promoted to their current roles. This background allows them to provide valuable insights from both the perspective of frontline workers and that of supervisory staff. In their current roles, they are involved in continuous improvement and training, overseeing daily operations, addressing immediate workplace challenges, and contributing to broader strategic planning and decision-making within the company.

Experts from the Field of Professional Learning and Technology

These respondents are researchers from the University of Twente, specializing in the application of technology to blue-collar workplaces, and field experts working closely with the targeted population on mLearning implementation success. Their expertise in workplace learning dynamics in blue-collar environments provides valuable insights into the current practices, challenges, and opportunities in blue-collar workplace learning.

Instrumentation

To gather data, I developed semi-structured interviews tailored for each category of respondents (Appendixes A and B). These interviews aimed to explore the current status quo of the participants' workplace. The questions were designed based on Tynjälä's (2013) moderated 3P model, Mobile Learning (mLearning), and Self-Directed Learning (SDL) to identify the key factors that affect learning in a blue-collar workplace and the role of mobile learning.

The interviews with field experts were designed to explore the broader learning context within blue-collar workplaces. Questions aimed to understand current learning practices, barriers, and facilitators to SDL, and the role of mLearning in enhancing workplace learning. The structure of the interviews allowed experts to discuss both the theoretical and practical aspects of learning in these environments, providing a comprehensive view of the current state of workplace learning and potential areas for improvement.

The interviews with team leads and supervisors were structured around Tynjälä's (2013) moderated 3P model, which includes Presage, Process, and Product phases. The questions were designed to explore various aspects of workplace learning. "Presage" questions focused on the individual characteristics of workers and the workplace context, examining what triggers the need for learning and how these initial conditions influence learning. "Process" questions delved into the formal and informal learning activities that

occur in the workplace, investigating how workers learn during their daily tasks. "Product" questions aimed to assess the outcomes of the learning process, such as the impact of learning new skills on job performance.

Procedure

After developing the semi-structured interview instrumentation, I obtained approval from the University of Twente's Ethics Committee of Humanities and Social Sciences. With approval in hand, SwipeGuide assisted in identifying respondents by leveraging their partner network, facilitating initial contact, and encouraging participation. Ultimately, a production line team from one of SwipeGuide's clients agreed to participate, though due to workers' limited mobility and job constraints, team leads and supervisors primarily represented their perspectives.

In addition, researchers specializing in Professional Learning and Technology from the University of Twente and experts from SwipeGuide were conducted, providing valuable insights into workplace learning dynamics. Respondents were approached via email with details about the study, confidentiality assurances, and their right to withdraw. They were required to read and sign an informed consent form before the interview (Appendix C).

Each interview, lasting approximately 30 minutes, began with an introduction and reiteration of the study's objectives to ensure respondent comfort. Interviews were recorded and transcribed verbatim, with manual corrections for accuracy. The transcriptions were then analyzed to address the research questions, guiding the subsequent research phases.

Data Analysis

To analyze the qualitative data from the interview transcripts, I employed the inductive category formation technique by Mayring (2014), facilitated by the computer

software ATLAS.ti. This method allowed me to focus on material relevant to answering the research questions while avoiding irrelevant content.

First, I broke down the primary research questions into specific, explorative sub-questions. This step ensured a clear focus and alignment with the inductive reasoning approach, as suggested by Mayring (2014). The breakdown of questions helped to target various aspects of self-directed learning (SDL) and mobile learning (mLearning) in blue-collar workplaces. It allowed for a more detailed examination of facilitators, barriers, benefits, and challenges within these contexts.

Next, I defined categories and the level of abstraction for each sub-question. These definitions served as criteria for selecting relevant data from the interview texts. The level of abstraction was set to ensure that the categories were neither too broad nor too specific. Specifically, I aimed to capture concrete actions, tools, conditions, and direct experiences mentioned by the interviewees, avoiding generalized statements or overly detailed individual cases.

I then coded the interview texts by reading through the transcripts line-by-line to identify data that matched the category definitions. Whenever data met the criteria, I established a corresponding code, ensuring it reflected the specified level of abstraction.

Continuous revision of the coding system was applied to maintain stability. This involved checking the system's fit with the sub-questions and adjusting the level of abstraction if needed. Once the coding system became stable, I coded all material using the established rules. Finally, after coding all the material, I organized the codes into categories that addressed the research questions. The formation of these categories was guided by the theoretical frameworks and the results from the literature review.

Table 2

Sub-questions and the corresponding category definition and level of abstraction

Research Question	What are the factors facilitating or hindering blue-collar WPL, and which of these factors can be used to foster SDL among blue-collar workers?	
Sub-questions	**Category Definition**	**Level of Abstraction**
What are the facilitators of WPL in a frontline workplace?	Perceived factors that encourage and support learning activities in a frontline workplace.	Specific examples of support mechanisms, tools, or practices that facilitate WPL. Excludes general statements.
What are the barriers to WPL in a frontline workplace?	Perceived obstacles that hinder or prevent learning activities in a frontline workplace.	Specific examples of obstacles or challenges that hinder WPL. Excludes general statements.

Research Question	How is mobile learning (mLearning) used in workplace learning among frontline workers?	
Sub-questions	**Category Definition**	**Level of Abstraction**
In what ways does mLearning benefit blue-collar workplace learning?	Perceived benefits and positive outcomes of using mobile learning tools and methods in a blue-collar workplace.	Concrete examples of how mLearning aids in blue-collar workplace learning. Excludes generalized statements.
What challenges do blue-collar workers face when adopting and engaging with mLearning?	Perceived obstacles and difficulties encountered when using mobile learning tools and methods in a blue-collar workplace.	Concrete examples of issues mentioned by interviewees. Excludes generalized statements.

Results

The results of the content analysis are presented in the following section, organized according to the four sub-questions, leading to four main outcomes: Facilitators of frontline WPL, Barriers to frontline WPL, Benefits of mLearning, and Disadvantages of mLearning. The findings are summarized in a table format for clarity and ease of interpretation, with categories listed in descending order based on their frequency of occurrence.

In the table, N refers to the total number of quotes or instances associated with each main category, which includes all the quotes from its sub-categories combined. This count indicates how often each category was discussed during the analysis. %C represents the percentage of the total coded quotes that each category accounts for within the entire dataset, offering insight into how much emphasis each theme received compared to others.

Facilitators of frontline WPL

This section highlights the key factors that facilitate WPL in frontline environments, including social support, social interaction, a supportive learning environment, autonomy in learning, and job responsibility (Table 3). Below are detailed descriptions of each category based on the analysis.

Table 3

Results of Problem Analysis: Facilitators of WPL

Categories	N	% of C
A1. Social Support and Interaction	14	38%
A2. Job Responsibility	12	32%
A3. Supportive Learning Environment	5	13%
A4. Autonomy in Learning	6	17%
	37	100%

A1. Social Support and Interaction. Social support and interaction emerged as the most significant and frequently mentioned factor in facilitating workplace learning (WPL). This category encompasses the critical roles of both interpersonal relationships and collaborative communication within the workplace, which together create a conducive environment for continuous learning and development.

The support provided by supervisors and peers forms the backbone of this learning environment. Supervisors play a key role by identifying learning needs, offering guidance, and providing real-time feedback. As one supervisor explained, "*They can work with the leads, and the leads can walk them through every issue they might be having.*" This hands-on support helps workers navigate challenges and accelerates their learning process. Similarly, peer support is vital, as experienced colleagues offer in-time feedback and foster a culture of collaboration. The collective nature of blue-collar work emphasizes the importance of these supportive relationships, which are integral to effective learning. One expert noted, "*The openness and comfort between colleagues... to admit that you do not know something... is something that could facilitate learning for sure,*" highlighting how a culture of openness and mutual assistance enhances learning opportunities.

Social interaction, intertwined with support, plays a crucial role in facilitating cross-team collaboration and communication. Effective communication across different teams and departments is essential for bridging knowledge gaps and ensuring that workers understand the broader context of their tasks. One supervisor pointed out, "*What affects assembly is not always obvious at the brake presses or in the fabrication department, so we have to kind of bridge that gap.*" This highlights how cross-team communication not only helps identify learning needs but also fosters a more integrated approach to problem-solving and skill development.

Together, these elements of social support and interaction create a strong foundation for workplace learning, where guidance, feedback, and collaborative communication work in harmony. This integrated approach ensures that learning is embedded in everyday activities, making it the most emphasized factor in WPL as observed in the interviews.

A2. Job Responsibility. In the interviews, all experts emphasized that most blue-collar workers are primarily motivated by the need to earn a living, with learning often being

secondary. This aligns with the prominence of job responsibility in driving workplace learning. The majority of learning in frontline environments is spurred by external factors, such as accountability and the fear of making mistakes, which reflects the strong influence of extrinsic motivation. As one team lead noted, "*Everything we do in fabrication has to be to set assembly up for success...if the line ever stops, that's time we never get back. And so that is money that we never get.*" Another interviewee mentioned, "*...having one guy do the safety stuff, one guy knowing the lean production. And then they also hold each other accountable.*" These quotes underscore how job responsibility drives learning to ensure efficiency and prevent costly errors, highlighting the extrinsic motivators at play.

   A3. Supportive Learning Environment. The supportive learning environment focuses on the structured, company-provided resources and systems that facilitate continuous workplace learning (WPL). This environment includes an error-tolerant atmosphere and organized learning support tools, which are distinct from the interpersonal support offered by peers or team leads (social support). In this context, an error-tolerant atmosphere, where "mistakes are allowed to be made," is embedded in the company's culture, encouraging workers to experiment and learn without the fear of failure. One team lead noted his perspective on this matter, "*If mistakes are allowed to be made...you try to develop together, you are curious, you're open.*" This environment fosters curiosity and collaboration among workers, making them more willing to engage in learning activities.

   Additionally, structured support, such as guided learning sessions, further enhances this environment by providing clear, organized guidance on skill development. One expert mentioned that structured support ideally "*gives them a very clear overview of where am I today and where do I need to go to actually reach my full potential.*" This systematic approach ensures that learning is not left to chance but is instead a deliberate part of the work process. A team lead highlighted the practical application of this support, saying, "*If we ran*

into a situation like a couple of nights ago, somebody broke an entire order of a particular thing, the opposite direction...I take the SwipeGuide over to him, show him the part, and walk him through the steps." This demonstrates how company-provided resources are used to address mistakes and reinforce learning in real-time. Unlike social support, which relies on personal interactions, the supportive learning environment is built on these formal structures and tools that the company provides to all employees, ensuring consistent and equitable access to learning opportunities.

A4. Autonomy in Learning. Autonomy, as mentioned in the literature inquiry, is one of the crucial factors fostering SDL among blue-collar workers. This concept is observed in the frontline workplace when workers actively pursue their development. For instance, a supervisor mentioned, *"If they are interested in being a team lead, they...take that development into their own hands and start doing these trainings."* However, since the interviewees were team leads and supervisors rather than frontline workers, the concept of autonomy in learning might be underrepresented in the data. This limitation suggests that while autonomy is recognized, the insights gathered may not fully capture the workers' own experiences or perceptions of their autonomy in learning.

Barriers to frontline WPL

In examining the barriers to WPL in a frontline workplace, three primary categories emerged: generational challenges, negative attitudes toward learning, and lack of learning support (Table 4).

