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Article

How Complementary Transformational Leadership Dimensions Facilitate Opportunities for Employees' Informal Learning in Technology-Enabled Remote Work Environments: A Three-Wave Study

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Abstract

The rise of technology-enabled remote work environments has raised important questions about how to sustain employees' informal learning activities, as these contexts often restrict interactions among coworkers and supervisors. Informal learning, which encompasses task-related learning (i.e., learning through reflection and experimentation) and interactional learning (i.e., learning from colleagues and supervisor), is crucial for adapting to dynamic work environments. While transformational leadership (TFL) is known to foster informal learning in traditional settings, its effectiveness in technology-enabled remote work environments remains unclear. Drawing on the Antecedents–Processes–Outcomes (APO) framework of informal learning, this multi-wave study (n = 1556) investigates the effects of two complementary TFL dimensions—intellectual stimulation and supportive leadership—on task-related and interactional learning in technology-enabled remote work environments, and examines whether these learning activities enhance employee performance. Using structural equation modeling, the results show that intellectual stimulation supports both task-related and interactional learning by promoting learning through reflection and experimentation as well as learning from supervisor, whereas supportive leadership is primarily associated with learning from supervisor and learning through experimentation. Contrary to expectations, no significant moderating effects of the degree of technology-enabled remote working were observed, indicating that the effects of TFL remain consistent across different work settings. Moreover, the findings emphasize the importance of employees' engagement in informal learning processes, particularly learning from supervisor, in enhancing performance. The study advances the APO framework by identifying specific leadership behaviors as key antecedents and testing their relevance in technology-enabled remote work environments. Practically, the findings suggest that leaders can facilitate informal learning and performance regardless of physical proximity by creating cognitively challenging and socially supportive conditions for informal learning.

Keywords: informal learning; transformational leadership; remote work; digital transformation
JEL: D83, M50, O33

1. Introduction

The shift toward technology-enabled remote work has become a defining characteristic of the modern digital workplace (Brünker et al., 2024). In 2023, 23.5% of all employed individuals in Germany worked in such settings (Destatis, 2024), which are defined as work environments where employees operate remotely by leveraging digital technologies (Dutta and Mishra, 2024). While these environments offer flexibility and autonomy (Gajendran et al., 2024), they also present significant challenges, particularly by altering how employees perform their tasks and interact with others (Ruhle and Süß, 2019). In this context, work-related learning becomes increasingly important, as it enables employees to acquire the knowledge and skills needed to adapt (Zajac et al., 2022).

A key form of such learning is informal learning, which encompasses task-related learning (i.e., learning through reflection and experimentation) and interactional learning (i.e., learning from colleagues and supervisor) (Nikolova et al., 2014). As Eraut (2004) emphasizes, informal learning is most effective when it takes place under conditions that are both cognitively challenging and socially supportive. However, technology-enabled remote work environments can restrict opportunities for both. For example, spontaneous idea exchanges, serendipitous encounters, and informal feedback loops are becoming less frequent (Zajac et al., 2022). A lack of creative space, along with frequent work-family interruptions, may occur, leading to a diminished sense of social connection (Haas, 2022; Perry et al., 2022). Therefore, such work environments may stifle the social interaction necessary for employees to successfully gain new knowledge and skills (Zajac et al., 2022).

Given these challenges, the question arises of how organizations can foster informal learning in technology-

enabled remote work environments. Prior research suggests that leadership plays a critical role in stimulating informal learning (Cerasoli et al., 2018; Zia et al., 2022). More precisely, transformational leadership (TFL) has been recognized for promoting adaptability and learning (Bass, 1999), especially in dynamic and changing environments (Faupel and Süß, 2019). While evidence supports the benefits of TFL in traditional work contexts, its effectiveness in technology-enabled remote work environments remains unclear, with recent studies (e.g., Eisenberg et al., 2019; Höddinghaus et al., 2024; Purvanova and Bono, 2009) yielding mixed results. Thus, it is still unclear to what extent TFL continues to facilitate employees' informal learning activities in technology-enabled remote work environments.

To address this gap, the present study examines the impact of TFL on informal learning activities in technology-enabled remote work environments. Specifically, we focus on two distinct but complementary TFL dimensions: intellectual stimulation and supportive leadership (Rafferty and Griffin, 2004). Drawing on Eraut's (2004) observation, we argue that intellectual stimulation addresses the cognitive challenge needed for task-related learning, while supportive leadership fosters the relational support critical for interactional learning. Since these favoring factors might be less pronounced or may not naturally arise in technology-enabled remote work settings, they must be deliberately facilitated by leaders.

Our study is grounded in the Antecedents–Processes–Outcomes (APO) framework of informal learning (Decius et al., 2021). We collected three-wave data from 1556 German employees working in technology-enabled remote contexts, including ratings of the complementary TFL dimensions (i.e., intellectual stimulation and supportive leadership), the two distinct informal learning categories (i.e., task-related learning and interactional learning), and employees' performance (i.e., task proficiency) as an informal learning outcome. Employees' performance is important for maintaining the organization's viability, especially in times of crisis or uncertainty. Moreover, employees' performance is an interesting outcome variable, as there are mixed findings on whether employees can also perform in work settings characterized by a high degree of virtuality (Bloom et al., 2024).

Although there is valuable research on technology-enabled remote and flexible work settings (e.g., Schmoll and Süß, 2019), TFL (e.g., DeRue et al., 2011), and informal learning (e.g., Cerasoli et al., 2018), the relationship between these three has not yet been explored despite its relevance for theory and practice. Thus, our study makes three unique contributions to leadership, informal learning, and technology-enabled remote work literature. First, we enrich the antecedent dimension of the APO framework of informal learning by adopting a facet-level approach to TFL, linking intellectual stimulation and supportive leadership to the "dual-path approach" of informal learning (Nikolova et al., 2014). In doing so, we conceptually translate Eraut's (2004) conditions for informal learning—namely, challenge and support—into concrete leadership behaviors.

Second, we integrate a contextual perspective into the APO framework by examining the effectiveness of these two TFL dimensions in technology-enabled remote work environments. While the APO framework traditionally assumes a sequential process structure, our study examines whether TFL's effectiveness in informal learning activities is contingent upon the technology-enabled remote work context. This extends the theoretical scope of the APO framework by testing its boundaries in technology-enabled remote work environments and contributes to the ongoing debate between universalist and contingent views of TFL's effectiveness.

Third, we provide insights into the effect chain of the APO framework over time by examining the relationship between the two complementary TFL dimensions on employees' performance, mediated through informal learning activities, using multi-wave data. This temporal aspect enriches the framework by illustrating not only that a learning outcome (i.e., task proficiency) emerges, but also how it unfolds in technology-enabled remote work environments (i.e., the mechanism). This offers an important insight into the often cross-sectional and static applications of the APO framework. In doing so, we respond to recent calls (e.g., Decius et al., 2019; Smet et al., 2022) to broaden our understanding of how informal learning translates into individual effectiveness, especially in times of workplace transformation.

2. Literature Review

2.1 Informal Learning in the Workplace

Informal learning refers to non-curricular, intentional, and self-directed activities that aim to acquire work-related and organizationally valued knowledge and skills outside formal learning contexts (Wolfson et al., 2018). It is considered a process that benefits both employees and organizations (Bednall et al., 2014). Grounded in social cognitive theory (Bandura, 1977) and subsequent workplace learning research (e.g., Kyndt and Baert, 2013), informal learning is conceptualized as comprising two distinct categories: task-related learning (i.e., learning through reflection and experimentation) and interactional learning (i.e., learning from colleagues and supervisor) (Nikolova et al., 2014). It is assumed that these two categories correspond to different learning paths: task-related learning is considered to reflect a cognitive-behavioral learning path, while interactional learning is thought to indicate a social learning path (Nikolova et al., 2014). This "dual-path approach" underscores the distinct yet interrelated nature of informal learning by modeling its underlying cognitive and social mechanisms. Eraut (2004) supports this duality by emphasizing that effective informal learning occurs when individ-

uals are both cognitively challenged and socially supported: "If there is neither a challenge nor sufficient support to encourage a person to seek out or respond to a challenge, then confidence declines and with it the motivation to learn" (p. 269). Therefore, effective informal learning conditions provide opportunities for cognitive engagement and a psychologically supportive environment.

