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Aligning Learning and Development with Demands in Practice: Challenges and Learning Needs in the Heat Pump Installation Sector

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Abstract

Energy transition in the installation sector increases the need for a skilled workforce to ensure that heat pump systems operate efficiently. However, many installers still face challenges that decrease the quality of installation and limit their ability to keep up with the latest innovations in the sector. In this context, the current study explores the learning needs and challenges by focusing on the barriers faced by installers. Fifteen semi-structured interviews were conducted with multiple stakeholders from the Netherlands, Germany, and Belgium, including an installer, training providers, managers, technical experts, and representatives from sector organizations. Qualitative content analysis was performed to gain a comprehensive insight into the learning needs and challenges from both industry and training perspectives. The frequency analysis provided two important insights. First, there is a clear need to enhance prior knowledge, particularly in hydraulics, the basics of heat pump systems, and heat pump sizing. Participants frequently highlighted that these fundamentals are crucial for conducting the installation effectively. Second, the content of existing learning opportunities often does not align with what installers consider necessary in practice. Many mentioned a weak connection between the current training programs and real-world practices, underlining the need for practical training, while also addressing the importance of including cross-domain perspectives (e.g., solar photovoltaic systems). Other challenges, such as adapting to new technologies, were present but relatively less mentioned. The results are further discussed in both white- and blue-collar contexts. Overall, the findings of this study show that enhancing the quality of heat pump installation goes beyond offering more training opportunities. These training programs need to be tailored to meet the learning needs and challenges of heat pump installers. Addressing these aspects can support the learning and development of a skilled workforce, thus contributing to the energy transition.

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Keywords: heat pump installers; learning needs; challenges; workplace barrier; blue-collar workers

1. Introduction

Fostering decarbonization and the energy transition, especially in the installation industry, requires a skilled workforce to enable the structural shift from fossil fuels to renewables [1]. The traditional education systems struggle to keep up with this increasing demand, in number and competence of their educated professionals/installers [2]. In practice, the consequences are already evident: a recent study analyzing sensor data from 1023 heat pumps across Central Europe found that 17% of air-source heat pumps do not meet the efficiency standards and approximately 10% of systems are improperly sized, mainly due to the lack of standardized guidance and training for installers [3]. This is also supported by Blois-Brooke et al.'s report (2013) [5], identifying technical problems, poor performance, and design issues as the most common

complaints reported by installers of domestic heat pumps. Such problems highlight a deeper misalignment between these blue-collar workers' education and the real-world demands of the energy transition, which requires a closer examination of their learning process in this particular context.

Blue-collar workers mainly work in small and medium-sized enterprises (SMEs) [4], where workers need to keep up with the evolving demands of their profession and directly apply what they have learned in practice [6]. To deal with these changing demands and to update the knowledge and skills of blue-collar workers, organizations offer both formal (e.g., curriculum-based offerings provided by the organization) and informal learning opportunities (e.g., asking questions while on the job) [7,8]. This learning and development process is dependent on contextual, organizational, and personal factors [9], resulting in challenges that prevent learning from starting, impede or interrupt learning [10], as well as leading to learning needs, defined as the gap between what someone knows and what someone needs or wants to know [11]. For industrial sectors such as metal processing, plastic manufacturing, and construction, Decius et al. (2021) [12] showed that building self-directed learning capacity, fostering social support, and developing organizational strategies that recognize and promote workplace learning are key to blue-collar workers addressing their learning needs. Furthermore, Kyndt et al. (2011) [13] found that low learning intention constitutes a key challenge for workers in blue-collar domains such as cleaning companies, messenger services, and assembly plants, leading to low participation in both formal and informal learning activities. Their study also showed that the learning process can be shaped by organizational aspects, such as job autonomy and financial benefits, as well as by socio-demographic variables, such as educational background.