Table 4

Results of Problem Analysis: Barriers of WPL

Categories	N	% of C

B1. Generational Challenges	15	54%
B2. Attitude towards learning	8	29%
B3. Lack of learning support	5	17%
	28	100%

B1. Generational Challenges. Generational challenges were the most frequently mentioned barrier, accounting for over half of the responses. This category encompasses issues like fear of replacement among older workers, a reluctance to learn new skills, and a heavy reliance on manual knowledge transfer. One expert highlighted the fear of replacement: *"How senior employees still try to portray as if they do have the expertise, even if they don't, just to maintain their status, etcetera."* This indicates that older workers may resist new learning opportunities to protect their job security, thereby hindering the overall learning culture. Another significant challenge is the reliance on implicit knowledge, where experienced workers struggle to articulate their skills to newcomers: *"... if you're in a state like that, you can't always tell the new guy about this thing that you do because you don't even think about it when you do it."* This reliance on undocumented knowledge can lead to a loss of valuable expertise as older workers retire, emphasizing the need for structured knowledge transfer methods.

B2. Negative Attitude Toward Learning. This category reflects a disinterest in learning among frontline workers. For starters, many workers view their jobs as merely a means to earn a paycheck, one expert noted, *"They want to earn their paycheck and that's it. Like, and then they go do the fun stuff, which is the rest of their life."* Such an attitude is often rooted in negative past educational experiences, where workers, especially those who struggled in formal schooling, associate learning with failure or discomfort. Another expert shared her research, stating, *"They didn't have the best experience there because usually these*

are people that were struggling through high school and finally when they got to do the practice-oriented vocational education, they could finally do something with their hands and weren't scolded by the teachers all the time." Despite these attitudes, it's crucial to note that such workers are often motivated by extrinsic factors, such as job security or incentives, which can still drive them to engage in necessary learning activities. While these negative attitudes hinder intrinsic motivation, they also underline the importance of leveraging extrinsic motivators to foster workplace learning among this group.

B3. Lack of Learning Support. The lack of learning support category includes insufficient time for training, a lack of adequate learning materials, and a misalignment between the learning needs of workers and the support provided by the organization. These challenges were prevalent before the implementation of structured learning solutions or technological interventions, highlighting the importance of considering these factors in designing effective learning strategies. However, the persistent issue of lack of time underscores the need for integrating learning into the workflow through workplace learning (WPL), ensuring that learning opportunities are seamlessly embedded into daily tasks. One supervisor expressed concern about the lack of time: "If I take all of the team leads off the floor and we were to come up here to the conference room, there's not gonna be a lot getting done out there on the floor." This highlights how critical it is to integrate learning into the workflow. Additionally, the absence of appropriate learning materials was noted, with one worker stating, "When I was trained out on the floor as a builder, I never seen a work instruction." This highlights the critical gap between what workers need to learn and the resources or support available to them.

Benefits of mLearning

The benefits of mLearning in blue-collar workplace learning were highlighted across several key areas during the interviews. These findings demonstrate how mLearning

enhances workplace learning by addressing specific challenges and leveraging the inherent

strengths of mobile technology (Table 5).

Table 5

Results of Problem Analysis: Benefits of mLearning

Categories	N	% of C
C1. Efficiency in Training and Problem-Solving	8	32%
C2. Organization and Structure	12	48%
C3. Learner Engagement and Autonomy	5	20%
	25	100%

C1. Efficiency in Training and Problem-Solving was frequently noted by

interviewees. The ability to access instructional content on the job allows workers to address

issues as they arise, ensuring minimal disruption to the workflow. For instance, one

supervisor pointed out, *"... it's all with it being on the tablet. They can understand at their*

own pace and work with the leads, and the leads can walk them through every issue that they

might be having." This reflects the literature on mLearning's role in making training more

accessible and directly applicable to daily tasks (Pimmer et al., 2014). Additionally, the

simplicity of learning materials, such as the use of visual aids over text, was highlighted as a

significant benefit. As one of the supervisors said, *"There was too much verbiage, not*

enough pictures... SwipeGuide has a few words but a lot of pictures," this underscores how

the clear and contextual images help simplify complex instructions.

C2. Organization and Structure of learning materials. This category was another

key benefit, particularly for new operators. The structured approach provided by SwipeGuide

helps streamline the onboarding process. One supervisor explained, *"It is helpful especially*

to the new operator... because everything is in there." This structure not only aids in

knowledge retention but also ensures that valuable information is preserved and easily

accessible, addressing one of the challenges frontline WPL has, a supervisor expressed this and said *"With SwipeGuide, we now have that information permanently with us."* This organized approach to learning aligns with the broader educational advantages of mLearning discussed in the literature, where structured and easily accessible content supports effective learning (Moreira et al., 2017).

      C3. Learner Engagement and Autonomy were also significantly enhanced through mLearning. After the implementation of SwipeGuide, workers are encouraged to take control of their learning, making the process more self-directed and responsive to individual needs. As a supervisor mentioned, *"It's nice for them to be able to access it themselves and then communicate their learnings to me."* This matches an ideal status stated by a field expert, highlighting how mLearning fosters autonomy, she said, *"As you're learning more skills... if you have a question, you actually have a tool that you can go and consult rather than stopping production to find your supervisor."* This aligns with the literature on mLearning's potential to support self-directed learning by providing just-in-time resources that enable learners to engage more actively with their development (Kyndt et al., 2023).

Disadvantages of mLearning

      The integration of mLearning in frontline workplace settings presents several challenges that can hinder its effectiveness, as seen in Table 6.

Table 6

Results of Problem Analysis: Disadvantages of mLearning

Categories	N	% of C
D1. Difficulty to Utilize Technology	6	75%
D2. Limited Access to Technology	2	25%
	8	100%

D1. Difficulty to Utilize Technology. The most prominent challenge identified is the difficulty in utilizing technology, especially among senior employees. This challenge reflects the generational divide in comfort and familiarity with digital tools. For instance, one supervisor noted that senior workers often feel overwhelmed by rapidly changing technology, which makes it difficult for them to adapt: "When it comes to technology, they're like, hey, I don't want much to do with that, but you'd be surprised." This reluctance is contrasted by younger employees, who tend to have a more natural affinity for technology, learning quickly and effectively. However, this disparity can lead to tension and a slower adoption rate for mLearning tools within the workforce.

D2. Limited Access to Technology. Another significant barrier is the limited access to necessary technology, such as tablets or smartphones, required for effective mLearning. Currently, only team leads have access to these devices, which limits opportunities for workers to self-direct their learning. One team lead expressed concerns about the insufficient availability of these devices: "I would say our biggest challenge is maybe just not having enough SwipeGuide out here." This lack of access not only restricts the workers' ability to engage with learning materials but also limits the potential benefits that mLearning could offer in improving job performance and learning outcomes. However, this challenge appears to be specific to the company in question, and whether this issue is prevalent in other companies would require further investigation.

Analysis and Exploration: Conclusion

This conclusion summarizes the key findings from the Analysis and Exploration phase, focusing on the critical factors influencing self-directed learning (SDL) among frontline workers, the role of mobile learning (mLearning), and the implications for refining the integrated framework.

Refining SDL in the Context of Frontline Work

The analysis of both literature and interview data highlights several key facilitators and barriers to Workplace Learning (WPL) that directly impact the potential for Self-Directed Learning (SDL) among frontline workers. In frontline work settings, the structured and routine nature of the environment often limits workers' autonomy in directing their own learning (Decius et al., 2021). Barriers such as generational differences, negative attitudes toward learning, and a lack of adequate learning support further restrict workers' ability to fully engage in SDL. These challenges suggest that achieving full learning autonomy is often difficult within these environments.

Given these constraints, the concept of Self-Directed Learning Orientation (SDLO) becomes crucial. SDLO refers to a worker's attitude, motivation, and willingness to take initiative in learning, even when their autonomy is limited by external factors (Decius et al., 2021; Raemdonck et al., 2012). Workers with a strong SDLO are more likely to seek out and engage in learning opportunities that fit within the constraints of their roles. This proactive approach can help mitigate the barriers to learning by encouraging workers to be more self-directed within the limits they face.

Social Support as the Key to Supporting SDLO in Frontline WPL

Social support and interaction play a pivotal role in fostering SDLO among frontline workers, enabling them to engage in SDL despite the structural limitations of their work

environment. Both the literature and interview findings highlight how supervisor and peer support are critical in creating a learning culture within the workplace. Social support, driven by collaborative relationships, helps integrate learning into daily tasks. This environment, often described by interviewees as an "apprenticeship culture," allows experienced workers to guide those with less experience, providing the necessary support to nurture SDLO and facilitate SDL (Jolly, 2020).

This supportive culture is not solely based on interpersonal dynamics. It is also built on the structured resources provided by the company, which lay the foundation for continuous learning. The supportive learning environment fostered by the company includes an error-tolerant atmosphere and organized learning tools, encouraging workers to experiment, learn from mistakes, and make learning an essential part of their work process.

Social support and interaction build upon this foundation, bringing the supportive learning environment to life. Supervisors and peers are instrumental in identifying learning needs, offering guidance, and providing continuous feedback. Additionally, social interaction across teams, particularly through cross-team communication, creates more opportunities for learning. It helps workers understand what they need to learn and provides a better structure for them to be aware of their learning needs, which fosters greater autonomy in their learning process. This combined support system, made possible by the company's structured environment, motivates workers to take more initiative in their learning, making them more proactive and engaged in their development.

The literature also support these findings. For instance, Grow (1991) suggested that learners at different stages of development require varying levels of support to become more self-directed. By fostering a supportive social environment, organizations can tailor learning experiences to meet the individual needs of workers, thereby enhancing their self-directedness in learning activities. Moreover, social support and interaction help reduce

common barriers to workplace learning, such as generational differences, negative attitudes toward learning, and the lack of formal learning support. By promoting open communication and teamwork, these social connections help ease fears about learning new skills, turn negative feelings about learning into positive ones, and fill in the gaps when formal resources are lacking.

New Insights on mLearning's Role in WPL

The analysis revealed that while mLearning effectively integrates learning into the daily workflow, offering just-in-time resources and structured learning processes, it also presents challenges that were less emphasized in the existing literature. The interviews highlighted significant barriers, such as difficulties in using technology, especially among senior workers, and limited access to necessary devices. These barriers hinder the full potential of mLearning in facilitating WPL.

However, mLearning does play a crucial role in supporting both WPL and SDLO by providing flexible, on-demand learning resources that workers can access at their own pace. For example, SwipeGuide helps streamline training processes, making information readily available and accessible, which is particularly beneficial in real-time problem-solving on the shop floor. Despite these benefits, the success of mLearning is contingent upon addressing the technological and accessibility challenges identified during the interviews.

Refinement of the Integrated Framework

Based on these findings, the integrated framework of WPL, SDLO, and mLearning should be refined to position social support and interaction as an underlying factor that encompasses all three concepts. Social support and interaction act as the foundation upon which WPL, SDLO, and mLearning are built, creating a continuous learning cycle that reinforces each element. In this refined framework:

- **WPL** benefits from social support and interaction by fostering an environment where learning is embedded in daily interactions and shared responsibilities.

- **SDLO** is strengthened as social support encourages workers to take initiative, providing the confidence and resources needed to engage in self-directed learning within the constraints of frontline work.

- **mLearning** is more effective when underpinned by a strong support network, which helps workers navigate technological barriers and integrate learning tools into their everyday tasks.

By positioning social support as an underlying factor, the refined framework ensures that the three concepts—WPL, SDLO, and mLearning—are not only interconnected but also continuously reinforced through a supportive learning culture. This integration creates a robust and sustainable learning environment that is particularly well-suited to the unique challenges and opportunities of frontline work, aligning with the ultimate goal of the Smart Skills platform: to foster continuous, self-directed learning and development among frontline workers.