Within this context, leadership has emerged as a key antecedent of informal learning (Cerasoli et al., 2018). However, existing research tends to focus predominantly on the relational aspects of leadership, such as fostering psychological safety, while the role of cognitively challenging leadership behaviors has received comparatively little empirical attention. For instance, Tannenbaum and Wolfson (2022) argue that leaders can enhance informal learning by fostering a safe climate and establishing positive team norms, while Jeong et al. (2018) emphasize the importance of leadership support. Thus, the cognitive stimulation needed to promote task-related learning requires further empirical investigation.

To systematically integrate antecedents of informal learning with underlying processes and outcomes, Decius et al. (2021) developed the APO framework of informal learning, drawing on Cerasoli et al.'s (2018) meta-analytic findings. This framework provides a structured lens for examining how leadership behaviors may facilitate informal learning activities. However, the findings synthesized in this meta-analysis do not explicitly differentiate between cognitive engagement and psychological support in the context of leadership and, in addition, pertain primarily to traditional, in-office settings. Therefore, Tannenbaum and Wolfson (2022) call for studies that examine informal learning in technology-enabled remote work environments, where physical distance might alter the nature of such learning.

2.2 TFL as Facilitator of Informal Learning in Technology-enabled Remote Work Environments

TFL is widely recognized for its potential to promote employee development and learning (Bass, 1999; Lundqvist et al., 2023). Despite this, empirical research on the specific impact of distinct TFL dimensions on informal learning remains scarce (Zia et al., 2022), as most existing studies treat TFL as a one-dimensional construct (e.g., van den Elsen et al., 2022; Zia et al., 2022), thus neglecting how differentiated leadership behaviors may align with the dual nature of informal learning (i.e., task-related and interactional learning).

This study addresses this gap by focusing on two dimensions of TFL as conceptualized by Rafferty and Griffin (2004): intellectual stimulation and supportive leadership. These dimensions are theoretically aligned with the two informal learning paths—cognitive–behavioral learning path and social learning path—and reflect dual yet complementary leadership dimensions. Intellectual stimulation encourages employees to question routines, engage in critical thinking, and experiment with new approaches (Rafferty and Griffin, 2004). These behaviors closely align with the cognitive–behavioral learning path, which emphasizes reflection and experimentation (Nikolova et al., 2014).

In contrast, supportive leadership encompasses attentiveness to employees' needs and the creation of a psychologically safe environment (Rafferty and Griffin, 2004). Such relational support particularly addresses the social aspects of learning, including learning from colleagues and supervisor (Nikolova et al., 2014). These two TFL dimensions are distinct in their mechanisms yet complementary in their impact: intellectual stimulation may provide the challenge needed to spark task-related learning, while supportive leadership can offer the social safety necessary for interactional learning to emerge.

These two dimensions become especially critical in technology-enabled remote work environments, where informal learning is often less visible and spontaneous (Zajac et al., 2022). Thus, if leaders actively create the cognitive and relational conditions necessary for such learning to occur (Eraut, 2004), they might still foster informal learning in technology-enabled remote work environments.

Despite the increasing reliance on digital technologies in the workplace, research has yet to systematically examine the impact of complementary TFL dimensions along the dual informal learning paths in these contexts. Furthermore, existing studies often rely on cross-sectional data and inconsistent measures of informal learning, which limit theoretical insights and practical application. To address these shortcomings, the present study investigates how intellectual stimulation and supportive leadership, assumed as complementary TFL dimensions, impact task-related and interactional learning, and how these, in turn, influence employees' performance. These relationships are conceptualized within the APO framework of informal learning (Decius et al., 2021), which structures the present research (see Fig. 1). This framework offers a systematic lens for understanding how leaders influence not only whether learning occurs, but also how it unfolds and what outcomes it yields. In the following, we develop hypotheses that reflect this process logic, linking specific leadership behaviors (antecedents) to distinct types of informal learning opportunities (process) and, ultimately, to task proficiency (outcome).

3. Hypothesis Development

3.1 Influence of Leaders' Intellectual Stimulation and Supportive Leadership on Employees' Informal Learning Activities

Leaders' intellectual stimulation encourages employees' interest in and awareness of problems while fostering their ability to approach challenges in new ways (Rafferty and Griffin, 2004). It helps employees to question assumptions, challenge the status quo, and explore novel ap-

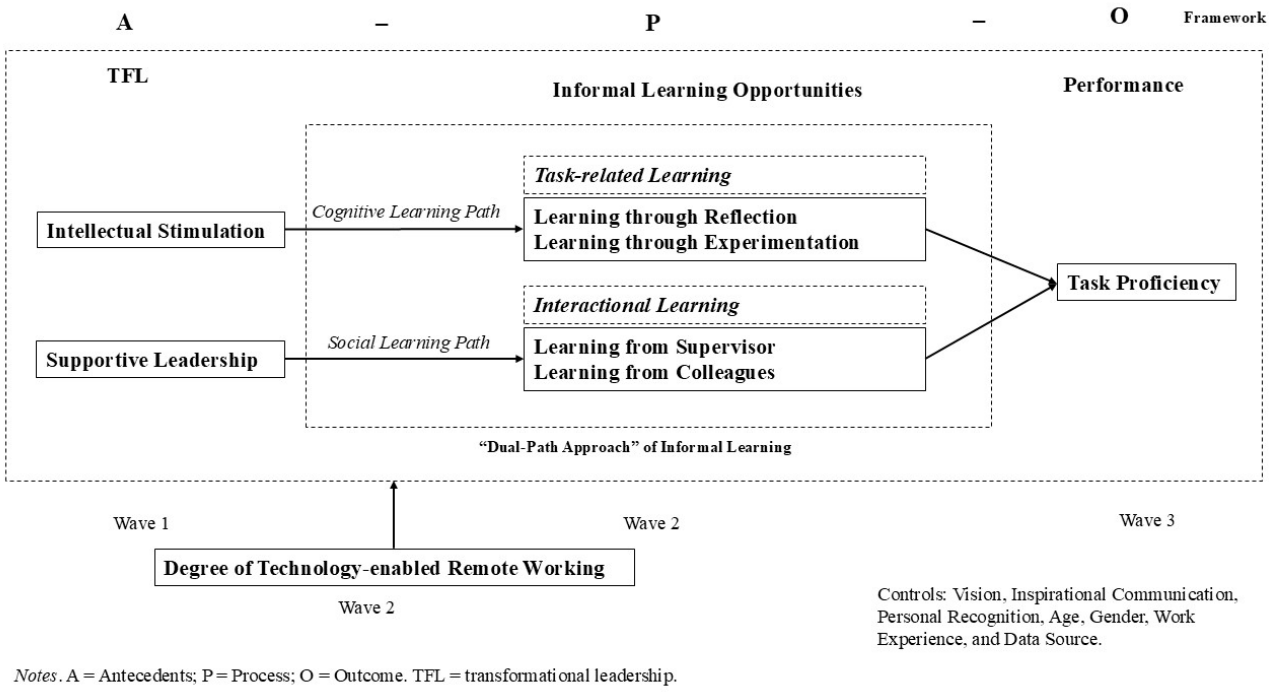

Fig. 1. Research model. *Notes*. A, Antecedents; P, Process; O, Outcome; TFL, transformational leadership.

proaches (Shin and Zhou, 2003). By enhancing employees' comprehension and analysis of problems, intellectual stimulation drives intrinsic task interest and encourages playful experimentation with ideas and solutions (Shin and Zhou, 2003). However, limited research has explored how intellectual stimulation affects task-related learning. Nevertheless, research on informal learning offers some insights that could be linked to leaders' intellectual stimulation. For example, leaders sharing their experiences to encourage reflection can boost employees' learning through reflection (Cerasoli et al., 2018). Such behavior is reflected in intellectual stimulation, where leaders encourage and challenge employees to rethink how they approach work-related tasks (Rafferty and Griffin, 2004). Similarly, leaders can directly stimulate informal learning activities by encouraging employees to reflect on a recent work experience (Tannenbaum and Wolfson, 2022) and facilitating discussions (Crans et al., 2021). Thus, such behaviors stimulate employees to rethink work-related approaches (Rafferty and Griffin, 2004), which might enhance employees' learning through reflection.