However, studies conducted in adjacent domains do not fully explain the challenges and learning needs workers face in the installation sector that is directly affected by the energy transition [14]. This rapid transformation requires blue-collar workers to keep pace with the development of new technologies and evolving regulatory frameworks, which create knowledge and skill-related gaps but also challenge how and where learning occurs. Therefore, we examine the learning needs and challenges of heat pump installers within workplace learning barriers, including resource, personal, content-related, technological, structural, and interpersonal constraints [15]. By reducing the scope beyond the general blue-collar settings to the specific domain of installation, the study aims to disclose reasons for the misalignment between installers' education and workplace practices, as such insights can lead to meaningful changes in practice [16]. We seek to answer the following two research questions:

1. What are the challenges that hinder learning and performance in the installation sector?

2. What learning needs do workers in the installation sector face?

To answer the research questions in the current study, a qualitative interview study was conducted with different stakeholders from the heat pump sector to shed light on the challenges and learning needs from different perspectives. We adopt the analytical framework of workplace learning barriers by Crouse et al. (2011) to conceptualize learning needs and challenges across resource, personal, interpersonal, structural and cultural, technological, and course-related constraints.

2. Method

2.1. Participants

A total of fifteen participants agreed to participate in the study, representing diverse stakeholder groups within the installation sector across the Netherlands (5), Germany (6), and Belgium (4). The participants involved various professionals from manufacturing companies (5), training (3), installation firms (3), hybrid (manufacturer and installer) firms (1), sector association (1), and software company (1). Specifically, the sample was composed of managers (4), training developers (5), technical experts (2), installer (1), heads of learning and development (2), and heads of association management (1). The purpose of selecting such a diverse group of people was to gain a comprehensive insight into the learning needs and challenges from both industry and training perspectives. All participants involved in the interview process were recruited through the project consortium and their network.

2.2. Data Collection

Data collection was based on a semi-structured interview guideline to explore participants' perspectives on the learning needs and challenges in heat pump installation. The interview guideline comprised a set of general questions applicable to everyone, focusing on perceived challenges and learning needs (e.g., What do you consider to be the biggest challenges in heat pump planning, installation, and maintenance?). Additionally, group-specific questions were included to gather information from distinct stakeholder categories, involving heating professionals (installers, planners, designers), manufacturers and industry associations, and educational providers (e.g., for manufacturers and industry associations: What are the most common mistakes or knowledge gaps you observe in the field?).

Fourteen interviews were conducted online, and one interview was held in person, all by a responsible consortium partner who also fully transcribed the excerpts afterward. The duration of the interviews ranged between 30-60 minutes, and all sessions were audio-recorded with participants' consent. All participants were informed about the study's objectives, their rights to withdraw at any time, and the confidentiality of their responses. The ethical approval was obtained from the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences (BMS) at the University of Twente (Request No. 241265), in accordance with the university's ethical guidelines for research involving human participants.

2.3. Data Analysis

The fifteen transcripts span 141 pages and contain a total of 84,444 words (M = 5,629; Min = 2,525; Max = 16,451). These transcripts were then analysed in ATLAS.ti using a qualitative content analysis following Mayring (2014) [17] to determine challenges and needs across dimensions of workplace learning barriers. In the first step, we deductively coded all interviews for workplace learning barriers using Crouse et al. (2011)'s framework [15] to create a coding scheme with respective categories and adapted subcategories. These categories distinguish between personal constraints, resource constraints, course/learning content and delivery, technological constraints, structural and cultural constraints, and interpersonal constraints. In the second step, we inductively revised and extended the sub-categories through codes that emerged from the data. In a third step, we examined the nature of each sub-category as learning needs or challenges. The new subcategories (e.g., Lack of Prior Knowledge), their relation to categories (e.g., Personal Constraints), and their nature (e.g., Learning Need) were discussed and agreed upon in regular intervals to ensure a common understanding of the iterated codebook. Table 1 shows the code book.

Table 1. Codebook with Categories, Subcategories, and Definitions – inductively adapted sub-categories are marked with an asterisk (*)

Main Categories	Subcategories	Definitions
Personal Constraints	Loss of Motivation	Decreased willingness to engage in learning when training is long, irrelevant, or lacks incentives.
	Prior Unsuccessful Learning	Negative past learning experiences that reduce confidence or willingness to continue learning.
	Lack of Prior Knowledge*	Foundational gaps in prior knowledge needed to efficiently carry out a task.
	Competency Barriers*	Insufficient skills in applying knowledge to practice (e.g., system design, planning, integration tasks).
Resource Constraints	Lack of Human Resources*	Shortage of a qualified workforce.
	Lack of Time	Limited time available for learning or performing essential tasks (e.g., maintenance, setup).
	Lack of Workspace	Physical constraints or cramped environments that hinder effective performance and learning on-site.