Figure 3

The refined integrated framework
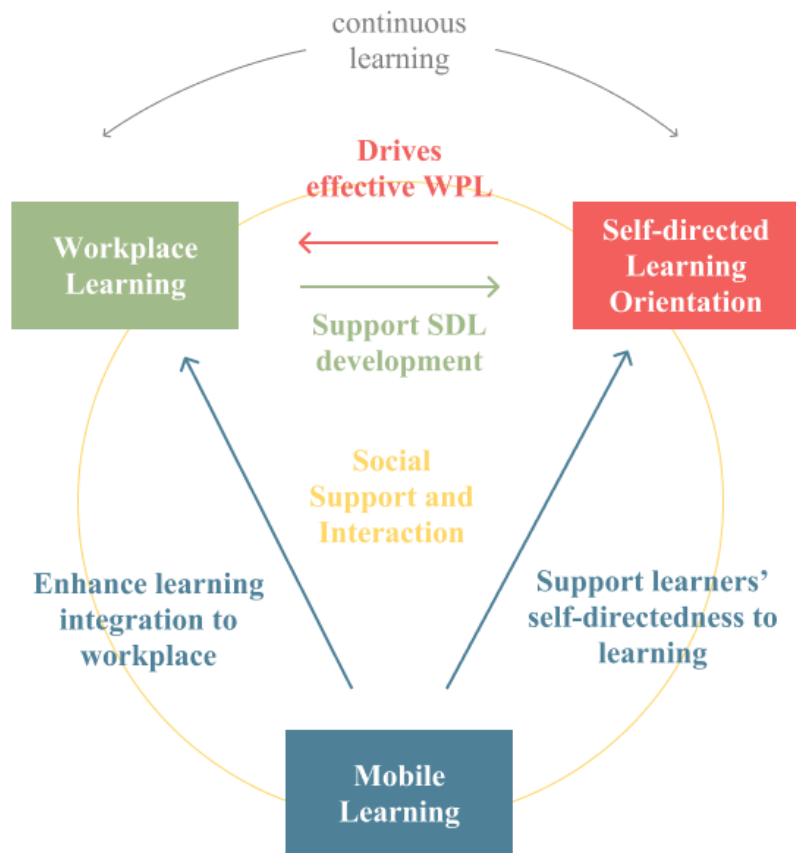
Analysis and Exploration: Synthesis

Refined Problem Statement

Initially, the problem statement aimed to enhance Self-Directed Learning (SDL) on the SmartSkills platform. However, after the analysis phase, it became clear that two critical refinements were necessary. First, the structured and routine-driven nature of frontline work environments limits workers' ability to engage fully in traditional SDL. As a result, the focus shifted to Self-Directed Learning Orientation (SDLO), which is more suited to the constraints of these environments. Second, the analysis highlighted that the most significant factor influencing both SDL and SDLO in this context is social support. Hence the refined problem statement is: *How can SmartSkills foster social support that improves self-directed learning orientation among frontline workers?* This shift in focus was driven by the recognition that in frontline working environments, where workers rely heavily on social structures for learning, strong social support is crucial for promoting SDL. The empirical findings underscored the apprenticeship culture and the pivotal role of supervisors and peers in guiding learning processes. The literature also emphasized that SDL in such contexts is significantly influenced by the presence of social support, especially in environments with lower autonomy. Therefore, the revised problem statement more accurately addresses the critical need to leverage the SmartSkills platform to enhance social support mechanisms, ensuring that SDL is both feasible and effective in a frontline workplace. This refinement ensures that the platform aligns with the unique learning dynamics of blue-collar workers, making it a more contextually relevant solution.

Long-Range Goal

The long-range goal defines the ultimate aim of the learning solution that will be developed in the Design and Construction phase, addressing the refined problem statement

(McKenney & Reeves, 2012). Building on the findings from the literature inquiry and interviews, the goal of the learning solution is to create a feature within Smart Skills to effectively foster social support among frontline workers. This feature will enhance their Self-Directed Learning (SDL) orientation by facilitating peer and supervisor interactions, thereby supporting workers in their learning journey.

Partial Design Requirements

Design requirements specify what needs to be accomplished in a specific setting to address identified challenges and leverage available opportunities (McKenney & Reeves, 2012). In alignment with the refined problem definition and the long-range goal, here are the design requirements:

- **Enhance Social Support Mechanisms:** The design should enhance mechanisms for social support, such as mentorship and peer interactions, to foster a strong, supportive network among workers. This requirement targets the development of interpersonal relationships that directly contribute to a collaborative learning culture, where workers support each other's learning and development.

- **Align with the Collaborative Nature of Frontline Work:** The design should incorporate features that reflect and support the inherent collaborative and collective nature of frontline work. This includes tools and processes that facilitate teamwork, cross-functional communication, and collective problem-solving, ensuring that the design aligns with the social structure and workflows typical of frontline environments.

- **Foster SDLO in the frontline workplace:** The design should facilitate SDLO by providing opportunities for workers to take initiative and actively engage in their learning process, even within the constraints of the frontline work environment.

- **Ensure Accessibility:** The design must be user-friendly and accessible, catering to different levels of technology proficiency among workers, addressing the A&E findings on the technological challenges faced by some workers.

- **Support Continuous Feedback and Reflection:** The design should include tools that enable continuous feedback and reflection, supporting ongoing learning. This ensures that learning is an iterative process, where workers can regularly assess their progress, reflect on their experiences, and adjust their learning strategies accordingly.

Initial Design Propositions

Design propositions guide how to meet design requirements to achieve the long-term goal (McKenney & Reeves, 2012). Below is an overview of the partial design requirements and corresponding initial design propositions, offering preliminary ideas for potential solutions.

Table 7

Partial Design Requirements and Initial Design Propositions

Partial Design Requirements	Initial Design Propositions
DR1: Enhance Social Support Mechanisms	DP1: Implement features like discussion forums or buddy systems to facilitate mentoring and peer-to-peer learning, strengthening social support networks.
DR2: Align with the Collaborative Nature of Frontline Work	DP2: Include collaborative learning activities, such as group challenges or shared learning goals, to align with teamwork-based roles.
DR3: Foster SDLO in the Frontline Workplace	DP3: Introduce tools that encourage self-assessment and goal-setting to empower workers to take initiative in their learning process.
DR4: Ensure Accessibility	DP4: Ensure the user interface is intuitive with options for varying levels of technology literacy

| DR5: Support Continuous Feedback and Reflection | DP5: Embed features like real-time quizzes or reflection prompts to allow continuous feedback, helping workers learn from experiences and continuously improve their skills |

Design and Construction

Building on the insights from the Analysis and Exploration phase, the Design and Construction phase focuses on developing a solution that enhances Self-Directed Learning Orientation (SDLO) among frontline workers through a feature integrated within the SmartSkills platform. This section details the ideation, development of a skeleton design, and the subsequent construction of a Figma prototype.

Idea Generation

I started the ideation with brainstorming, leveraging the insights from the A&E phase as well as the RQ of the phase: *What feature can be implemented in the Smart Skills platform to enhance frontline workers' self-directedness in WPL?* Two main ideas were generated through brainstorming from the design requirements and the current interface of the Smart Skills platform provided by SwipeGuide:

Idea 1: Digital Mentor Program

The Digital Mentor Program is designed to harness the apprenticeship culture inherent in frontline workplaces, which was emphasized repeatedly in the interviews. This program pairs experienced workers (mentors) with less experienced colleagues (mentees) in the Smart Skills platform, facilitating knowledge transfer and reinforcing the collective learning nature of frontline work (i.e., DR1 and DR2). It enhances social support, which was identified as a critical facilitator in WPL, by formalizing mentorship and creating opportunities for guided learning, addressing the need to foster SDL orientation within the constraints of frontline work (i.e., DR3). The program also helps to bridge the gap in technological proficiency, as mentors can guide mentees through both the learning material and the use of digital tools (i.e., DP4). By integrating these elements, the Digital Mentor Program not only leverages the

existing social structures but also supports the development of SDL, making it a highly effective solution for enhancing learning outcomes.

Idea 2: Virtual Team Forum

The Virtual Team Forum aims to foster a collaborative learning environment by enabling frontline workers to engage in discussions, share experiences, and participate in team-based challenges (i.e., DR2). This idea directly responds to the need to enhance social interaction and peer learning, which was identified as crucial in the A&E phase. The forum supports the social nature of frontline work by creating a space where workers can discuss challenges, seek advice, and learn from each other's experiences, thus reinforcing a supportive learning environment (i.e., DR2). Furthermore, the forum includes features for continuous feedback and reflection, aligning with the goal of fostering SDL orientation (i.e., DR3). By integrating these elements, the Virtual Team Forum not only supports the development of a community of practice but also enhances the overall learning experience.

Much like the Digital Mentor Program, the Virtual Team Forum also addresses the challenge of technological proficiency by providing a platform where workers can assist each other in navigating digital tools and learning resources (i.e., DP4). However, the forum offers a more flexible, less structured approach compared to the mentorship program, allowing workers to engage at their own pace and according to their individual needs.

Considering Ideas

To make an informed decision, I closely compared the two ideas with how each idea aligns with the design requirements established from the Analysis and Exploration (A&E) phase. The comparison focused on the capacity of each idea to meet these requirements effectively and their potential for successful implementation in the work environment. For this purpose, I established specific criteria for each design requirement to guide this

comparison and ensure that the selected idea aligns closely with the needs of the workplace environment.

Design Requirements and Criteria

- Enhance Social Support Mechanisms (DR1): Does the idea effectively implement and strengthen social support systems, such as mentorship programs and peer-to-peer interactions?

- Align with the Collaborative Nature of Frontline Work (DR2): Does the idea integrate well with the team-based, collaborative nature of frontline work, enhancing teamwork and shared responsibilities?

- Foster SDLO in the Frontline Workplace (DR3): Does the idea help workers take more initiative in their learning and provide the guidance they need?

- Ensure Accessibility (DR4): Is the idea easy to use for workers, regardless of their experience with technology?

- Support Continuous Feedback and Reflection (DR5): Does the idea include ways for workers to get regular feedback and reflect on their learning?

Idea Evaluation

Idea 1: Digital Mentor Program. The Digital Mentor Program is designed to capitalize on the apprenticeship culture that is deeply embedded in frontline work environments. This idea strongly aligns with DR1 by formalizing mentor-mentee relationships, thus enhancing social support mechanisms, particularly supervisor support, which was identified as a key facilitator of workplace learning (WPL). The program also effectively meets DR2 by integrating seamlessly with the collective nature of frontline work, promoting the transfer of knowledge through digital apprenticeships.

Regarding DR3, the Digital Mentor Program supports SDLO by providing tailored learning paths and structured guidance that align with the Presage phase of the 3P model (Tynjälä, 2013), fostering an active and self-starting approach to learning. This idea also addresses DR4 by allowing mentors to assist mentees with technology, thus mitigating potential challenges related to technology proficiency. Lastly, while DR5 was absent during idea generation, it can be addressed by encouraging continuous feedback and reflection within the mentorship framework, ensuring that learning is both adaptive and ongoing.

Idea 2: Virtual Team Forum. The Virtual Team Forum is conceptualized to enhance collaboration and peer learning by creating a digitl space for discussions, experience sharing, and team-based challenges. This idea aligns with DR1 and DR2 by broadening social interaction to include both peers and supervisors, promoting a sense of community and belonging among workers. The forum also supports DR3 by fostering SDLO through peer interaction; however, it lacks the structured guidance necessary to fully support SDL.