Moreover, a work environment where experimentation is valued signals that trying new approaches is acceptable (Tannenbaum and Wolfson, 2022). Moreover, leaders who allow for mistakes and provide freedom for experimentation encourage employees to expand their roles and engage in learning through experimentation (Crans et al., 2021). Intellectual stimulation intrinsically motivates employees to pursue their intellectual curiosity by playfully experimenting with ideas and solutions (Shin and Zhou, 2003). Thus, intellectual stimulation might be key to enhancing learning through experimentation. Therefore, we hypothesize:

H1: Intellectual stimulation has a positive effect on employees' opportunities for task-related learning, i.e., (a) learning through reflection and (b) learning through experimentation.

Supportive leadership focuses on satisfying employees' needs by displaying concern for their welfare and creating a psychologically supportive work environment (Rafferty and Griffin, 2004). Research on how supportive leadership influences employees' interactional learning is still scarce. However, research on informal learning in general (e.g., Jeong et al., 2018) points out that leaders' support bolsters employees' informal learning by creating or highlighting informal learning opportunities. More precisely, it is likely that employees who feel supported by their leaders develop a heightened sense of security to learn new things (Cerasoli et al., 2018), annotating them the role of a mentor or coach (Crans et al., 2021; Ellinger, 2005). Supportive leadership creates a psychologically supportive work environment that involves paying close attention to employees' needs and interests as well as considering employees' personal feelings before they act (Rafferty and Griffin, 2004), which might, therefore, facilitate employees' informal learning activities. More precisely, such a psychologically supportive environment, in which leaders encourage employees to admit their own learning needs (Tannenbaum and Wolfson, 2022) and exchange with their leader on a personal and trustful level, for example, by giving advice and

feedback based on their experiences and knowledge (Crans et al., 2021), might enhance specifically employees' learning from the supervisor.

Moreover, supportive leaders who create a psychologically supportive environment (Rafferty and Griffin, 2004) encourage employees to seek input from team members from whom they can learn (Tannenbaum and Wolfson, 2022), receive collegial feedback (Doornbos et al., 2008), help each other, and share concerns and experiences (Crans et al., 2021), which likely enhance employees' learning from colleagues. Thus, we hypothesize:

H2: Supportive leadership has a positive effect on employees' opportunities for interactional learning, i.e., (a) learning from the supervisor and (b) learning from colleagues.

3.2 Moderating Effect of the Degree of Technology-enabled Remote Working

As hypothesized, we assume that intellectual stimulation enhances employees' task-related learning (i.e., learning through reflection and experimentation). It encourages employees to reflect critically, challenge existing assumptions, and explore new approaches to problem-solving (Bass and Riggio, 2006). However, the effectiveness of intellectual stimulation may depend on the availability of rich cognitive cues, which help employees interpret, internalize, and respond to intellectually stimulating inputs (Zhou et al., 2012). These cues are typically conveyed through timely, contextualized communication and real-time interactions, such as immediate feedback, verbal emphasis, or spontaneous probing questions (Eisenberg et al., 2019). Compared to traditional face-to-face work settings, technology-enabled remote work environments may attenuate the ability to obtain cognitive cues due to reduced opportunities for informal brainstorming, delays in feedback, and fewer spontaneous follow-up interactions (Trevor and Holweg, 2022). Additionally, the absence of physical co-presence limits leaders' ability to assess the team's dynamics in real time, identify cognitive blind spots among team members, pose challenging questions, or initiate timely interventions aimed at fostering intellectual stimulation (Eisenberg et al., 2019). Consequently, the reduced availability of cognitive cues in technology-enabled remote work environments might make intellectual stimulation less effective in facilitating learning through reflection and experimentation. While we assume that intellectual stimulation is generally conducive to task-related learning, its positive effect may be diminished in technology-enabled remote work environments that limit the transmission of cognitive cues. Thus, we hypothesize:

H3: The degree of technology-enabled remote working moderates the positive relationship between intellectual stimulation and task-related learning, such that this positive relationship is stronger at low levels of technology-enabled remote working and weaker at high levels.

We assume that supportive leadership fosters employees' interactional learning (i.e., learning through colleagues and supervisor) by creating a psychologically safe and trusting environment where employees feel comfortable seeking feedback, admitting learning needs, and engaging with others (Tannenbaum and Wolfson, 2022). Research highlights that the effectiveness of TFL, particularly supportive leadership, relies heavily on rich relational cues, including nonverbal signals (e.g., eye contact, facial expressions, tone), emotional expressiveness, and a sense of immediacy and presence (Elfenbein, 2023). However, technology-enabled remote work environments may attenuate these relational cues (Höddinghaus et al., 2024). Although collaborative technologies facilitate communication, they lack the richness, spontaneity, and immediacy of face-to-face interactions (Avolio et al., 2014). In such environments, it becomes more challenging for leaders to effectively convey emotional support (Eisenberg et al., 2019), reduce perceived distance (Lauring and Jonasson, 2018), correctly recognize employees' needs and concerns (Malhotra et al., 2007), and foster a sense of presence and inclusion (Avolio et al., 2014). As a result, employees may find it harder to perceive their leaders' supportive intent, potentially feeling less emotionally acknowledged or understood. Moreover, social connections may weaken or dissolve entirely when employees spend less time in shared physical spaces (Haas, 2022). Weaker and less trusting social connections between leaders and employees, as well as among colleagues, can make it more difficult for leaders to encourage informal interactions and peer-based exchanges through supportive leadership. Consequently, employees may be less inclined to engage in interactional learning activities with their supervisors or colleagues. Hence, while supportive leadership may generally promote interactional learning, its effectiveness may be diminished when technology-enabled remote work environments limit the transmission of relational cues. Thus, we hypothesize:

H4: The degree of technology-enabled remote working moderates the positive relationship between supportive leadership and interactional learning, such that this positive relationship is stronger at low levels of technology-enabled remote working and weaker at high levels.

3.3 Employees' Task Proficiency as an Informal Learning Outcome

Several studies (e.g., Smet et al., 2022) reveal a positive relationship between employees participating in learning activities and their performance in traditional work settings. For example, when employees actively solve a challenging problem and navigate their way toward a solution, they produce better results (Bell and Kozlowski, 2008). Similarly, Wolfson et al. (2019) reveal a positive relationship between employees' informal learning and their performance improvements in specific instances, such as in jobs characterized by problem-solving requirements. Er-

icsson and Charness (1994) argue that individuals develop deep expertise over time through ongoing trial-and-error and experiential learning, positively linked to employees' job performance. Moreover, in traditional work settings, employees who receive advice and feedback from both colleagues and their supervisors are able to perform their tasks better as they gain new knowledge and skills through interactional learning. Although knowledge of antecedents of employees' performance, such as employees' informal learning activities, in technology-enabled remote work settings is scarce (Malhotra, 2021), we suppose that when employees can engage in informal learning activities in technology-enabled remote work settings, there is a positive link between employees' informal learning and their performance (i.e., task proficiency). Thus:

H5: Task-related learning (i.e., (a) learning through reflection and (b) learning through experimentation) and interactional learning (i.e., (c) learning from the supervisor and (d) learning from colleagues) have positive effects on employees' task proficiency.

3.4 The Mediating Effect of Employees' Informal Learning Activities

Building on the APO framework of informal learning (Decius et al., 2021), we propose that employees' informal learning activities serve as the central mechanism through which the two complementary TFL dimensions impact task proficiency. From this perspective, intellectual stimulation and supportive leadership represent an enabling input that fosters informal learning as a proximal process, enhancing employees' performance as a distal outcome.