Learning Content and Delivery	Acquiring Inappropriate Knowledge	Training content that does not translate well to real-world tasks (e.g., oversimplified or generic information).
	Expectations of In-house Training Not Met	Mismatch between what learners expect to learn and what training actually provides.
	Inhibiting Factors Related to Learning Content*	Training includes confusing, overly theoretical, or regulation-heavy information that complicates learning.
	Failure to Meet Learning Preferences and Training Needs*	Training formats or content that do not align with learners' needs.
Technological Constraints	User of New Technology	Difficulties adapting to digital tools (e.g., tablets, apps) or advanced system features due to low digital literacy.
Structural and Cultural Constraints	Fast Pace of Change	Continuous updates in regulations, technologies, and market demands that require frequent knowledge adaptation.
	Policy-Driven Barriers*	External policy or subsidy-related mechanisms that indirectly impact learners' work conditions.
	Lack of Interdisciplinary Coordination*	Limited collaboration across related trades (e.g., electrical, solar, HVAC), leading to learning and coordination challenges.
Interpersonal Constraints	Poor Managerial Skills	Insufficient communication, coordination, or leadership among supervisors affecting learning and workflow.

3. Results

As part of the qualitative content analysis, we calculated frequencies by counting how often each subcategory was coded across all transcripts. Percentages reflect each subcategory's share of the total coded segments, allowing us to identify the most prominent challenges and learning needs. The frequency analysis (see Table 2) revealed that course/learning content and delivery (48%) as well as personal constraints (37%) are by far the most important barriers to installers' workplace learning, making up more than four-fifths of all mentioned challenges and needs. The remaining mentions refer to resource constraints (7%), structural and cultural constraints (5%), technological constraints (3%), and finally interpersonal constraints (1%).

Challenges make up about one-third of mentions across all barriers. Amongst them, acquiring inappropriate knowledge (6%) and inhibiting factors related to learning content (6%) were the most frequently mentioned, followed by lack of human resources (5%) and unmet expectations of in-house training (3%). Other notable challenges included the use of new technologies (3%) and the fast pace of change in the sector (3%). Personal challenges, like loss of motivation and prior unsuccessful learning experiences, were mentioned less frequently (2% each). A few structural and organizational issues, such as policy-driven barriers, lack of interdisciplinary coordination, and poor managerial skills, were only mentioned once each (1%). Overall, these findings highlight a broad set of challenges that range from different factors.

Regarding learning needs, failure to meet learning preferences and training needs (33%) was by far the most frequently mentioned, closely followed by lack of prior knowledge (28%). Competency barriers (6%) play a comparable smaller role but still represent a noteworthy learning need. Together, they make up about two-thirds of all the mentioned learning needs and challenges.

Table 2: Frequencies and percentages of challenges and learning needs across subcategories and subcategories

Deductive Category	Frequency(n)/ Percentage (%)	Challenge / Need	Deductive / Inductive Subcategory	Frequency(n)/ Percentage (%)
Personal Constraints	45/36,89	Challenge	Loss of Motivation	2/1,64

		Challenge	Prior Unsuccessful Learning Experience	2/1,64
		Need	Lack of Prior Knowledge*	34/27,87
		Need	Competency Barriers*	7/5,74
Resource Constraints	8/6,56	Challenge	Lack of Human Resources*	6/4,92
		Challenge	Lack of Time	1/0,82
		Challenge	Lack of Workspace	1/0,82
Course/Learning Content and Delivery	58/47,54	Challenge	Acquiring Inappropriate Knowledge	7/5,74
		Challenge	Expectations of In-House Training Not Met	4/3,28
		Challenge	Inhibiting Factors Related to Learning Content*	7/5,74
		Need	Failure to Meet Learning Preferences and Training Needs*	40/32,79
Technological Constraints	4/3,28	Challenge	Use of New Technologies	4/3,28
Structural and Cultural Constraint	6/4,92	Challenge	Fast Pace of Change	4/3,28
		Challenge	Policy-Driven Barriers*	1/0,82
		Challenge	Lack of Interdisciplinary* Coordination	1/0,82
Interpersonal Constraints	1/0,82	Challenge	Poor Managerial Skills	1/0,82

We structured the insights from qualitative analysis according to Crouse et al.'s (2011) [15] workplace learning barriers, and present challenges that hinder learning and the learning needs that highlight gaps in knowledge or skills for each barrier separately. The findings are supported by examples and quotes from the interviews.