In terms of DR4, the Virtual Team Forum may face challenges due to limited access to technology, which could hinder its effectiveness. While the forum does meet DR5 by supporting continuous feedback through team discussions, this feedback is less structured compared to the Digital Mentor Program.

The following table provides an overview of how each idea aligns with the design requirements and meets the established criteria:

Table 8

Overview of ideas' alignment with design requirements

Design Requirement	Digital Mentor Program	Virtual Team Forum
Enhance Social Support Mechanisms (DR1)	Strongly formalizes supervisor-mentee relationships, enhancing structured guidance and social support.	Enhances social interaction broadly, involving both peer and supervisor support, but less structured.

Align with the Collaborative Nature of Frontline Work (DR2)	Integrates the apprenticeship culture into digital formats, supporting seamless knowledge transfer.	Promotes collaboration and peer learning, fostering team-based engagement.
Foster SDLO in the Frontline Workplace (DR3)	Provides tailored learning paths and structured guidance, effectively fostering SDLO.	Promotes SDLO through peer interaction, but lacks the structured guidance necessary for effective SDL.
Ensure Accessibility (DR4)	Mentors assist mentees with technology, improving ease of use and technology adoption.	May face challenges due to limited access to technology, potentially hindering effectiveness.
Support Continuous Feedback and Reflection (DR5)	Encourages reflection and continuous feedback within the mentorship framework, supporting ongoing learning.	Supports continuous feedback through team discussions, but is less structured and more informal.

Idea Decision

After a thorough comparison of the two ideas, the Digital Mentor Program emerges as the more effective solution. It not only addresses a broader range of design requirements but also aligns more closely with the key factors identified in the A&E phase. The program's ability to leverage existing social structures, provide tailored learning support, and integrate seamlessly into the current workplace culture makes it the most promising approach for fostering SDLO among frontline workers.

The Virtual Team Forum also presents valuable opportunities to enhance social interaction and foster a sense of community. However, its potential limitations in terms of technology access and lack of structured guidance make it less suitable as the primary solution.

Given these considerations, I decided to proceed with the Digital Mentor Program, focusing on its potential to fulfill the design requirements and enhance workplace learning outcomes effectively.

Skeleton Design

The development of the Digital Mentor Program began with a skeleton design phase, which focused on translating initial design ideas into specific, actionable features that would be integrated into the Smart Skills platform. The process was guided by a dual framework: McKenney and Reeves' (2019) skeleton design framework, focusing on three key areas—Materials & Resources, Activity/Task Structures, and Participation/Practices—and Tynjälä's (2013) moderated 3P model of Workplace Learning (WPL). Each feature was carefully designed to address specific design requirements (DRs) while aligning with the phases of the 3P model, ensuring a comprehensive approach to fostering self-directed learning orientation (SDLO) among frontline workers and seamlessly integrated into their existing workflows.

Materials and Resources

The design process began by identifying the essential tools and resources that would support the implementation of the Digital Mentor Program (McKenney & Reeves, 2019) , which corresponds to the Presage Phase of the 3P model (Tynjälä, 2013). This phase is crucial for setting up a conducive learning environment by considering the individual learner characteristics and workplace context.

Given the nature of frontline work, where mentors and mentees are often engaged in hands-on tasks throughout the day, the decision was made to focus primarily on a mobile interface for the program. This mobile-first approach ensures that learning can be seamlessly integrated into daily routines, offering the flexibility and accessibility that workers need. The mobile interface was chosen over the desktop version, which is reserved for managerial tasks such as assigning and building training materials. This ensures that the Digital Mentor Program remains authentic and aligned with the practical realities of frontline work environments.

To enhance social support mechanisms (DR1), the Mentorship Matching feature was introduced. This feature facilitates structured mentorship by enabling supervisors to pair mentors and mentees based on their skills and learning needs. By formalizing these relationships, the program cultivates a supportive learning environment where experienced workers can guide and assist their less experienced peers. This structured approach reinforces a culture of mutual support and collaboration, establishing a strong foundation for learning within the organization.

Activity / Task Structures

In the next phase of the skeleton design, the focus shifted to establishing the activity and task structures that would drive the program's learning processes (McKenney & Reeves, 2019), aligning with the Process Phase of the 3P model (Tynjälä, 2013). This phase involves the actual learning activities and interactions that are essential for effective workplace learning.

A key feature developed during this phase is the Mentorship Dashboard (DR2: Align with the Collaborative Nature of Frontline Work). The Mentorship Dashboard serves as a central hub, integrating mentorship activities into the daily workflow. It offers tools for task management, communication, and progress tracking, all of which are essential for supporting teamwork and collective problem-solving. Notably, the Mentorship Dashboard spans both the Materials & Resources and Activity/Task Structures areas, as it not only provides the tools needed for learning but also structures the activities through which learning occurs. By embedding mentorship within the day-to-day tasks, this feature ensures that learning is a collaborative, ongoing process, seamlessly integrated into the work environment.

To foster Self-Directed Learning Orientation (SDLO) in the frontline workplace (DR3), the Personalized Learning Paths (PLP) feature was developed. This feature acknowledges that Self-Directed Learning (SDL) is not a one-size-fits-all process (Loeng, 2020). Drawing

on Grow's (1991) model, the PLP allows for a gradual increase in learner autonomy. Initially, mentors guide the learning process by assigning specific skills and tasks. As learners develop their capabilities and confidence, they gain more control over their learning paths, eventually selecting and pursuing skills independently. This gradual transition supports varying levels of learner autonomy and ensures that the learning experience is tailored to individual needs, making it contextually relevant and effective.

Participation / Practices

Finally, the skeleton design considered how participants would engage with the program's tools and activities (McKenney & Reeves, 2019), which also aligns with the Process Phase of the 3P model (Tynjälä, 2013). This phase involves the interactions and engagement of workers as they participate in the learning process.

The Feedback and Reflection Section was developed to support DR5: Support Continuous Feedback and Reflection. This feature is integral to the learning process, emphasizing regular self-reflection and structured feedback. By enabling workers to reflect on their progress and receive constructive feedback from their mentors, the program encourages continuous learning and personal development. The Feedback and Reflection Section ensures that learning is an ongoing, iterative process, helping workers to continually refine their skills and adapt to new challenges. This element of the design supports both the Process and Product Phases of the 3P model by fostering an environment where feedback and reflection are regular parts of the learning journey, thereby enhancing the effectiveness of learning activities and leading to better learning outcomes.

Moreover, to address DR4 (Ensure Accessibility), offline collaboration between mentors and mentees plays a crucial role. This collaboration focuses on working together to overcome technological challenges, ensuring that all participants can fully engage with the program. This aspect of participation aligns with both the Process and Product Phases of the

3P model. In the Process Phase, it involves active engagement and problem-solving, while in the Product Phase, it leads to outcomes such as improved digital literacy and enhanced capability to use learning tools effectively.

Positioning the Design within the 3P Model

In summary, the Digital Mentor Program's design was intricately guided by both the design requirements (DRs) and Tynjälä's (2013) moderated 3P model. Each feature of the program was developed with a clear understanding of how it fits within the Presage, Process, and Product Phases of the 3P model. The design effectively sets up the learning environment (Presage), structures the learning activities (Process), and ensures that outcomes are achieved through continuous feedback and reflection (Product). By aligning these features with the 3P model, the Digital Mentor Program not only addresses the specific needs of frontline workers but also fosters an environment of continuous learning and development, ultimately enhancing the effectiveness of workplace learning.

Table 9

Overview of features of Digital Mentor Program

| Design Requirement	Refined Design Proposition/Feature	3P Model Phase
Enhance Social Support Mechanisms (DR1)	Mentorship Matching	Presage
Align with the Collaborative Nature of Frontline Work (DR2)	Mentorship Dashboard	Presage & Process
Foster SDLO in the Frontline Workplace (DR3)	Personalized Learning Paths	Process
Ensure Accessibility (DR4)	Addressed offline	Process & Product
Support Continuous Feedback and Reflection (DR5)	Feedback and Reflection Section	Process & Product

Construction

In the construction phase, the development of the Digital Mentor Program began with initial sketching and the creation of low-fidelity wireframes. These early drafts were essential in visualizing the basic structure and flow of the program's features, ensuring that the design concepts from the skeleton phase were accurately represented. After refining these initial designs through iterative feedback, a high-fidelity prototype was constructed using Figma. This prototype served as a detailed and interactive representation of the Digital Mentor Program, integrating the features seamlessly into the existing Smart Skills platform. The high-fidelity prototype was crucial for testing the usability and functionality of the program in a format that closely resembled the final product.

Starting with Sketching

With the features ideas generated from the skeleton design in mind, I proceeded to sketch out initial wireframes that would eventually be refined into low-fidelity prototypes. I began the process by sketching initial wireframes. Sketching is a crucial early step in the design process, as it allows for rapid exploration of ideas without getting bogged down in details. Using simple lines and shapes, I sketched out the basic structure of each feature. These sketches focused on the layout and flow of information, providing a visual guide for how users would interact with the Digital Mentor Program.

Figure 4

Example sketch of the design
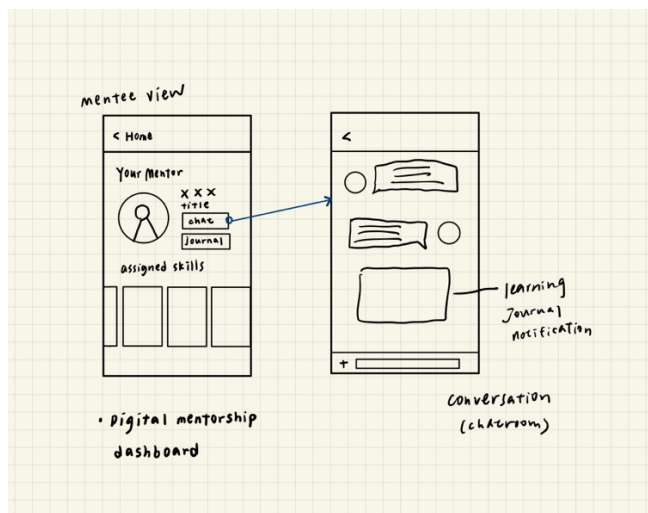
Transition to Low-Fidelity Wireframes

After refining the sketches and ensuring they aligned with the design requirements, I transitioned to creating low-fidelity wireframes. Low-fidelity wireframes are more detailed than sketches but still lack color, images, or intricate design elements. They serve as a bridge between the rough ideas of sketches and the more polished high-fidelity prototypes.

Using digital tools, I recreated the initial sketches in a more structured format, focusing on the layout and organization of the content. In these wireframes, I defined where key elements such as buttons, text fields, and menus would be placed. The process was iterative so that the elements were posited to not only be feasible for users but also align with the interface of the Smart Skills platform. For instance, the Mentorship Dashboard was designed with a clear layout where mentors could easily see mentees' progress and upcoming tasks. The Personalized Learning Paths were laid out to allow for easy navigation and adjustments, emphasizing the need for adaptability as mentees progress in their learning.