First, leaders who engage in intellectual stimulation encourage employees to reflect critically on their work, challenge existing assumptions, and experiment with new approaches (Rafferty and Griffin, 2004; Shin and Zhou, 2003). These behaviors are likely to shape how employees engage in task-related learning processes. Over time, such learning activities help employees to develop and refine their skills, adapt to novel situations, and improve job performance (Bell and Kozlowski, 2008; Ericsson and Charness, 1994). Thus, we assume that intellectual stimulation enhances employees' task proficiency by affecting employees' task-related learning.

Second, leaders who show supportive leadership create a psychologically safe work environment that fosters trust, openness, and personal development (Rafferty and Griffin, 2004). Such an environment encourages employees to express their learning needs, seek feedback, and interact informally with both their supervisors and colleagues (Cerasoli et al., 2018; Crans et al., 2021; Tannenbaum and Wolfson, 2022). These interactional learning activities not only help employees to gain new perspectives and knowledge but also promote performance (Ellinger, 2005; Jeong et al., 2018). Following the logic of the APO framework, we assume that supportive leadership facilitates interactional learning, which then leads to improved task proficiency.

In sum, we posit that informal learning activities mediate the relationship between the two TFL dimensions and employees' task proficiency, aligning with the APO framework's input–process–output structure. This view is also supported by empirical evidence demonstrating that TFL positively influences performance, often through learning and skill development mechanisms (Dong et al., 2016). Accordingly, we hypothesize:

H6: Task-related learning (i.e., (a) learning through reflection and (b) learning through experimentation) mediates the relationship between intellectual stimulation and employees' task proficiency.

H7: Interactional learning (i.e., (a) learning from the supervisor and (b) learning from colleagues) mediates the relationship between supportive leadership and employees' task proficiency.

4. Methodology

4.1 Sample and Procedure

We recruited 1618 white-collar employees to participate in a three-wave study, evaluated and favorably approved by the University of Hohenheim's Ethics Committee, by distributing a survey link via professional and personal networks. Specifically, these respondents were drawn from LinkedIn (n = 703), two German academic institutions (n = 563, n = 251), and personal sources (n = 39). Importantly, participants receiving the survey link via the two German academic institutions are not necessarily employed at those institutions; for example, they participate in part-time programs (e.g., a Master of Business Administration (MBA) program) while working for other companies.

From the original sample, we eliminated 62 cases based on data quality checks. These included participants who: (1) provided the same response to an unusually high proportion of the Likert-type questions (one respondent who gave the same response to more than 95% of the questions), (2) completed the survey in an unusually short time (ten respondents who finished the survey in less than half of the median response time), (3) provided inconsistent demographic information across waves (33 respondents), and (4) provided seemingly random responses across multiple scales indicated by high Mahalanobis distance scores (29 respondents). 11 participants were excluded based on multiple criteria. Thus, our final sample consists of 1556 participants.

Out of 1556 participants, 848 responded in Wave 1, 706 responded in Wave 2, and 453 responded in Wave 3. Note that not all participants have participated in all three waves. The overall data collection window spanned from September 2021 to March 2022, with Wave 1 conducted between September and November 2021, Wave 2 between November 2021 and February 2022, and Wave 3 between January and March 2022. To assess the possibility of at-

trition bias, we conducted a logistic regression to predict missingness at each wave based on demographic variables (see Appendix Table 6), including gender, age, and work experience. We found that demographics were unrelated to missingness, except for a very small effect of work experience at Wave 3. To address this concern, we included work experience as a control at all waves.

Each participant was invited to complete the survey within a two-week window, and the time lag between measurement points was designed to be approximately six weeks. Although participants from different institutions began at slightly different times, the interval between waves was consistently about six weeks for each participant. Accordingly, all variables referred to the same six-week retrospective period across all waves. We chose a six-week reference period to ensure that participants could reflect on a meaningful and representative sample of recent leadership behaviors, learning experiences, and performance-related activities. This time frame offers a balance between recall accuracy and the ability to capture stable behavioral patterns (Podsakoff et al., 2003). Among these participants, 58.3% (907) identified as women, 41.3% (643) as men, and 0.4% (6) as gender diverse. As we had insufficient cases to reliably estimate differences for gender diverse participants, we coded their gender identity data as missing for the analyses but included the remainder of their data. The average age was 37.36 (Standard deviation (SD) = 13.06), and 75% possessed a university degree.

4.2 Measures

All measures are drawn from validated scales from published studies, and all items are presented in the Appendix Table 7. Each measure used a 7-point Likert scale (1 = strongly disagree to 7 = strongly agree), and all were found to be reliable (Cronbach's alpha >0.70 for all scales). Intellectual stimulation and supportive leadership were measured using Rafferty and Griffin's (2004) scale. Rafferty and Griffin's (2004) scale was developed as an alternative to existing, popular measures, such as the Multifactor Leadership Questionnaire (Bass, 1999), to address the critics (e.g., validity and endogeneity concerns) those scales face, underlining our choice to use this scale. We measured the two TFL dimensions in Wave 1. Opportunities for informal learning activities were measured based on the scale of Nikolova et al. (2014), which is intended to measure opportunity for four types of informal learning activity and includes measures of opportunity for (1) learning through reflection, (2) learning from colleagues, (3) learning from supervisor, and (4) learning through experimentation. We measured the opportunities for informal learning in Wave 2. We included task proficiency as a measure of work role performance, which was obtained from the scale of Griffin et al. (2007). The scale measures the extent to which employees report performing well on their core job responsibilities. Task proficiency was captured in Wave 3. To assess how often respondents worked remotely, we asked them: "Please indicate the extent to which you have worked from home in the last six weeks." This metric was recorded as a percentage and measured in Wave 2. As TFL comprises five dimensions (i.e., intellectual stimulation, supportive leadership, vision, personal recognition, and inspirational communication) (Rafferty and Griffin, 2004), we controlled for the latter three, as the TFL dimensions typically co-occur. Moreover, we included age and work experience as control variables, as they have been shown to influence participation in informal learning activities (Berg and Chyung, 2008). We also included gender, as studies show differences in men's and women's willingness to participate in informal learning (Kyndt and Baert, 2013), and controlled for our data sources.

5. Results

5.1 Descriptive Statistics

Table 1 presents the means, standard deviations, and correlations among the study variables. We observed positive correlations between each TFL dimension and the opportunities for informal learning activities. We also observed small but positive correlations between learning from colleagues and task proficiency as well as between learning from the supervisor and task proficiency. As age, gender, and work experience were correlated with both model predictors (i.e., TFL) and outcomes (i.e., informal learning and task proficiency), we opted to include them in the later structural equation model as control variables to account for the possibility of omitted variable bias.