3.1. Personal Constraints

The analysis of personal constraints of installers revealed two different challenges that can influence how installers engage with learning opportunities: loss of motivation and prior to unsuccessful learning experiences. Especially when there is no extrinsic incentive and the content doesn't feel directly relevant, installers tend to lose interest, highlighting a general lack of motivation for long-term training (P2): *"My brother-in-law, for example, is willing to attend a training for 2–3 days if there is good food and a nice program. But if I say it is a six-week module, they are not willing to do it."* Another challenge was related to prior unsuccessful learning experiences, underlining the high dropout rate (P1): "*An apprentice comes in on the first day, and by the second day, they've already lost interest. Our dropout rate is shocking—it's at 40%. That means 40% of apprentices drop out between their first and third year of training."* This kind of experience (e.g., losing interest) can affect someone's willingness to keep learning. Overall, these examples show how personal motivation and previous learning experiences can influence how installers engage with learning opportunities.

We found that learning needs in personal constraints were mostly attributed to a lack of prior knowledge. This included frequent gaps in hydraulics (n=8), basic knowledge on heat pump systems (n=6), heat pump sizing (n=4), and electrical integration (n=3). For instance, the learning needs related to hydraulics include the ability to design and evaluate hydraulic circuits that prevent maldistribution and imbalance. Moreover, regarding heat pump sizing, the learner should be able to determine the required heating load under different operating conditions, such as variations in ambient temperature and part-load scenarios. As one participant (P1) said: "*The absolute key is hydraulics. Understanding how hydraulics work is essential!*". These gaps highlight a broader difficulty in building up fundamental technical understanding. Competency barriers also belong to learning needs in personal constraints, especially around system design and planning (n=4). As one participant (P1) shared: "*So that's one issue. The second point relates to what I mentioned earlier: system design and planning*.". Gaps in storage tank integration, defrost planning, and maintenance experience, reflecting difficulties in applying knowledge to real-world systems, were each mentioned only once. Together, these

needs underline that the development of knowledge and skills is key to learning and performance in heat pump installation.

3.2. Resource Constraints

The analysis of resource constraints revealed three key challenges affecting the learning and performance of installers. The most prominent challenge was a lack of human resources, highlighting how workforce shortages may hinder efficient installation. Many reported difficulties in finding skilled workers who can correctly install heat pumps (n=6). One participant (P2) noted, "*The biggest challenge is having well-qualified employees. It is a complex system, and only 20% of companies can install a heat pump correctly. It needs to be calculated properly, and I need well-qualified employees.*" In addition, time constraints were also raised, particularly in relation to completing essential maintenance tasks (P4): "*They don't have the time. It's a time investment; you have to deal with it, set it up again, and so on*." Lastly, a lack of workspace (n=1) was noted, where cramped on-site conditions negatively impacted installation feasibility. Together, these resource-related challenges demonstrate how external factors, such as staff availability, time pressure, and physical conditions, can shape the installers' performance at work.

3.3. Course/Learning Content Delivery

Challenges related to learning content were mainly centered around three points. The most frequent one was acquiring inappropriate knowledge, mostly related to oversizing heat pumps (n=4). One participant (P3) stated, "*The heating load calculation also tends to be oversized, right, so the room-based heating load calculation tends to be oversized because you often calculate with general values that then make it oversized*." This shows that installers may struggle with translating theoretical guidelines into context-specific practices. Other challenges were mentioned only once, including expectations of in-house training not met (e.g., unrealistic training expectations) and inhibiting factors related to learning content (e.g., regulation in heat pump systems). This indicates that mismatches between training content and installers' practical work environments can lead to confusion and reduced learning effectiveness.

Learning needs in the learning content were mostly related to failure to meet learning preferences and training needs. This is reflected in the need for practical training (n=2), needs for product-related information (n=3), cross-domain training needs (n=3), and needs for hydraulics training (n=3). As one participant (P15) said, "*But the biggest feedback was always that we need more practical training, especially from the installers who say their attention span is not very high during theoretical training. Practical training is the most important. Especially on-site training.*" This highlights the importance of tailoring training formats and content to installers' needs, particularly through hands-on learning experiences.