Figure 5

Low-fidelity wireframe
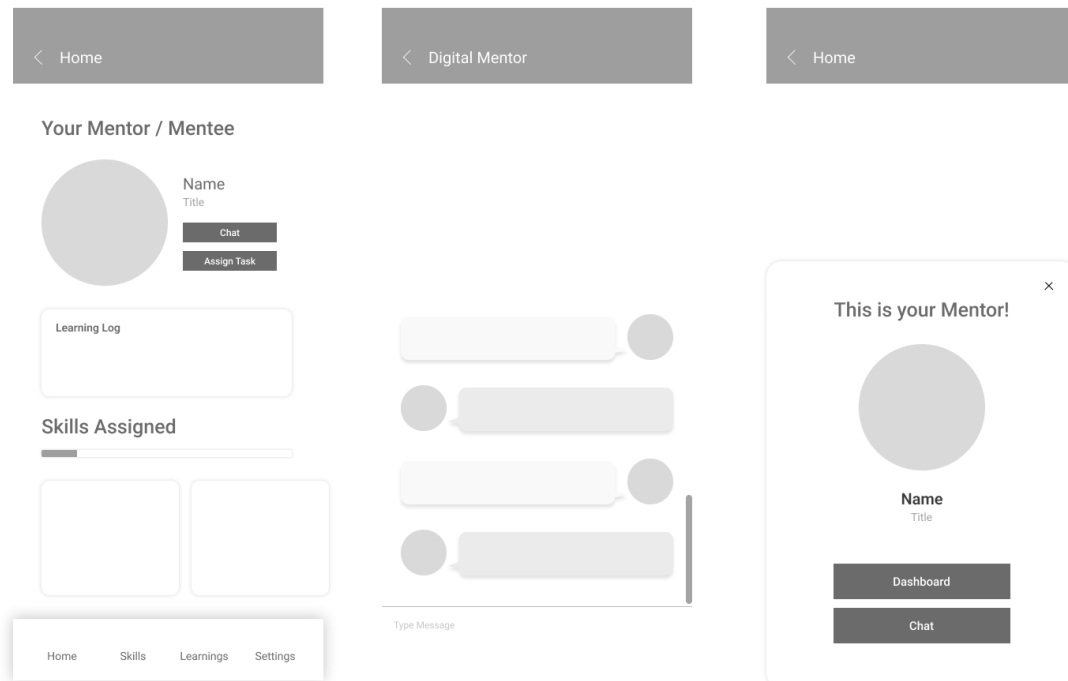
Creating a high-fidelity prototype

With the Figma app, I crafted each element of the Digital Mentor Program. Figma was chosen for its robust design capabilities, particularly its ability to create detailed, high-fidelity prototypes that can be easily shared and tested with users. The process began by building out the interface elements from the wireframes into fully fleshed-out designs. I focused on ensuring that the design was not only visually consistent with the Smart Skills platform but also functionally intuitive for the end-users.

The high-fidelity prototype was then enhanced with interactive elements to simulate real interactions within the platform. This included creating clickable components, such as buttons and menus, which allow users to navigate through the various features of the Digital Mentor Program as they would in the final product. This interactive prototype serves as a critical tool for testing and refining the design before moving into full-scale development. The prototype can be accessed via this link. The key features developed in the prototype include:

- **Mentorship Matching (DR1: Enhance Social Support Mechanisms)**

  Feature Overview: The Mentorship Matching feature is designed to formalize and structure the mentorship process by allowing supervisors or team leads to pair experienced workers with less experienced colleagues. This feature leverages the existing apprenticeship culture in frontline workplaces to foster meaningful mentorship relationships that enhance social support mechanisms.

  Functionality: Although the selection process for mentor matching occurs on the desktop version of the Smart Skills platform and is not part of the mobile prototype, the high-fidelity prototype includes features that allow mentors and mentees to view their assigned pairings. Once mentors are matched with mentees, both parties receive notifications on their mobile devices (as seen in the right screenshot in Figure 6), and the mentorship process can begin.

- **Mentorship Dashboard (DR2: Align with the Collaborative Nature of Frontline Work)**

  Feature Overview: The Mentorship Dashboard serves as the central hub for managing the mentoring relationship. It offers a streamlined, user-friendly interface where mentors can assign tasks, provide feedback, and track the progress of their mentees. This dashboard integrates mentorship activities into daily work routines, reinforcing the collaborative nature of frontline work.

  Functionality: Mentors can assign tasks and milestones directly through the dashboard. The progress of each task is tracked in real-time, providing both mentor and mentee with a clear view of the mentee's advancement. The dashboard also includes communication tool, such as a messaging option, ensuring ongoing support and interaction within the platform.

- **Personalized Learning Paths (DR3: Foster SDLO in the Frontline Workplace)**

Feature Overview: The Personalized Learning Paths feature allows mentors and mentees to collaboratively create customized learning plans tailored to the mentee's specific needs and job role. This feature acknowledges the context-specific nature of SDL, which requires learning paths to be adaptable to individual learners' needs (Loeng, 2020). Grounded in Grow's (1991) model, this feature allows for a gradual increase in learner autonomy, starting with mentor-led learning and progressing toward self-directed skill development.

Functionality: Initially, mentors assign specific skills and tasks to the mentee, guiding their learning process. As the mentee progresses and gains confidence, they are given more control over selecting and pursuing skills independently, reflecting a growing level of autonomy. This feature ensures that learning paths are tailored to the individual needs and developmental stages of each worker, promoting SDL in a way that is both relevant to the workplace context and adaptable to varying levels of learner independence.

- **Feedback and Reflection Section (DR5: Support Continuous Feedback and Reflection)**

  Feature Overview: The Feedback and Reflection Section is designed to encourage continuous learning and self-improvement by providing a space for structured feedback and personal reflection. This feature is essential for creating a supportive learning environment, which is critical in fostering SDLO.

  Functionality: After each completion of a skill, mentees are required to submit feedback through a comment box integrated into the mentorship dashboard. This feedback mechanism enhances the original report function by creating a more elaborate form of feedback submission, allowing mentees to address their learning struggles in a detailed manner. Mentors review these reflections and provide

structured feedback, using text, audio, or video messages. This interactive system allows mentors to highlight key areas for improvement and recognize achievements, helping mentees to see their growth over time. Additionally, a learning journal is maintained within the mentorship dashboard, serving as a personal documentary of the mentee's learning development and reflections.

Figure 6

High-fidelity prototype
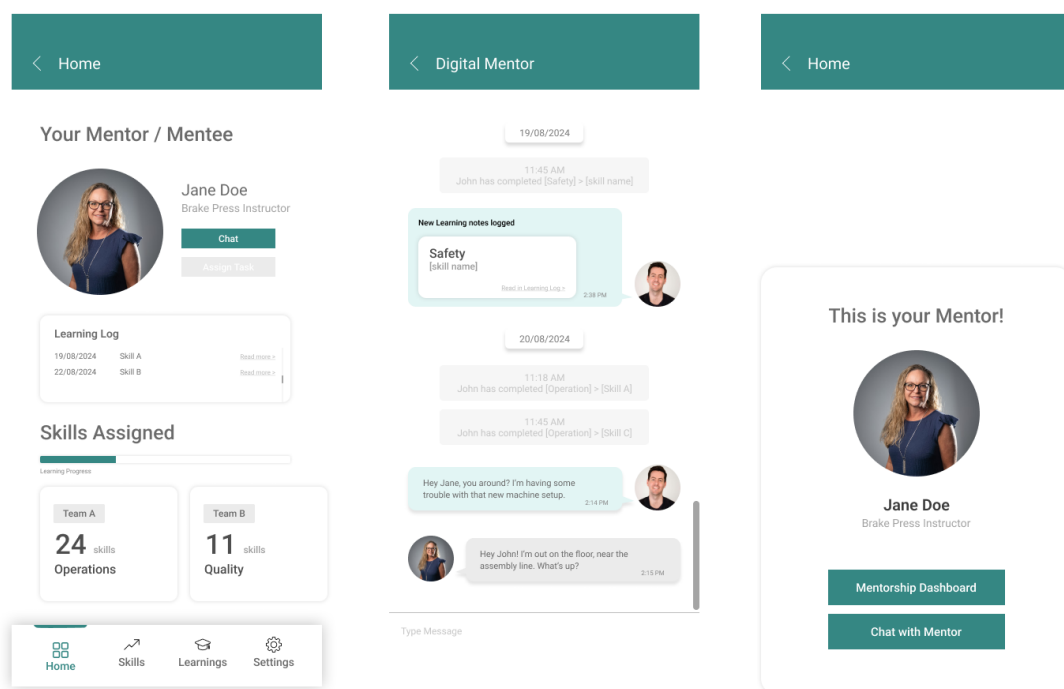
Evaluation and Reflection

The final step in this project is to conduct an Alpha-testing evaluation of the Digital Mentor Program within the Smart Skills platform. The research question guiding this phase is: *How effective are the core features of the Digital Mentor Program in supporting self-directed learning (SDLO) during the initial Alpha testing phase?* Alpha testing is crucial for assessing the robustness and feasibility of the intervention's design, allowing researchers to gather critical feedback on its theoretical foundations and potential effectiveness in real-world scenarios (McKenney & Reeves, 2014). This section outlines the key steps for testing the features developed in the design phase to ensure they effectively foster SDLO among frontline workers, which will enhance the program's success in later implementation stages.

Evaluation Design Recommendation

Participant Selection and Evaluation Duration

A purposive sampling method will be employed, selecting a group of 25-30 participants, including both new hires and experienced workers (Tongco, 2007). This sample size is justified by the need to balance qualitative and quantitative data collection within a mixed-methods framework (Nielsen, 2000; Moran & Budiu, 2021). According to the Nielsen Norman Group (NNG), while smaller sample sizes can uncover a significant percentage of usability issues, a larger group is necessary to obtain reliable quantitative data that can complement qualitative insights (Nielsen, 2000; Moran & Budiu, 2021). This approach allows for a comprehensive evaluation of the program's usability and functionality, ensuring that both in-depth user feedback and broader statistical trends are captured effectively during the Alpha testing phase.

The Alpha testing phase is planned to last approximately 3 months. This duration aligns with the iterative nature of Alpha testing in design research, which involves cycles of

feedback, adjustment, and retesting to ensure the robustness and feasibility of the design (McKenney & Reeves, 2014). The three-month timeframe allows for sufficient interaction with the program's features, enabling multiple rounds of feedback and refinement to optimize the design before broader testing or implementation. This diverse group should reflect varying levels of expertise and self-directed learning capabilities within the workforce. New hires will offer insights into how the mentorship program supports their onboarding process, while experienced workers will assess the program's role in ongoing skill development and knowledge transfer.

Data Collection and Analysis

Throughout the Alpha testing phase, both quantitative and qualitative data will be collected to provide a comprehensive evaluation of each feature. Usage metrics—such as the frequency of feature interaction, task completion rates, and response times—will be tracked to measure engagement and effectiveness. Additionally, qualitative data will be gathered through surveys, interviews, and content analysis, offering deeper insights into user satisfaction, usability, and the practical application of the program's features in real-world settings. This combination of data will be crucial in identifying specific aspects of the Digital Mentor Program that require refinement, ensuring the design is optimized to better meet the needs of users and enhance the learning culture within the organization.

Key Features for Alpha Testing

The Mentorship Dashboard

One of the core features to be tested during the alpha testing is the Mentorship Dashboard. This dashboard is designed to be the central hub where mentors can assign tasks, track progress, and provide feedback. The testing should involve integrating this dashboard into the daily routines of selected mentors and mentees to assess how effectively it supports

their interactions. The goal is to determine whether the dashboard is user-friendly and whether it effectively facilitates the management of mentorship tasks. Mentors will be encouraged to use the dashboard extensively, and their feedback will be crucial in identifying any usability issues or barriers to effective use. By analyzing task completion rates and the frequency of dashboard usage, it can be gauged how well this feature is being adopted and whether it enhances the overall mentorship experience.