5.2 Measurement Model

All analyses were performed in Mplus 8.8 (3463 Stoner AvenueLos Angeles, CA 90066) (Muthén and Muthén, 2017) using the maximum likelihood estimator. Our hypothesized measurement model comprised ten latent variables reflected by the items in the five transformational leadership scales, the four informal learning opportunity scales, and the task proficiency scale (see Supplement 2 for all scales and reliability statistics). This model was tested using confirmatory factor analysis, which yielded the following fit statistics: $\chi^2(\text{df} = 360) = 984.163$, $p < 0.001$, CFI = 0.968, RMSEA = 0.033, SRMR = 0.052. Although the approximate fit indices indicated close model fit according to conventional criteria (Hu and Bentler, 1999), the chi-square test was significant. To investigate possible model misspecifications, we examined the residual correlation matrices and modification indices to identify sources of poor fit. This inspection did not reveal any systematic pattern of misspecification. We assessed convergent validity by examining the composite reliability statistic (coefficient omega; [Green and Yang, 2015]) of each measure. Each coefficient was above 0.74 (task proficiency), indicating strong convergent validity. To assess discriminant validity, we inspected the 99% confidence intervals around

Table 1. Means, standard deviations, and correlations among variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Gender (1 = Women, 2 = Men)	--	0.04	0.06*	0.00	–0.08	–0.12***	0.04	0.09*	0.02	0.04	0.01	0.04	0.08	–0.07	0.00	0.06	–0.26***
2. Age (years)	0.04	--	0.89***	0.02	–0.06	0.19***	–0.47***	–0.14	–0.15*	–0.17*	–0.11	–0.12	0.02	–0.14	–0.27***	0.12	–0.10
3. Work Experience (years)	0.06*	0.89***	--	–0.03	–0.09	0.08***	–0.34***	–0.02	0.07	0.10	–0.02	0.05	0.04	–0.03	0.08	–0.13	0.06
4. Remote Work (%) (Wave 2)	0.00	0.02	–0.03	--	0.58***	–0.11**	–0.23***	–0.04	0.00	–0.04	0.09	0.02	0.01	–0.03	–0.04	0.00	–0.11
5. Remote Work (%) (Wave 3)	–0.08	–0.06	–0.09	0.58***	--	–0.09	–0.05	0.05	0.12	0.04	0.06	0.05	0.01	0.11	0.03	0.01	–0.05
6. Academic Institution #1	–0.12***	0.19***	0.08***	–0.11**	–0.09	--	–0.33***	0.07	0.10**	0.05	0.02	–0.03	–0.11**	0.02	0.08*	–0.02	0.03
7. Academic Institution #2	0.04	–0.47***	–0.34***	–0.23***	–0.05	–0.33***	--	0.03	0.01	0.12**	0.06	0.02	–0.09	0.13**	–0.03	–0.03	0.05
8. Intellectual Stimulation	0.07*	–0.15***	–0.13***	–0.04	–0.02	0.01	0.08*	(0.91)	0.64***	0.65***	0.63***	0.72***	0.42***	0.44***	0.70***	0.41***	0.05
9. Supportive Leadership	0.01	–0.08*	–0.06	0.02	0.10**	0.06	0.03	0.61***	(0.94)	0.55***	0.77***	0.81***	0.36***	0.48***	0.77***	0.35***	0.03
10. Vision	0.02	–0.12***	–0.08*	–0.10*	–0.02	–0.02	0.15***	0.62***	0.54***	(0.95)	0.52***	0.66***	0.26***	0.44***	0.63***	0.23***	0.19*
11. Personal Recognition	0.01	–0.15***	–0.13***	0.12**	0.12**	–0.03	0.11**	0.59***	0.73***	0.50***	(0.94)	0.80***	0.30***	0.52***	0.70***	0.24***	0.03
12. Inspirational Communication	0.04	–0.09**	–0.07	0.04	0.08*	–0.06	0.07*	0.65***	0.76***	0.61***	0.74***	(0.90)	0.44***	0.55***	0.75***	0.36***	0.08
13. Learning through Reflection	0.09*	0.09*	0.09*	0.04	0.05	–0.08*	–0.08*	0.37***	0.33***	0.26***	0.22***	0.35***	(0.86)	0.37***	0.42***	0.68***	–0.14
14. Learning from Colleagues	–0.06	–0.22***	–0.19***	–0.05	0.06	–0.05	0.21***	0.43***	0.45***	0.40***	0.48***	0.49***	0.29***	(0.81)	0.58***	0.36***	0.05
15. Learning from Supervisor	–0.01	–0.18***	–0.15***	–.004	0.02	0.04	0.07	0.66***	0.70***	0.58***	0.64***	0.66***	0.36***	0.52***	(0.89)	0.42***	0.19*
16. Learning through Experimentation	0.07	0.05	0.00	0.03	0.05	0.00	–0.06	0.39***	0.35***	0.25***	0.18**	0.30***	0.66***	0.29***	0.44***	(0.86)	–0.12
17. Task Proficiency	–0.23***	–0.07	–0.04	–0.16**	–0.07	0.06	0.07	0.05	0.00	0.15	0.06	0.06	–0.03	0.18*	0.16*	–0.04	(0.66)
Mean (below diagonal)	1.42	37.36	12.26	0.51	0.52	0.36	0.16	4.34	4.70	4.72	5.13	4.98	5.70	5.62	4.95	4.82	5.69
SD (above diagonal)	0.49	13.06	11.44	0.39	0.39	0.48	0.37	1.70	1.80	1.72	1.77	1.68	1.22	1.19	1.58	1.54	0.85
SD (below diagonal)	0.49	13.06	11.44	0.39	0.40	0.48	0.37	1.67	1.74	1.69	1.79	1.63	1.21	1.18	1.59	1.44	0.87
AVE (square root)	--	--	--	--	--	--	--	0.88	0.92	0.93	0.92	0.86	0.83	0.79	0.86	0.84	0.73

Notes. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Cronbach's alpha reliability coefficient is presented in the diagonal. Correlations between observed variables are presented below the diagonal; correlations between latent variables from the confirmatory factor analysis are presented above. The square root of the average variance extracted (AVE; Fornell and Larcker, 1981) is also presented. SD, standard deviation.

Table 2. Fit statistics for alternative measurement models.

Measurement model	χ^2	DF	p	CFI	RMSEA	SRMR	BIC
Hypothesized model	984.163	360	<0.001	0.968	0.033	0.052	67,866.08
TFL (second-order factor)	1105.07	385	<0.001	0.963	0.035	0.061	67,882.66
TFL (single factor)	5239.721	390	<0.001	0.752	0.089	0.075	71,996.44
Informal learning (second-order factor)	1200.14	380	<0.001	0.958	0.037	0.080	67,998.59
Informal learning (single factor)	3312.896	384	<0.001	0.850	0.070	0.117	70,094.66

Notes. TFL, transformational leadership; DF, degrees of freedom; CFI, comparative fit index; RMSEA, root mean square error of approximation; SRMR, standardized rootmean square residual; BIC, Bayesian information criterion.

each latent variable correlation; we found that none of these intervals crossed one (the largest correlation was observed between inspirational communication and supportive leadership: $r = 0.81$; 99% CI = [0.76, 0.84]). For each variable, we also inspected the square root of the average variance extracted (AVE; Fornell and Larcker, 1981) and found it was greater than each of the latent variable correlations (see Table 1). Thus, we proceeded with this measurement model.

We also compared the hypothesized model to a series of plausible alternative models, whose fit statistics are presented in Table 2. We examined two alternative models of TFL, which included a model where a general TFL factor was introduced as a second-order factor, and a second model in which all TFL items loaded on a single factor. We also examined two alternative models of informal learning opportunity with a second-order general factor model and a single factor model. All alternative models produced worse model fit, and they were less parsimonious according to the sample-size adjusted Bayesian Information Criterion (BIC). Thus, we proceeded with the hypothesized model.

5.3 Tests of Hypotheses

In support of Hypothesis 1 (see Table 3), the results show that leaders' intellectual stimulation was positively associated with opportunities for task-related learning activities, including learning through reflection (H1a; $\beta = 0.22$, $p < 0.01$) and learning through experimentation (H1b; $\beta = 0.30$, $p < 0.01$). Although not hypothesized, we additionally found that intellectual stimulation was positively associated with learning from supervisor ($\beta = 0.18$, $p < 0.05$).

In partial support of Hypothesis 2 (see Table 3), we found that supportive leadership was positively associated with opportunities to learn from supervisor (H2a: $\beta = 0.30$, $p < 0.001$), but not learning from colleagues (H2b; $\beta = 0.02$, p = not significant (ns)). We additionally found that supportive leadership was positively associated with opportunities to learn through experimentation ($\beta = 0.24$, $p < 0.05$).