3.4. Technological Constraints

Challenges related to technological constraints were mentioned less frequently but still raised concerns around digital adaptation. One key issue was the use of digital tools for work (n=2), where installers were expected to use tablets or apps but often lacked comfort in doing so due to a lack of digital literacy. This could reduce their confidence in performing basic digital tasks (e.g., navigating interfaces) and integrating them into daily work routines. As one participant (P15) noted, "*That is sometimes a problem. The craftsmen are not very digital; they are more hands-on, and sometimes it is missing.*" Another challenge was the lack of experience with heat pumps (n=1), particularly among companies transitioning from gas or oil systems. Additionally, the increased complexity of new technologies (n=1), such as advanced control systems, was mentioned as a barrier for some businesses. These challenges reflect limited readiness and digital literacy for adapting to evolving technical demands.

3.5. Structural and Cultural Constraints

Challenges in this category revolved around the fast pace of change in the industry. The most frequently mentioned challenge was the knowledge update pressure (n=2), driven by rapid shifts in gas regulation or emerging technologies. One participant (P6) explained, "*One of the biggest challenges lies in the speed of developments and the level of knowledge that's going up.*" In addition, we identified policy-driven barriers (n=1), where subsidy-related mechanisms influenced market conditions and customers' demands, and a lack

of interdisciplinary coordination (n=1), particularly the need to work more closely with related sectors like solar, electrical, and HVAC. These findings highlight both systemic and policy-level constraints impacting the installers' learning and performance.

3.6. Interpersonal Constraints

One challenge was identified under interpersonal constraints, specifically poor managerial skills (n=1). As one participant (P10) described, "*The biggest challenges are many communicating with everyone involved in the project.*" This highlights the importance of clear communication across all parties involved in the integration of heating systems.

4. Discussion

This study qualitatively explored the challenges and learning needs of heat pump installers through workplace learning barriers with managers, training developers, technical experts, installers, heads of learning and development, and heads of association management. Specifically, the sample was composed of managers, training developers. We revealed in our analysis that course/learning content and delivery, and personal constraints were by far the most frequently mentioned barriers, which together accounted for more than 80% of all interviewees' mentions. Within these, the most important learning needs were failure to meet learning preferences and training needs and lack of prior knowledge, indicating the importance of tailoring training formats (e.g., cross-domain training) and specific topics (e.g., hydraulics) in the installers' context. In terms of challenges, interviewees mentioned most frequently acquiring inappropriate knowledge, inhibiting factors related to learning content, and a lack of human resources. These challenges point to mismatches between training content and field practices, important factors leading to confusion in the learning process, and shortages of a qualified workforce.

We found differences in how resource and personal constraints appear across white- and blue-collar settings when comparing the findings to Crouse et al.'s (2011) [15] study conducted with human resource management (HRM) practitioners. In that study, five out of the six reported challenges fell under the resource constraints, including lack of time, high workload, financial limitations, insufficient access to technology, and geographic accessibility. Among these, only the lack of time was mentioned once in our study, indicating that time pressure may be less of an issue for installers. This is supported by Toppinen-Tanner et al.'s (2002) [18] study showing that time pressure was more frequently mentioned as a job-related stressor among white-collar workers compared to those in blue-collar professions. Instead, we found other challenges for the profile of heat pump installers. For instance, a lack of human resources emerged as the dominant challenge in resource constraints, demonstrating difficulties in finding qualified workers in this sector. This highlights that, unlike in the white-collar context, the main resource-related challenge in the blue-collar context is not time or budget, but workforce availability. This is supported by Milligan's (2022) [19] study underlining widespread labor shortage in blue-collar professions across the United States. In addition, the lack of workspace indicates the presence of unfavorable working environments for blue-collar workers in our study. This is consistent with findings by Gadrey et al. (2006) [20], who reported that skilled blue-collar workers rated their working conditions as less favorable than those of skilled white-collar workers.