Personalized Learning Paths

Another key component to be evaluated is the Personalized Learning Paths feature. This feature enables mentors and mentees to collaboratively develop tailored learning plans that address specific job roles and individual needs. However, the primary focus during Alpha testing will be on assessing whether mentors and mentees can successfully create and navigate these personalized learning plans within the platform. The evaluation will determine whether the interface is intuitive and whether users have access to the necessary tools and resources to build and modify learning paths effectively. At this stage, the goal is to ensure that the basic functionality for creating and adjusting learning paths is both operational and user-friendly, setting the foundation for more detailed testing of adaptability and effectiveness in subsequent phases. Additionally, the evaluation will consider whether users have sufficient resources and access to support the effective creation and implementation of these learning paths. Feedback from participants will be essential in identifying any usability issues or technical barriers that could impede the efficient use of this feature.

Feedback and Reflection

The Feedback and Reflection Section will be tested primarily for its basic functionality and ease of use. This section is designed to provide a structured space where mentors and mentees can exchange feedback and engage in reflective discussions. The Alpha

testing will focus on assessing whether users can easily navigate and utilize this feature, whether the interface supports seamless communication, and whether initial usage patterns suggest that the feature is being integrated into users' routines. Key metrics will include the frequency of use and the ease with which users can provide and access feedback. This phase of testing will help identify any usability issues or technical barriers that might prevent users from effectively engaging with the feature. The goal at this stage is to ensure that the Feedback and Reflection Section is functional, user-friendly, and ready for more extensive testing in later phases.

Table 10

Overview of the Alpha Testing for the key features

Feature	Evaluation Focus	Goals	Key Metrics
Mentorship Dashboard	Integration into daily routines of mentors and mentees	Assess user-friendliness and effectiveness in managing mentorship tasks	Task completion rates (Quant) Frequency of dashboard usage (Quant) Identification of usability issues (Qual)
Personalized Learning Paths	Basic functionality and usability in creating and navigating learning paths	Ensure users can successfully create and modify learning paths; assess availability of necessary tools and resources	Successful creation and modification of learning paths (Quant) Identification of usability issues or technical barriers (Qual)
Feedback and Reflection	Basic functionality and ease of use	Ensure feature is functional, user-friendly, and ready for more extensive testing	Frequency of use (Quant) Ease of feedback exchange (Qual) Identification of usability or technical barriers (Qual)

Refinements and Final Adjustments

Based on the findings from Alpha testing, recommendations will be made to refine the program, such as improving the Mentorship Dashboard interface, enhancing learning path flexibility, or optimizing feedback mechanisms. These adjustments are essential to fully optimize the program before broader testing or implementation. Alpha testing is crucial for validating the initial design by providing insights for final adjustments, ensuring the program is both effective and tailored to the workforce's needs, ultimately fostering a culture of continuous, self-directed learning.

Discussion

This thesis explored how the Smart Skills platform can be improved to encourage Self-Directed Learning (SDL) among frontline workers in blue-collar jobs through a Digital Mentor Program. The findings suggest that integrating mentorship and personalized learning paths within a mobile learning (mLearning) framework can help overcome common challenges in blue-collar workplace learning and support continuous skill development. However, there are some limitations to this study, and practical steps need to be considered for effective implementation and evaluation.

Addressing Challenges in Blue-Collar Workplace Learning

Blue-collar workers often face barriers to learning, such as limited time, difficulty applying external training to their jobs, and seeing formal training as irrelevant (Decius et al., 2021; Burnham & Ponton, 2021). The Digital Mentor Program aims to address these issues by embedding learning opportunities directly into the daily work routine using a mobile learning platform.

The program leverages experienced workers as mentors to provide timely and relevant support, making learning more applicable and immediate. Personalized Learning Paths allow workers to take control of their development by aligning learning goals with their specific roles and career goals. This approach makes learning more engaging and relevant, supporting the development of SDL in environments where workers typically have low autonomy (Decius et al., 2021).

Limitations and Future Research

One key limitation of this study is the lack of direct input from frontline workers. Most insights came from team leads and supervisors, which might not fully capture the workers' perspectives and needs. Future research should involve frontline workers directly

through surveys, interviews, and observations to ensure the program meets their needs and increases their engagement.

Another limitation is that the study was conducted in a single organization, which may limit how well the findings apply to other industries or settings. Future studies should test the program in different types of organizations to see how well it adapts and works in various environments. It would also be valuable to study the long-term effects of the program on job performance, satisfaction, and retention.

Practical Implications for Smart Skills Implementation

To successfully implement the Digital Mentor Program within Smart Skills, several key factors should be considered:

- User-Friendly Design: The platform should be easy to use, with clear instructions and support available to help workers of all skill levels use it effectively.

- Integration with Daily Work: The program should be designed to fit smoothly into the existing workflow, so learning becomes a natural part of the workday without causing disruptions.

- Feedback and Evaluation: Regular feedback from users should be collected and used to make continuous improvements to the program. It's important to track engagement, progress, and skill development to ensure the program is working effectively.

- Scalability and Flexibility: The program should be designed to scale across different departments and locations and be flexible enough to adapt to various work environments and needs.

By focusing on these areas, the Digital Mentor Program can be successfully implemented and help create a culture of continuous learning, enabling frontline workers to take charge of their development.

Conclusion

This research has provided insights into how SDL can be enhanced among blue-collar workers using a mobile learning platform like Smart Skills. The proposed Digital Mentor Program offers a promising way to integrate personalized learning and mentorship into the daily routines of frontline workers, making learning more relevant and engaging. Addressing the study's limitations and following the practical implementation strategies outlined here will be crucial for maximizing the program's potential. Ultimately, fostering SDL in blue-collar environments can benefit both workers and organizations by promoting ongoing skill development and adaptability in a constantly changing work landscape.

References

Aljarrah, E., Elrehail, H., & Aababneh, B. (2016). E-voting in Jordan: Assessing readiness and developing a system. *Computers in Human Behavior*, *63*, 860–867. https://doi.org/10.1016/j.chb.2016.05.076

Annuar, N., & Shaari, R. (2014). The Antecedents toward Self-Directed Learning among Distance Learner in Malaysian Public Universities. *Journal of Social Sciences Research*, 3(2), 415–421. https://doi.org/10.24297/jssr.v3i2.3207

Baber, H., Deepa, V., Elrehail, H., Poulin, M., & Mir, F. (2023). Self-directed learning motivational drivers of working professionals: confirmatory factor models. Higher Education, Skills and Work-Based Learning. https://doi.org/10.1108/heswbl-04-2023-0085.

Billett, S. (2001). Learning through work: workplace affordances and individual engagement. *Journal of Workplace Learning*, *13*(5), 209–214. https://doi.org/10.1108/eum0000000005548

Boyer, S. L., Edmondson, D. R., Artis, A. B., & Fleming, D. (2014). Self-Directed Learning: A Tool for Lifelong Learning. Journal of Marketing Education, 36(1), 20-32. https://doi.org/10.1177/0273475313494010

Brandt, C. & National Center for the Improvement of Educational Assessment. (2020). *Measuring student success skills: A review of the literature on self-direction.* https://files.eric.ed.gov/fulltext/ED607782.pdf

Brown, A. (2000, June 28). Costs and benefits of self-directed learning at work: interaction of social influences and individual commitment. *Education, Training, Professional Development and Performance Seminar*

Burnham, J. D., & Ponton, M. K. (2021). An exploration of the deterrents to adult basic education among blue collar workers. *Journal of Studies in Education*, *11*(1), 26. https://doi.org/10.5296/jse.v11i1.18169

Cascio, W. F., & Montealegre, R. (2016). How technology is changing work and organizations. *Annual Review of Organizational Psychology and Organizational Behavior*, *3*(1), 349–375. https://doi.org/10.1146/annurev-orgpsych-041015-062352

Cerasoli, C., Alliger, G., Donsbach, J., Mathieu, J., Tannenbaum, S., & Orvis, K. (2018). Antecedents and Outcomes of Informal Learning Behaviors: a Meta-Analysis. *Journal of Business and Psychology*, 33, 203-230. https://doi.org/10.1007/S10869-017-9492-Y.

Çiçek, I. (2013). Relationship between Balance of Job Demands-control and Shared Mission/Vision for Blue-collar Employees. *Procedia: Social & Behavioral Sciences*, *99*, 1093–1104. https://doi.org/10.1016/j.sbspro.2013.10.583

Deci, E. L., & Ryan, R. M. (2000). Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. *American Psychologist*, 55–55, 68–78. https://selfdeterminationtheory.org/SDT/documents/2000_RyanDeci_SDT.pdf

Decius, J., Schaper, N., & Seifert, A. (2019). Informal workplace learning: Development and validation of a measure. *Human Resource Development Quarterly*, *30*(4), 495–535. https://doi.org/10.1002/hrdq.21368

Decius, J., Schaper, N., & Seifert, A. (2021). Work characteristics or Workers' characteristics? An Input-Process-Output perspective on informal workplace learning of Blue-Collar workers. *Vocations and Learning*, *14*(2), 285–326. https://doi.org/10.1007/s12186-021-09265-5

Du Toit-Brits, C., & Van Zyl, C. (2017). Self-directed learning characteristics: making learning personal, empowering and successful. *Africa Education Review*, *14*(3–4), 122–141. https://doi.org/10.1080/18146627.2016.1267576

Gandomkar, R., & Sandars, J. (2018). Clearing the confusion about self-directed learning and self-regulated learning. Medical Teacher, 40(8), 862–863. https://doi.org/10.1080/0142159X.2018.1425382

Gijbels, D., Raemdonck, I., & Vervecken, D. (2010). Influencing Work-Related Learning: The Role of Job Characteristics and Self-Directed Learning Orientation in Part-Time Vocational Education. *Vocations and Learning*, 3, 239-255. https://doi.org/10.1007/S12186-010-9041-6.

Hampel, N., Sassenberg, K., Scholl, A., & Reichenbach, M. (2021). Introducing digital technologies in the factory: determinants of blue-collar workers' attitudes towards new robotic tools. *Behaviour & Information Technology*, *41*(14), 2973–2987. https://doi.org/10.1080/0144929x.2021.1967448

Infelise, L. (1994). In-company training: new frontiers in Europe. *Third International Interdisciplinary Conference*

Irugalbandara, A.-M. (2023, June 18). *Upskilling and reskilling for Blue-Collar trainees: Adapting to an evolving industry*. https://www.future1st.com.au/post/upskilling-and-reskilling-for-blue-collar-trainees-adapting-to-an-evolving-industry

Istenič, T., Zupan, N., Česnik, M., Nosan, E. G., & Podpeskar, N. (2022). Reskilling and upskilling in support of company competitiveness. In P. D. Muren, M. Koman, T. Redek (Eds.), *Metaversing the corporate strategy: the opportunities and challenges of digital transformation* (pp. 225-243). Časnik Finance.

J. Lang and P. Palát, "Enriching traditional education by evaluation driven tool for mLearning," 2012 IEEE 10th International Conference on Emerging eLearning Technologies and Applications (ICETA), Star Lesn, Slovakia, 2012, pp. 235-240, doi: 10.1109/ICETA.2012.6418329.