To test Hypotheses 3 and 4, we calculated the interactive effect of the degree of technology-enabled remote working (Wave 2) and each of the two TFL dimensions on informal learning. Hypothesis 3 predicted that technology-enabled remote working would weaken the effect of intellectual stimulation on task-related learning activities. This hypothesis was not supported; the effect of intellectual stimulation did not vary across high/low levels of technology-enabled remote working for both experimentation ($\beta = 0.08$, $p = ns$) and reflection ($\beta = 0.05$, $p = ns$). Hypothesis 4, which predicted that the degree of technology-enabled remote working would weaken the effect of supportive leadership on interactional learning activities, was also not supported. The effects of supportive leadership were similar across high/low levels of technology-enabled remote working for both learning from colleagues ($\beta = 0.14$, $p = ns$) and learning from supervisor ($\beta = 0.05$, $p = ns$).

We found partial support for Hypothesis 5 (see Table 4), which considers employees' task proficiency as an informal learning outcome. More precisely, the results show that task-related learning (i.e., learning through reflection [$\beta = –0.11$, $p = ns$] and learning through experimentation [$\beta = –0.06$, $p = ns$]) was not significantly associated with employees' task proficiency. In contrast, learning from supervisor was positively associated with task proficiency ($\beta = 0.29$, $p < 0.05$). Learning from colleagues had no discernible effect on task proficiency ($\beta = –0.06$, $p = ns$).

Regarding Hypotheses 6 and 7, we used bootstrapping (with 5000 resamples) to estimate indirect effects. We only found an indirect path from supportive leadership (via learning from supervisor) to task proficiency, which was significant: $\beta = 0.09$, 95% CI = [0.01, 0.24]. This finding suggests that learning from supervisor fully mediates the relationship between supportive leadership and employees' task proficiency. This relationship holds in technology-enabled remote work settings as the degree of technology-enabled remote working does not appear to influence the relationship between supportive leadership and learning from the supervisor, and it appears to have no direct effect on task proficiency.

Among the control variables, men were significantly less likely to report opportunities for learning from colleagues ($\beta = –0.22$, $p < 0.01$) and they reported lower task proficiency ($\beta = –0.42$, $p < 0.001$). The main effects of technology-enabled remote working were small and non-significant. For the other TFL dimensions, we found that vision was positively related to learning from supervisor ($\beta = 0.15$, $p < 0.05$) and inspirational communication was

Table 3. Predictors of informal learning activities (Wave 2).

	Learning through Reflection		Learning through Experimentation		Learning from Colleagues		Learning from Supervisor	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Intellectual Stimulation	0.22** (0.08)	[0.06, 0.38]	0.30** (0.10)	[0.11, 0.50]	0.03 (0.08)	[–0.12, 0.17]	0.18* (0.07)	[0.04, 0.32]
Supportive Leadership	0.05 (0.09)	[–0.13, 0.22]	0.24* (0.11)	[0.02, 0.45]	0.02 (0.08)	[–0.14, 0.18]	0.30*** (0.08)	[0.15, 0.45]
Controls								
Vision	–0.07 (0.08)	[–0.22, 0.09]	–0.05 (0.09)	[–0.24, 0.13]	0.07 (0.07)	[–0.07, 0.21]	0.15* (0.07)	[0.02, 0.28]
Personal Recognition	–0.12 (0.10)	[–0.32, 0.08]	–0.23 (0.12)	[–0.47, 0.01]	0.11 (0.09)	[–0.07, 0.30]	0.13 (0.09)	[–0.04, 0.30]
Inspirational Communication	0.27* (0.13)	[0.01, 0.53]	0.16 (0.16)	[–0.15, 0.47]	0.22 (0.12)	[–0.02, 0.45]	0.09 (0.11)	[–0.13, 0.30]
Gender (1 = Women, 2 = Men)	0.10 (0.10)	[–0.10, 0.29]	0.08 (0.12)	[–0.16, 0.32]	–0.22* (0.09)	[–0.40, –0.03]	–0.10 (0.11)	[–0.31, 0.11]
Age (years)	0.01 (0.01)	[–0.01, 0.03]	0.02 (0.01)	[0.00, 0.04]	0.00 (0.01)	[–0.02, 0.01]	–0.02 (0.01)	[–0.04, 0.00]
Work Experience (years)	0.00 (0.01)	[–0.02, 0.02]	–0.02 (0.01)	[–0.04, 0.01]	–0.01 (0.01)	[–0.03, 0.01]	0.01 (0.01)	[–0.01, 0.03]
Academic Institution #1	–0.31** (0.11)	[–0.52, –0.10]	–0.13 (0.13)	[–0.39, 0.13]	0.03 (0.10)	[–0.17, 0.23]	0.15 (0.11)	[–0.07, 0.37]
Academic Institution #2	–0.30 (0.16)	[–0.61, 0.01]	–0.13 (0.20)	[–0.51, 0.26]	0.38* (0.15)	[0.08, 0.68]	–0.22 (0.17)	[–0.56, 0.12]
Remote Work (%)	0.07 (0.14)	[–0.21, 0.35]	0.10 (0.18)	[–0.25, 0.45]	–0.11 (0.13)	[–0.37, 0.15]	–0.17 (0.16)	[–0.48, 0.14]
R^2	0.26		0.24		0.36		0.71	

Notes. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. CI, confidence interval.

Table 4. Predictors of employees' performance (Wave 3).

	Task Proficiency	
	β	95% CI
TFL		
Intellectual Stimulation	–0.06 (0.09)	[–0.23, 0.11]
Supportive Leadership	–0.16 (0.10)	[–0.35, 0.04]
Informal Learning Opportunities		
Learning through Reflection	–0.11 (0.10)	[–0.32, 0.09]
Learning through Experimentation	–0.06 (0.08)	[–0.21, 0.10]
Learning from Colleagues	–0.06 (0.10)	[–0.25, 0.14]
Learning from Supervisor	0.29* (0.12)	[0.06, 0.52]
Controls		
Vision	0.07 (0.09)	[–0.10, 0.24]
Personal Recognition	–0.08 (0.11)	[–0.29, 0.13]
Inspirational Communication	0.13 (0.15)	[–0.16, 0.43]
Gender (1 = Women, 2 = Men)	–0.42*** (0.09)	[–0.60, –0.24]
Age (years)	0.00 (0.01)	[–0.01, 0.02]
Work Experience (years)	0.00 (0.01)	[–0.02, 0.02]
Academic Institution #1	0.00 (0.10)	[–0.21, 0.20]
Academic Institution #2	0.17 (0.16)	[–0.14, 0.47]
Work from Home (%) (W3)	–0.08 (0.12)	[–0.32, 0.15]
R^2	0.23	

Notes. * $p < 0.05$, *** $p < 0.001$. TFL, transformational leadership; W3, Wave 3.

positively related to reflection ($\beta = 0.27$, $p < 0.05$)[1] ([1]We tested an alternative model that excluded the other three TFL dimensions. This model yielded somewhat stronger effects of intellectual stimulation and supportive leadership on informal learning activities, except for the effects of supportive leadership on learning through experimentation; however, the core conclusions of the study remain unchanged). Overall, Table 5 provides an overview of hypotheses testing.

6. Discussion

Research (e.g., Cerasoli et al., 2018) suggests that leaders can directly boost employees' informal learning activities. However, knowledge of how specific leadership behaviors affect employees' opportunities for informal learning is still scarce (Zia et al., 2022). Also, little is known whether technology-enabled remote work contexts could be a hindrance factor in this context. Addressing calls for future research (e.g., Tannenbaum and Wolfson, 2022), the current study utilizes multi-wave data from 1556 German employees to examine the impact of intellectual stimulation and supportive leadership on employees' opportunities for informal learning. As hypothesized, the results show that leaders' intellectual stimulation significantly enhances employees' task-related learning by stimulating employees' opportunities to learn through reflection and experimentation. Additionally, we find that intellectual stimulation partially increases employees' interactional learning opportunities (i.e., learning from supervisor). This underscores the importance of intellectual stimulation in encouraging employees to learn not only through reflection and experimentation but also directly from their leaders, which might be conclusive, for example, when leaders intellectually encourage their employees to learn informally by sharing their own leader experiences (Cerasoli et al., 2018).