Regarding the personal constraints in Crouse et al.'s (2011) [15] study, a lack of learner interest was the only challenge mentioned among HRM professionals. While loss of motivation aligns closely with the lack of interest reported by Crouse et al. (2011), we identified an affective challenge for installers: prior unsuccessful learning experiences. These suggest that emotional factors (e.g., negative past experiences) might play a more important role in the blue-collar context [21], especially given the inconsistent training histories found in their learning pathways [12]. In contrast, personal constraints represented a prominent barrier in our study, and a lack of prior knowledge emerged as a frequently mentioned learning need. This reflects a domain-specific need for installers, many of whom struggle with knowledge gaps in hydraulics, system sizing, and the basics of heat pump systems. These findings suggest that personal constraints in blue-collar settings are shaped by foundational knowledge limitations, likely due to different educational backgrounds [19] and the rapid technical and practical innovations in the energy sector [14].

In addition, we identified several challenges and learning needs that were not reported in Crouse et al.'s (2011) [15] analysis of white-collar professionals. Specifically, course/learning content and delivery, technological

constraints, structural and cultural constraints, and interpersonal constraints differed in the context of our study. The importance of course/learning content and delivery in our data, especially in relation to unmet training needs, highlights misalignments between existing learning formats and the practical realities of installation work. This mismatch has already been well documented in the field of heat pump installation [3]. One possible explanation for this misalignment could be the separation between professional and vocational learning systems, which have traditionally been conceptualized differently in both purpose and design [22]. Additional contributing factors might include financial constraints, limited digital skills, negative prior schooling experiences, employees' unwillingness, and language difficulties in the blue-collar context [23, 24, 25, 26]. Moreover, we found that technological constraints, such as the use of new technologies (e.g., tablets, apps), represented a challenge in our study, but were absent in Crouse's (2011) [15] sample. This may reflect the greater technological complexity of heat pump systems [27] and digital skills gaps (e.g., IT skills) in the learning process of heat pump installers [28]. Similarly, structural and cultural constraints, including rapid changes in the industry and policies, and a lack of interdisciplinary coordination, reflect broader shifts in the energy sector, which might result in pressures experienced by installers. These issues are rarely faced by white-collar workers, whose organizational factors are more stable [29]. Finally, interpersonal constraints (e.g., poor managerial skills), though infrequent in our sample, point to communication challenges in small-team settings typical in the blue-collar context [30].

Across different blue-collar professions, some patterns are consistent with the findings of the current study. For instance, Decius et al. (2021) [12] claimed that supporting self-directed learning, building social support, and having organizational strategies play an important role in addressing the learning needs of industrial sectors such as metal processing, plastic manufacturing, and construction. This idea aligns with tailoring training programs based on the learning needs and challenges that installers experience (e.g., strengthening prior knowledge and providing more practical training). Furthermore, Kyndt et al. (2011) [13] found out that low learning intention is deemed a key barrier for blue-collar domains such as cleaning companies, messenger services, and assembly plants, constraining participation in formal and informal learning opportunities. A similar tendency also emerged from our study when participants described a lack of motivation, especially when there is no extrinsic reward, and the content doesn't feel directly relevant. At the same time, some different aspects become more evident in the installation sector. Whereas previous studies focus more on learning intentions or workplace learning realities at a general level [12, 13], participants in the installation sector highlighted a clear gap in prior knowledge, particularly in hydraulics, heat pump basics, and system sizing. These kinds of knowledge gaps are less evident in the other blue-collar contexts mentioned. Moreover, the need for cross-sectional domain perspectives (e.g., connections with solar systems) shows the complexity of heat pump installation, which goes beyond the issues mentioned in the aforementioned sectors (e.g., cleaning services). This suggests that, even though heat pump installers share common learning patterns with other blue-collar professions, the content and structure of their learning process are more specialized due to the complex technical aspects of their profession.

4.1. Implications for Barriers to Workplace Learning Model

A key theoretical implication of this study is the refinement of the Crouse et al. (2011) framework [15]. As previously noted, Crouse et al. (2011)'s framework has been developed to examine workplace learning barriers in the white-collar context [15], where factors are conceptualized as barriers that impede the learning process at work. In contrast, the current study in the blue-collar context suggests that many of these factors could function not only as challenges but also as indicators of unmet learning needs. Therefore, extending the framework by differentiating between challenges and learning needs could provide a more refined conceptualization of workplace learning barriers in blue-collar settings. Furthermore, while the deductive categories remained the same as in the original framework, the subcategories have been inductively extended in the present study. Together, the modified version of this framework could be used to examine the learning needs and challenges in the blue-collar settings. In the following, we illustrate the value of this refinement by discussing the most frequently mentioned inductive subcategory related to learning needs within personal constraints and the most frequently mentioned challenge within the course/content and delivery category.