Kankaraš, M. (2021). Workplace learning: determinants and consequences: insights from the 2019 European company survey. Luxembourg: Publications Office. Cedefop working paper; No 7. http://data.europa.eu/doi/10.2801/111971

Kasriel, S. (2017). Skill, re-skill and re-skill again. How to keep up with the future of work. *World Economic Forum*. https://www.weforum.org/agenda/2017/07/skill-reskill-prepare-for-future-of-work/

Karaali, D., Gumussoy, C. A., & Calisir, F. (2011). Factors affecting the intention to use a web-based learning system among blue-collar workers in the automotive industry. *Computers in Human Behavior*, *27*(1), 343–354. https://doi.org/10.1016/j.chb.2010.08.012

Knowles, M.S. (1975). *Self-directed learning: a guide for learners and teachers*. NY: Cambridge Books.

Kruszelnicki, W. (2020). Self-Directedness and the Question of Autonomy: From Counterfeit Education to Critical and Transformative Adult Learning. Studies in Philosophy and Education, 39, 187-203. https://doi.org/10.1007/s11217-019-09697-6.

Kyndt, E., Endedijk, M. & Beausaert, S. (2023). The how and why of workplace learning: Towards an integrative model [Manuscript submitted for publication]. BMS-PLT, University Twente.

Lasfeto, D., & Ulfa, S. (2020). The relationship between self-directed learning and students' social interaction in the online learning environment. *Journal of learning and knowledge society, 16*(02), 34-41. https://doi.org/10.20368/1971-8829/1135078

Lejeune, C., Mercuri, D., Beausaert, S., & Raemdonck, I. (2016). Personal development plans supporting employee learning and perceived performance: the moderating role of self-directedness. *Human Resource Development International*, *19*(4), 307–328. https://doi.org/10.1080/13678868.2016.1203639

Lemmetty, S., & Collin, K. (2020). Self-directed learning as a practice of workplace learning: Interpretative repertoires of self-directed learning in ICT work. *Vocations and Learning*.

Loyens, S. M. M., Magda, J., & Rikers, R. M. J. P. (2008). Self-Directed Learning in Problem-Based Learning and its Relationships with Self-Regulated Learning. *Educational Psychology Review*, *20*(4), 411–427. https://doi.org/10.1007/s10648-008-9082-7

Loeng, S. (2020). Self-Directed learning: a core concept in adult education. *Education Research International*, *2020*, 1–12. https://doi.org/10.1155/2020/3816132

McKenney, S. & Reeves, T. C. (2014). Methods of evaluation and reflection in design research. Zeitschrift für Berufs- und Wirtschaftspädagogiek, 27, 141-153

Morandini, S. (2023). The impact of artificial intelligence on workers' skills: upskilling and reskilling in organisations. *Informing Science: The International Journal of an Emerging Transdiscipline*, *26*(2023), 039-068. https://doi.org/10.28945/5078

Moreira, F., Ferreira, M. J., Santos, C. P., & Durão, N. (2017). Evolution and use of mobile devices in higher education: A case study in Portuguese Higher Education Institutions between 2009/2010 and 2014/2015. *Telematics and Informatics*, *34*(6), 838–852. https://doi.org/10.1016/j.tele.2016.08.010

Moran, K., & Budiu, R. (2021). *How many participants for Quantitative usability studies: A summary of Sample-Size Recommendations*. Nielsen Norman Group. https://www.nngroup.com/articles/summary-quant-sample-sizes/

Morris, T. H. (2019). Self-directed learning: A fundamental competence in a rapidly changing world. *International Review of Education*, *65*(4), 633–653. https://doi.org/10.1007/s11159-019-09793-2

Nielsen, J. (2000). *Why You Only Need to Test with 5 Users*. Nielsen Norman Group. https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/

Niemiec, C. P., & Ryan, R. M. (2009). Autonomy, competence, and relatedness in the classroom: Applying self-determination theory to educational practice. *Theory and Research in Education*, 7(2), 133-144. https://doi.org/10.1177/1477878509104318

Parietti, M. (2024). *Blue-Collar vs. White-Collar: What's the Difference?* Investopedia. https://www.investopedia.com/articles/wealth-management/120215/blue-collar-vs-white-collar-different-social-classes.asp

Pilling-Cormick, J., & Garrison, D. R. (2013). Self-Directed and Self-Regulated Learning: conceptual links. *Canadian Journal of University Continuing Education*, 33(2). https://doi.org/10.21225/d5s01m

Pugh NS. Educating blue-collar workers: the challenge of program development. AAOHN J. 1992 Sep;40(9):419-22. Erratum in: AAOHN J 1993 Jan;41(1):preceding 6. PMID: 1524614.

Regan, J. (2003). Motivating students towards self-directed learning. *Nurse Education Today*, *23*(8), 593–599. https://doi.org/10.1016/s0260-6917(03)00099-6

R. Sabharwal, R. Chugh, M. R. Hossain and M. Wells, "Learning Management Systems in the Workplace: A Literature Review," *2018 IEEE International Conference on*

Teaching, Assessment, and Learning for Engineering (TALE), Wollongong, NSW, Australia, 2018, pp. 387-393, doi: 10.1109/TALE.2018.8615158.

S Acharya, A., Prakash, A., Saxena, P., & Nigam, A. (2013). Sampling: Why and how of it. *Indian Journal of Medical Specialties*, 4(2), 330-333.

Sawant, Rhea; Thomas, Bryan; and Kadlag, Swati (2022) "Reskilling and Upskilling : To Stay Relevant in Today's Industry," *International Review of Business and Economics*: Vol. 7: Iss. 1, Article 4.

Saari, T., Leinonen, M., & Tapanila, K. (2021). Sources of meaningful work for Blue-Collar workers. *Social Sciences*, *11*(1), 2. https://doi.org/10.3390/socsci11010002

Sharma, M., & Srivastav, G. (2020). Study and review of learning management system software. In *Lecture notes in networks and systems* (pp. 373–383). https://doi.org/10.1007/978-981-15-2043-3_42

Schweder, S., & Raufelder, D. (2021). Examining positive emotions, autonomy support and learning strategies: Self-directed versus teacher-directed learning environments. Learning Environments Research, 25, 507-522. https://doi.org/10.1007/S10984-021-09378-7.

Sponselee HCS, Ter Beek L, Renders CM, Robroek SJW, Steenhuis IHM, Kroeze W. Stakeholders' Perceptions Regarding Adaptation and Implementation of Existing Individual and Environmental Workplace Health Promotion Interventions in Blue-Collar Work Settings. *Int J Environ Res Public Health*. 2022 Oct 19;19(20):13545. doi: 10.3390/ijerph192013545. PMID: 36294131; PMCID: PMC9603088.

Tongco, M. D. C. (2007). *Purposive sampling as a tool for informant selection*. https://scholarspace.manoa.hawaii.edu/items/bb41a2e3-2408-436b-933d-8fbc47465d79

Trede, F., Markauskaite, L., Mcewen, C., & Macfarlane, S. (2019). mLearning in Workplace Learning. *Understanding Teaching-Learning Practice*. https://doi.org/10.1007/978-981-13-7410-4_3.

Tynjälä, P. (2012). Toward a 3-P Model of Workplace Learning: a Literature Review. *Vocations and Learning*, *6*(1), 11–36. https://doi.org/10.1007/s12186-012-9091-z

Urhahne, D., Wijnia, L. Theories of Motivation in Education: an Integrative Framework. *Educ Psychol Rev 35*, 45 (2023). https://doi.org/10.1007/s10648-023-09767-9

Xu, W., & Zammit, K. (2020). Applying Thematic Analysis to Education: A hybrid approach to interpreting data in practitioner research. *International Journal of Qualitative Methods*, *19*, 160940692091881. https://doi.org/10.1177/1609406920918810

Yew Wong, K. and Aspinwall, E. (2004), "Characterizing knowledge management in the small business environment", *Journal of Knowledge Management*, Vol. 8 No. 3, pp. 44-61. https://doi.org/10.1108/13673270410541033

Zimmerman, B. J. (2002). Becoming a Self-Regulated Learner: An Overview. *Theory Into Practice, Digital/Theory Into Practice*, *41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2

Appendix

Appendix A: Interview Prompt for Team Leads and Supervisors

Hello and welcome to this interview. First, I want to thank you for taking the time to participate. I'll start by introducing myself and providing some context for our discussion. My name is May, and I am currently pursuing a master's degree in Educational Science and Technology at the University of Twente. I have invited you to participate in this interview because I am researching how learning takes place in a frontline workplace.

By learning, I mean gaining new knowledge or skills while working, not in a school setting. 'Workplace learning' includes training on new tools, learning to communicate with peers, or picking up tips from senior colleagues. In this interview, I want to understand how this learning happens during your daily work and how it starts. Do you have any questions about workplace learning?

Great! In total, there are 9 main questions I will ask.. This interview should take about 30 minutes. I will be making audio and video recordings of our conversation, which will be used solely for transcription purposes. These recordings will be deleted once the research is completed. All information you provide will be kept confidential and anonymous; your responses will not be linked to your name in any reports. I will analyze the interview and use the result to guide the next steps of my project, and the final thesis will later be shared with the University of Twente, its online database, and SwipeGuide.

Before we start, I'd like to know how the two of you usually work together. OK! Later I will start the questions with XXX, then move on to XXX, do you have any questions about this interview?

Start recording

1. **Presage: Individual Characteristics and Workplace Context**

To begin, I'd like to understand what triggers the need for learning.

Q1: (For workers) As I mentioned earlier, this learning does not necessarily have to be book knowledge. It can be anything that helps you do your job better or avoid errors in the future (e.g., a new skill, learning how to use a tool, safety precautions, communication skills…). In this case, can you give some examples of what you need to learn for work?

Follow-up: Which of these are learned through training programs and what are the training programs like?

Follow-up: Which of these are learned more informally while working?

Follow-up: (For supervisors) Do you want to add some more learning that is required or expected for the workplace?

Follow-up: (For supervisors) What role do you play in triggering the learning process?

Q2: (For workers) When and how do you know you need to learn something new from your job?

Follow-up: What would you say about yourself (the workers) that helps you (them) know what you (they) need to learn? (e.g., personality, past experience, knowledge of industry,…)

Q3: (For workers) After acknowledging what to learn, how do you decide if you want to learn it?

Follow-up: How do your colleagues, seniors, or supervisors affect your deciding what to learn?

Follow-up: How does the workplace environment (e.g., learning culture, promotion criteria) affect your deciding what to learn?

Follow-up: (For supervisors) How does the company, or any managerial team decide/design what workers need to learn?

2. Process: Workplace Learning Characteristics and Activities

After knowing how you approach learning, I'd like to know about the learning activities and methods you use to gain new skills and knowledge at your work

Q4: (For workers) Can you describe the typical learning activities you engage in during work?

Follow-up: (For supervisors) How are these activities decided and designed?

Follow-up: (First workers, then supervisor) What resources (time, people, money, tools, programs) are available for these learning activities?

Follow-up: How can the learning be supported with these resources?

Follow-up: Which kind of activities do you find to be most effective and why is that?

Q5: (Both) If you could decide, what kind of learning activities do you think would be more effective?

Q6: (Both) Do you use technology, such as mobile apps or online platforms, to help you gain new knowledge for your job?

Follow-up: Is it compulsory to use or do you engage in the platform on your own?

Follow-up: Can you describe your experience with these tools?

Follow-up: What is your opinion on these technologies?

Q7: (For workers) Are there any obstacles/difficulties/challenges that stop you from learning?

Follow-up: (For supervisors) Have you noticed any recurring challenges when arranging learning activities or when workers participate in the learning activities?

Follow-up: How do you usually deal with these challenges?