As hypothesized, the findings indicate that supportive leadership significantly enhances employees' opportunities to learn from the supervisor. However, in contrast to our hypothesis, we find no significant influence of supportive leadership on employees' opportunities to learn from colleagues. As supportive leadership has a strong focus on the individual instead of the team (Rafferty and Griffin, 2004), it might, therefore, play little role in enhancing relationships among team members or facilitating communication. However, we found that supportive leadership facilitates employees' opportunities to learn through experimentation. Thus, it seems that supportive leaders who create a psychologically supportive and safe environment (Rafferty and Griffin, 2004) help employees feel free and confident to experiment with their tasks.

Surprisingly, our findings reveal that the degree of technology-enabled remote working does not significantly moderate the relationship between either intellectual stimulation or supportive leadership and employees' informal learning opportunities. This is unexpected, given widespread concerns in the literature that technology-enabled remote work environments and their associated challenges, such as communication and coordination difficulties, fewer social connections, and less feedback, hin-

Table 5. Overview of hypotheses testing.

Hypotheses		
H1a)	Intellectual Stimulation → Learning through Reflection	✓
H1b)	Intellectual Stimulation → Learning through Experimentation	✓
H2a)	Supportive Leadership → Learning from Supervisor	✓
H2b)	Supportive Leadership → Learning from Colleagues	✗
H3	Intellectual Stimulation × Remote Work (%) → Learning through Reflection	✗
	Intellectual Stimulation × Remote Work (%) → Learning through Experimentation	✗
H4	Supportive Leadership × Remote Work (%) → Learning from Supervisor	✗
	Supportive Leadership × Remote Work (%) → Learning from Colleagues	✗
H5a)	Learning through Reflection → Task Proficiency	✗
H5b)	Learning through Experimentation → Task Proficiency	✗
H5c)	Learning from Supervisor → Task Proficiency	✓
H5d)	Learning from Colleagues → Task Proficiency	✗
H6a)	Intellectual Stimulation → Learning through Reflection → Task Proficiency	✗
H6b)	Intellectual Stimulation → Learning through Experimentation → Task Proficiency	✗
H7a)	Supportive Leadership → Learning from Supervisor → Task Proficiency	✓
H7b)	Supportive Leadership → Learning from Colleagues → Task Proficiency	✗

Note. ✓, Hypothesis supported; ✗, Hypothesis not supported.

der employees' informal learning activities (e.g., Gratton, 2023; Zajac et al., 2022) and thus, assumably diminish leaders' effectiveness in creating informal learning conditions. One possible explanation for the non-significant moderation effect lies in the increasing availability and effectiveness of communication technologies. Drawing on Media Richness Theory (Daft and Lengel, 1986), which posits that media vary in their ability to convey nuanced information and reduce ambiguity, today's digital collaboration tools may compensate for the absence of physical co-presence. Compared to earlier remote work tools that relied on lean media such as email, contemporary technologies, such as video conferencing, screen sharing, and synchronous collaboration platforms, enable richer exchanges by transmitting both verbal and nonverbal cues and allowing for immediate feedback (Greimel et al., 2023; Krehl and Büttgen, 2022). These features may enable transformational leaders to communicate essential cognitive and relational cues, thereby maintaining the effectiveness of intellectual stimulation and supportive leadership, even in technology-enabled remote work environments (Höddinghaus et al., 2024). Additionally, technology-enabled remote work environments may even facilitate specific cognitive learning processes. Greater autonomy, fewer workplace interruptions, and flexible time management (Gajendran et al., 2024) may create favorable conditions for reflection and experimentation, two aspects of task-related learning that are stimulated by intellectual stimulation. These conditions align closely with the mechanisms activated by intellectual stimulation, offering a potential explanation for its continued effectiveness across work contexts. However, the limited literature on TFL and virtual teams presents a mixed picture. Some studies suggest that TFL is less effective in highly dispersed teams due to a transformational leader's difficulty in facilitating team communication (Eisenberg et al., 2019). In contrast, other research (e.g., Purvanova and Bono, 2009) indicates that TFL may even exert stronger effects in virtual settings, as employees rely more heavily on leadership behaviors to fill social and motivational gaps. Moreover, a recent systematic literature review by Höddinghaus et al. (2024) highlights the complexity of TFL dynamics in virtual work settings. Specifically, the authors find that TFL tends to remain effective in highly virtual environments when virtuality refers to interactions among team members. In contrast, its effectiveness appears to diminish when virtuality concerns interactions between leaders and followers. These divergent findings underscore the need for more nuanced research into how specific dimensions of TFL unfold in technology-enabled remote work environments and under which conditions they remain impactful.

6.1 Theoretical Implications

This study provides several theoretical contributions to the literature on TFL, informal learning, and technology-enabled remote work environments. First, we advance the antecedents dimension of the APO framework of informal learning (Decius et al., 2021) by providing a differentiated, dimension-specific leadership perspective. Prior research has often operationalized TFL using a global score (e.g., Hughes et al., 2018), thereby overlooking the distinct effects of specific leadership behaviors on informal learning processes. Our study addresses this limitation by disentangling the impact of intellectual stimulation and supportive leadership and relating them to the "dual-path approach" of informal learning (Nikolova et al., 2014). While prior research has primarily focused on the social aspect of informal learning in conjunction with leadership (i.e.,

Table 6. Logistic Regression Predicting Missingness at Waves 1 to 3.

	Missingness		
	Wave 1	Wave 2	Wave 3
Gender	0.09 (0.07)	0.03 (0.07)	0.00 (0.07)
Age	0.00 (0.01)	0.00 (0.01)	–0.01 (0.01)
Work experience	–0.01 (0.01)	0.00 (0.01)	0.02* (0.01)

leader support; Tannenbaum and Wolfson, 2022), relatively little empirical attention has been paid to the cognitive-behavioral path, despite its foundational role in informal learning. By empirically linking intellectual stimulation to task-related learning, our study contributes theoretically by emphasizing the cognitive-behavioral path that has not been a specific focus in existing research on the relationship between leadership and informal learning opportunities. In doing so, we extend existing theory by demonstrating how leaders can foster both learning paths through distinct but complementary TFL dimensions. Notably, although the APO framework systematically links antecedents, informal learning processes, and outcomes, it does not explicitly account for the dual-path structure of informal learning. Our study helps to fill this conceptual gap by integrating this perspective and showing how complementary TFL dimensions facilitate the cognitive-behavioral and social learning paths. Our results thus support a facet-level approach to TFL and illustrate the value of distinguishing between its dimensions when examining the antecedents of informal learning. From this facet-level approach, our results particularly emphasize the importance of leaders' intellectual stimulation, as it addresses not only employees' task-related learning but also the social component of informal learning by enhancing employees' learning from their supervisors, thereby benefiting both cognitive-behavioral and social learning components. More precisely, intellectual stimulation simultaneously enhances three out of four informal learning activities, making this dimension the primary driver of employees' informal learning activities. This expands theoretical understanding by showing that cognitive stimulation can also facilitate social learning processes. By empirically linking intellectual stimulation to both learning paths, our study makes a theoretical contribution that rebalances the emphasis within research on leadership and informal learning, and highlights the role of cognitive-challenging leadership behaviors in fostering comprehensive informal learning activities.

Second, we enrich the APO framework by integrating a contextual contingency into its traditionally sequential process structure. Specifically, we assess whether the influence of the two TFL dimensions on informal learning varies across technology-enabled remote work environments. While previous applications of the APO framework have concentrated on traditional work settings, they have largely overlooked the role of moderating conditions that could strengthen or diminish these effects. By incorporating a contingency perspective, our study situates informal learning within a technology-enabled remote work context and contributes to leadership theory by engaging with the debate on a universalist versus contingent perspective of TFL effectiveness (Peng et al., 2021). Although we did not find statistically significant moderation effects, the integration of a contextual factor enriches the APO framework by empirically testing its robustness across technology-enabled remote work environments. Our findings indicate that both intellectual stimulation and supportive leadership remain effective in technology-enabled remote work environments, suggesting that these dimensions are robust across various work contexts, which may be attributed to the use of media-rich technologies that allow for the transmission of both cognitive and relational cues. Thus, our research not only reinforces the robustness of key leadership mechanisms but also enriches the APO framework by incorporating and empirically examining contextual boundary conditions. This finding underscores the significant role leaders play in employees' informal learning processes, regardless of the specific work environment.