Within the personal constraints, the lack of prior knowledge emerged as the most mentioned inductive subcategory related to learning needs. In the original framework proposed by Crouse et al. (2011) [15], these constraints are primarily attributed to attitudinal or motivational barriers, such as a lack of interest in learning. However, our results showed that personal constraints among the target group are shaped by foundational

knowledge gaps rather than only by motivational factors. The lack of prior knowledge was viewed as a crucial need, reflecting difficulties in building a conceptual understanding of a particular topic. Previous studies suggest that existing background knowledge supports the learners in making sense of the materials covered in the curriculum [32], ultimately improving confidence and learning performance at work [33]. This is also evident in the blue-collar context in terms of achieving higher performance levels and professional recognition [34]. Ultimately, this inductive subcategory extends the original framework by additionally focusing on knowledge-related learning needs. This underlines that, in the blue-collar context, personal constraints are closely linked to the accumulation and application of knowledge, in addition to the motivational barriers proposed in the white-collar settings.

Within the course/content and delivery category, failure to meet learning preferences and training needs emerged as the most mentioned challenge. Whereas Crouse et al. (2011) defined this category as the content of information and training expectations (e.g., acquiring inappropriate knowledge, expectations of in-house training not met, etc.) [15], our findings suggest that the nature and alignment of training content itself could be a strong barrier to learning for such a group. Failure to meet learning preferences and training needs highlights a misalignment between traditional training formats and the practice-based learning preferences of installers. Rather than a lack of training opportunities, this subcategory reflects a mismatch between how training is designed and how learning occurs at work. Together, this inductive subcategory extends the original framework by shifting the focus from the availability of learning content to its usability and contextual fit, highlighting the need to conceptualize course-related barriers in blue-collar settings in terms of relevance, clarity, and practical applicability rather than access-related issues. Eventually, this will inform the design process of a training program that is grounded in work tasks and installers' practice-based learning preferences.

4.2. Limitations

While this study provides valuable insights into the learning needs and challenges of heat pump installers, several limitations must be considered. Although 15 interviews are sufficient for interview-based qualitative studies to reach saturation [31], our multi-stakeholder sample across three countries might have required a larger scope beyond these countries. This limitation was apparent in the results: the lack of time was not viewed as an issue, even though this contradicts the realities of SMEs in the working environment (e.g., a lack of workforce, resources, etc.). This discrepancy might stem from the lack of installers in the interview process (1 out of 15 participants), resulting in data that mostly reflects the management's perspective rather than the realities of the workforce. Therefore, future research should include a larger sample size with a focus on installers (e.g., 20-30 interviews) from different countries to increase the generalizability of the results and to capture more specific perspectives of heat pump installers and newly emerging codes. Additionally, we used a framework of workplace learning barriers that was originally developed in the white-collar context [15]. While it provided a useful structure for organizing data across six dimensions, some of its categories may not fully capture the types of learning needs and challenges in the blue-collar context. Certain aspects that are more specific to technical professions might have been underrepresented. Therefore, future studies could further adapt or even expand this framework for the same purpose to ensure this framework is well-suited to the realities of the blue-collar context.

5. Conclusion

The current study shows that the learning needs and challenges of heat pump installers are shaped by different barriers encountered at work. A key finding is that there is a need to close the gaps in installers' prior knowledge, especially on topics of hydraulics, the basics of heat pump systems, and heat pump sizing. Moreover, unmet training needs highlight that the training programs should be structured to cover these topics in a way that is relevant, concrete, and practical, while also including cross-domain perspectives. At the same time, challenges, such as acquiring inappropriate knowledge, keeping up with the fast pace of developments, and adapting to new technologies, should be addressed to improve the effectiveness of the learning and development process of the heat pump installer.

Overall, the findings suggest that improving the quality of installation does not only rely on offering more training, but also tailoring the learning process by considering the learning needs and challenges experienced by the installers. Supporting this target group in this way will help them keep up with the latest developments of the energy transition and carry out installations with greater efficiency and confidence.

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