3. Product: Outcomes of the Learning Process

Q8: (Both)How has learning new skills or knowledge impacted your job performance? Can you give specific examples?

Follow-up: How does the learning affect your relationship with your peer workers and your supervisors? (e.g., did this make them proud to be faster or did it help a colleague to work safer)

Q9: From your perspective, do you think these learning outcomes help you (workers) engage in more learning in the future?

Thank you for your time and valuable insights. Your responses will greatly contribute to understanding how to better support learning among production line workers. Do you have any questions or comments about this interview?

In the coming weeks, I will conduct further interviews with other stakeholders. If you are interested in the results of this research, I can send them to you once the study is completed. Thank you again for your participation.

Appendix B: Interview Prompt for Experts

Hello and welcome to this interview. First, I want to thank you for taking the time to participate. I'll start by introducing myself and providing some context for our discussion. My name is May, and I am currently pursuing a master's degree in Educational Science and Technology at the University of Twente. I have invited you to participate in this interview because I am researching how to support self-directed learning (SDL) among blue-collar workers in the workplace.

In this interview, I want to know more about the learning context in a blue-collar workplace. Therefore, the interview will be broken down into sections to understand different aspects of your learning experiences. In total, there are 10 main questions I will ask. This interview should take about 30 minutes. I will be making audio recordings of our conversation, which will be used solely for transcription purposes. These recordings will be deleted once the research is completed. All information you provide will be kept confidential

and anonymous; your responses will not be linked to your name in any reports. I will analyze the interview and use the result to guide the next steps of my project, and the final thesis will later be shared with the University of Twente, its online database, and SwipeGuide.

Before we begin, do you have any questions or concern about the interview?

Start Recording

1. **Current Learning Engagement**

   This section will gather insights into the current state of workplace learning for blue-collar workers from the experts' perspective. Questions will cover the prevalent learning practices, factors influencing learning approaches, examples of learning activities, and the outcomes of these activities.

   Q1: From your perspective, what are the prevalent learning practices of workplace learning for blue-collar workers?

   Follow-up: How do blue-collar workers learn at their workplace?

   Q2: How do blue-collar workers identify what they need to learn?

   Follow-up: Are learning objectives self-generated or externally regulated?

   Q3: What kind of support do workers have from the workplace that encourages them to learn?

   Follow-up: How do individual factors (personality, motivation, personal circumstances) affect blue-collar workers to learn required skills? Either in a positive way or negative way

   Follow-up: How do individual factors (personality, motivation, personal circumstances) affect blue-collar workers to learn additional skills/soft skills? Either in a positive way or negative way

Q4: What learning activities do blue-collar workers commonly engage in at work?

Q5: What are the benefits mobile learning methods have on frontline workers learning?

Q6: What are some common challenges with mobile learning?

- How do workers deal with or plan to deal with it?
- What aspect of mLearning do you think can be improved to encourage engagement?

2. **Barriers and Facilitators to Self-Directed Learning**

This section will focus on identifying the resources available for SDL, helpful factors for learning independently, and the challenges faced by blue-collar workers in their SDL efforts.

Q7: What resources (time, people, money, tools, programs) are available for self-directed learning at work?

Q8: What can help blue-collar workers learn new knowledge and skills on their own?

Q9: What challenges do blue-collar workers face when trying to learn new skills on their own?

Thank you for your time and valuable insights. Your responses will greatly contribute to understanding how to better support self-directed learning among blue-collar workers. Do you have any questions or comments about this interview?

In the coming weeks, I will conduct further interviews with team leads, supervisors, and managers. If you are interested in the results of this research, I can send them to you once the study is completed. Thank you again for your participation.

Appendix C: Informed Consent Form

Consent Form for SDL in blue-collar workplace

Please tick the appropriate boxes   **Yes**   **No**

Taking part in the study

I have read and understood the study information, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	□	□
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	□	□
I understand that taking part in the study involves an audio and video recorded interview and I agree to be audio/video recorded.	□	□

Use of the information in the study

I understand that personal information collected about me that can identify me will not be shared beyond the study team.	□	□
I agree that my information can be quoted in research outputs	□	□

Future use and reuse of the information by others

I give permission for the anonymized transcripts and audio recordings that I provide to be archived in university-approved secure servers and encrypted cloud storage so they can be used for future research and learning.	□	□
I give the researchers permission to keep my contact information and to contact me for future research projects.	□	□

Signatures

_____   _____   _____
Name of participant [printed]   Signature   Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____Min-Yu Wu_____   _____   _____
Researcher name [printed]   Signature   Date

Study contact details for further information:

- Name: Min-Yu Wu
- Email: m.y.wu@student.utwente.nl
- Phone: +31630593170

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee/domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-hss@utwente.nl

Appendix D: Codebook

Research Question	What are the factors facilitating or hindering frontline WPL, and which of these factors can be used to foster SDL among frontline workers?	
Sub-RQ	What are the facilitators of workplace learning in a frontline workplace?	
Categories	**Codes**	**Example Quotes**
A1. Social Support and Interaction	Team Lead/Supervisor support	"…they can understand at their own pace and they can work with the leads and the leads can walk them through every issue that they might be having."
	Peer support	"you need to have a environment and you have to have colleagues with whom you feel that it's comfortable to do that."
	Cross-Team Collaboration	"…when making products that engineers, for example, they ask for feedback from production workers about making a particular product and and that they actually seek feedback in order to be able to improve the product the same as production workers…"
A2. Job Responsibility	Accountability	"…having the guy, one guy do the safety stuff. One guy, knowing the lean production. And then they also hold each other accountable."
	Fear of mistake, prevent error	"So I have, everything we do in fabrication has to be to set, assembled up for success because if the line ever stops, that's time we never get back. And so that is money that we never get."
A3. Supportive Learning Environment	Error-Tolerant Learning Environment	"if mistakes are allowed to be made, if there is, you know, examples of people who take learning and initiate and you know you try to develop together, you are curious, you're open."
	Structured learning support	"we'll have somebody like XX going over that same stuff with them using the swipe guide add like bullet points for what stuff they're gonna learn that day."
A4. Autonomy in Learning	Interest in skill development	"So then if they are interested in being a team lead, they construct to take those you know, you know, take that development into their own hands and start doing these trainings." "you could also talk to your manager if you do

		want to make a next step in your career and you want to move up." "…those that wanna be developed and that you know they wanna grow with the company and they wanna better themselves, they are the ones participating the most…"
	Seek for feedback	"when making products that engineers, for example, they ask for feedback from production workers about making a particular product and and that they actually seek feedback in order to be able to improve the product the same as production workers"

Research Question	What are the factors facilitating or hindering frontline WPL, and which of these factors can be used to foster SDL among frontline workers?
Sub-RQ	What are the barriers to WPL in a frontline workplace?

Categories	**Codes**	**Examples**
A1. Generational Challenges	Fear of replacement	"How senior employees still try to portray as if they do have the expertise, even if they don't, just to maintain their status, etcetera."
	Lack of interest in learning new things	"they sometimes can be very stubborn and say that, well, I don't need for you to explain me how to make things" "we'd have certain people that want to learn everything and then we'd have certain people that feel like they're too old to maybe wanna learn or they already know and they don't want to learn."
	Reliance on manual knowledge transfer	"once they retire, which can be quite soon, that's that knowledge will just be gone because it is just in their knowledge."
	Implicit Knowledge Barrier	"if you don't, if you're in a state like that, you can't always tell the new guy about this thing that you do because you don't even.You don't even think about it when you do it." "it's harder sometimes to convince those people that it is indeed important that you have those soft skills and that you can able you are able to transfer your knowledge"
B2. Negative Attitude towards learning	Money-Driven work attitude	"They they uh, they want to earn their paycheck and that's it, like. And then they go do the fun stuff, which is the rest of their life."
	Bad school experience	"They didn't have the best experience there because usually these are people that were struggling through high school and finally when they got to do the practice-oriented vocational education, they could finally do something with their hands and weren't scolded by the teachers all the time."

B3. Lack of learning support	Lack of time	"if I take all of the team leads off the floor and I and if we were to come up here to the conference room, there's not gonna be a lot getting done out out there on the floor."
	Lack of learning materials	"So when I was trained out on the floor as a builder, I never seen a work instruction."
	Misalignment of learning need and support provided	"If you then have an organization that says, yeah, it doesn't matter how much it cost, we have all these orders and we want people to be able to work with technology, but we don't know how to do it." "in order to be able to transfer their knowledge, they also need to have those soft skills, which often are not there and they are overlooked as not important etetera, which then the management recognizes that it's very important."

Research Question	How is mobile learning (mLearning) used in workplace learning among frontline workers?

Sub-RQ	In what ways does mLearning benefit blue-collar workplace learning?

Categories	**Codes**	**Examples**
C1. Efficiency in Training and Problem-Solving	On-the-Job Problem Solving	"if someone can explain something in a different way that they can attribute to now it's all with it being on the tablet, they can understand at their own pace and they can work with the leads and the leads can walk them through every issue that they might be having."
	Simplified Learning with Clear and Contextual Images	"There was too much verbiage, not enough pictures. Today's learner is not a lot of verbiage and a, you know, a lot of verbiage in very few pictures. SwipeGuide has a few words but a lot of picture."
	Easy to Access	"Now, I would say it's gotten much easier to develop those skills because of everything's on a tablet right in front of them."
C2. Organization and Structure	Organized Learning Materials	"so you have like an onboarding operator that's like stage one, you know, I guess you're operator one and then you go to operator two and as you progress, you know by the time you're done with your two week training, you should be in operator 4." "It is helpful especially to the new operator whenever what's don't have any idea when it comes to brakes when it comes to parts, when it comes to toolings it was helpful because everything is in there."

		"I can from my computer pull up with the parts are and put most of the wording in like the the standard wording in and all she has to do is add the pictures and those fonts and then and then once that's over, we can review the stuff that's critical to quality."
	Structured Knowledge Transfer	"So with swipe guide, we now have that information permanently with us." "It used to be our senior operators out were the only ones that knew how to break these difficult parts.Now everyone knows how to break these parts.Now our swipe guides improve every day and we're that's why we continue to use them every day as well."
C3. Learner Engagement and Autonomy	Enhanced Involvement of Learners	"it's nice for them to be able to access it themselves and then then communicate their learnings to me."
	Foster Autonomy in Learning	"as your learning more skills or becoming more accustomed to different skills on the shop floor is that if you have a question, you actually have a tool that you can go and consult rather than relying on, you know, hey, I have a question, I need to go stop production and go find my supervisor"
	Creating Communication Access	"Like I said, with the feedback options and then being able to tell us what they think and us basically going to them as the experts and you guys are the experts and what you do, I might have been on that machine for 10 years, but they're on it every day and we get new units every day."
Research Question	How is mobile learning (mLearning) used in workplace learning among frontline workers?	
Sub-RQ	What challenges do blue-collar workers face when adopting and engaging with mLearning?	
Categories	**Codes**	**Examples**
D1. Difficulty to Utilize Technology	Difficulty to Utilize Technology	"the senior people also recognize that because the technology is changing so much that many of the junior people also have very valuable knowledge and skill which the seniors don't have, and they can even learn quicker than seniors would have ever because of this maybe more natural kind of affiliation with technology." "for some of our veterans that have been here for a number a number of years and you know, when it comes to technology, they're like, hey, I don't want much to do with that, bet you'd be surprised."

D2. Limited Access to Technology	Limited Access to Technology	"I would say our biggest challenge is maybe just not having enough swipe guide out here." "especially since we don't have, we don't have as many tablets as I think we should have."