Third, we provide insights into the effect chain of the APO framework by demonstrating that learning from the supervisor positively influences employees' task proficiency over time. Responding to calls for using multi-wave data when investigating informal learning processes and outcomes (Decius et al., 2019; Smet et al., 2022), our multi-wave design shows that employees' learning from supervisor mediates the relationship between supportive leadership and performance. This is particularly relevant given ongoing debates about employee effectiveness in technology-enabled remote work environments (e.g., Bloom et al., 2024). Our findings suggest that informal learning remains relevant for enhancing performance even when face-to-face interactions are limited, and that supportive leadership is a key enabler in this context. This enhances understanding not only of what learning outcome results from informal learning activities but also of how it emerges. Thus, we enhance our understanding of how informal learning contributes to individual performance and how leaders can influence this learning outcome in technology-enabled remote work environments.

Together, these contributions deepen the theoretical foundations of informal learning by expanding both the antecedents and outcomes of the APO framework and by integrating a possible contextual boundary condition into its structure. Furthermore, we complement literature by high-

Table 7. Standardized Factor Loadings for the Measurement Model.

Indicator	Loading
Vision (Omega (% var explained) = 0.95; AVE = 0.87)	
Has a clear understanding of where we are going.	0.97
Has an idea of where the organization is going.	0.92
Has a clear sense of where he/she wants our unit to be in 5 years.	0.90
Intellectual Stimulation (Omega (% var explained) = 0.92; AVE = 0.78)	
Has ideas that have forced me to rethink some things that I have never questioned before.	0.92
Challenges me to think about old problems in new ways.	0.89
Has challenged me to rethink some of my basic assumptions about my work.	0.84
Personal Recognition (Omega (% var explained) = 0.94; AVE = 0.85)	
Commends me when I do a better than average job.	0.94
Personally compliments me when I do outstanding work.	0.92
Acknowledges improvement in my quality of work.	0.90
Inspirational Communication (Omega (% var explained) = 0.90; AVE = 0.74)	
Says things that make employees proud to be a part of this organization.	0.88
Encourages people to see changing environments as situations full of opportunities.	0.86
Says positive things about the work unit.	0.85
Supportive Leadership (Omega (% var explained) = 0.95; AVE = 0.84)	
Behaves in a manner which is thoughtful of my personal needs.	0.96
Considers my personal feelings before acting.	0.93
Sees that the interests of employees are given due consideration.	0.86
Learning through Reflection (Omega (% var explained) = 0.87; AVE = 0.69)	
In my work I am given the chance to think about how I can conduct my tasks more efficiently.	0.89
In my work I am given the opportunity to contemplate about different work methods.	0.80
When confronted with difficulties in my tasks, I am given the opportunity to consider what the best possible approach is.	0.80
Learning from Colleagues (Omega (% var explained) = 0.83; AVE = 0.62)	
My colleagues advise me if I don't know how to conduct a certain task.	0.88
My colleagues are eager to collaborate with me in finding a solution to a work problem.	0.87
My colleagues tell me if I make mistakes in my work.	0.58
Learning from Supervisior (Omega (% var explained) = 0.90; AVE = 0.74)	
My supervisor is eager to think together with me how to solve a work-related problem.	0.91
My supervisor helps me see my mistakes as a learning experience.	0.86
My supervisor tips me on how to do my work.	0.80
Learning through Experimentation (Omega (% var explained) = 0.88; AVE = 0.70)	
In my job I am offered sufficient time to find out how to conduct tasks more efficiently.	0.93
In my job I am offered sufficient time and opportunities to search for new solutions regarding task-related problems.	0.91
In my job I can try different work methods even if that does not deliver any useful results.	0.66
Task Proficiency (Omega (% var explained) = 0.74; AVE = 0.53)	
Ensured your tasks were completed properly.	0.94
Carried out the core parts of your job well.	0.76
Completed your core tasks well using the standard procedures.	0.37

Notes. All factor loadings were significant ($p < 0.001$). The composite reliability (coefficient omega) (Green and Yang, 2015) and average variance extracted (AVE; Fornell and Larcker, 1981) statistics are presented.

lighting how distinct TFL dimensions align with different informal learning mechanisms and operate effectively across diverse work environments.

6.2 Practical Implications

Our study offers important implications for leaders and organizations in the context of the digital transformation of work. First, we recommend that leaders prioritize intellectual stimulation to enhance task-related and inter-

actional learning, enabling employees to thrive in both office and technology-enabled remote work environments. In this context, organizations should set up actions to sensitize leaders about intellectual stimulation to enhance both informal learning types so that they exhibit such welcomed behavior.

Second, intellectual stimulation might be especially relevant in digital transformation processes where employees need to be reskilled or retrained for new roles (World Economic Forum, 2025). These transformations often lead to new job profiles requiring advanced competencies related to artificial intelligence (AI) and other digital technologies. Intellectual stimulation is invaluable in such contexts as it encourages employees to experiment with ideas and solutions playfully and imaginatively, enabling them to acquire digital competencies. Thus, intellectual stimulation could ensure that employees are equipped with new knowledge and competencies regarding AI, contributing to a successful digital workforce transformation.

Third, we found that learning from the supervisor fully mediates the relationship between supportive leadership and employees' task proficiency in both technology-enabled remote and in-person work environments. This highlights leaders' critical role in facilitating informal learning processes, even when teams are dispersed or work remotely. Thus, organizations should recognize the value of informal learning, particularly learning from supervisor, and implement efforts to create environments where this type of learning can thrive.

6.3 Limitations and Future Research

This study considers the degree of technology-enabled remote working as a moderator, which has no significant influence on the relationship between the two TFL dimensions and opportunities for informal learning. While we measured the degree of technology-enabled remote work, future research should more precisely capture qualitative aspects, such as the richness of communication tools used or the frequency and quality of leader-follower interactions, to better understand under which conditions TFL dimensions remain effective. Additionally, future research could zoom in on important boundary conditions. For example, employees' characteristics (e.g., preference for informal learning) or the social ties between leaders and employees could be interesting factors to study in traditional and technology-enabled remote work contexts. Such studies would further shed light on the discussion regarding the contingency vs. universalist view of TFL.

Our study also possessed several methodological limitations. First, as our study employed same-source data generated from the same survey method, common method variance may have distorted the results (Podsakoff et al., 2012). While our three-wave study design somewhat mitigated this threat by separating our data collection across time (Tehseen et al., 2017), other confounding variables may limit our ability to infer causality. Second, our study was conducted over a six-month period, and this schedule may have been insufficient to fully capture the dynamic relationship between TFL, informal learning, and performance. Third, our measures also relied on our survey respondents' ability to recall leadership behavior, informal learning, and the degree of technology-enabled remote working over time. Thus, future studies should consider employing experimental or intervention designs (e.g., linked with a leadership development program), collect data from multiple sources, and consider a longitudinal intensive design to better understand the day-to-day impact of TFL and informal learning.

7. Conclusion

This study adds significant insights to the literature on leadership, informal learning, and the evolving landscape of digital transformation of work. In this context, our research underscores leaders' significant role in employees' informal learning process—regardless of whether employees work in the office or remotely.

Availability of Data and Materials

To promote research transparency, the author team commits to making the data available upon legitimate request. In this case, we would fully ensure participants' anonymity (e.g., not sharing the demographic variables). Moreover, the study's measures and procedures are already included in the paper.

Author Contributions

EW, TB, MB, and FM contributed to the study's conception and design. Material preparation and data collection were performed by FM, EW, and MB. Data analysis was performed by TB. The manuscript was written by EW, except for the methods and results sections, which were written by TB. All authors contributed to editorial changes in the manuscript. All authors have read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

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Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

See Tables 6,7.

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