

# Who are the champions of workplace innovations? Playful use of technology and psychological ownership for championing Industry 4.0 technologies

I-Shuo Chen & Jin Nam Choi

To cite this article: I-Shuo Chen & Jin Nam Choi (03 Feb 2026): Who are the champions of workplace innovations? Playful use of technology and psychological ownership for championing Industry 4.0 technologies, Industry and Innovation, DOI: [10.1080/13662716.2026.2617173](https://doi.org/10.1080/13662716.2026.2617173)

To link to this article: <https://doi.org/10.1080/13662716.2026.2617173>

 View supplementary material 

---

 Published online: 03 Feb 2026.

---

 Submit your article to this journal 

---

 View related articles 

---

 View Crossmark data 

---

## Who are the champions of workplace innovations? Playful use of technology and psychological ownership for championing Industry 4.0 technologies

I-Shuo Chen<sup>a</sup> and Jin Nam Choi<sup>b</sup>

<sup>a</sup>Faculty of Business and Law, Anglia Ruskin University, Cambridge, UK; <sup>b</sup>Graduate School of Business, Seoul National University, Seoul, South Korea

### ABSTRACT

Drawing on extended self theory, we propose that developing psychological ownership of an innovation is a key mechanism for cultivating innovation champions—employees who actively advocate for and support innovation within organisations. To test this framework, we examined the implementation of Industry 4.0 technologies (I40T) using three-wave, multisource data from 255 employees and their managers. The findings indicate that engaging with workplace technologies in a playful manner fosters psychological ownership of I40T, which in turn predicts innovation championing. Moreover, employees' implementation efficacy strengthened the positive relationships. This study offers a novel perspective on innovation implementation through the lens of extended self theory and provides actionable insights into how playful use of technology can foster a stronger sense of ownership, thereby developing champions of innovation in the workplace. By utilising a non-Western sample, the study also extends the scope of playful work design and psychological ownership research beyond Western contexts.

### KEYWORDS

Innovation championing; playful work design; playful use of technology; psychological ownership; implementation efficacy; industry 4.0 technology

### JEL CLASSIFICATION

M54; M15; O31

Rapid technological advancements and an evolving business environments have made innovation a critical challenge for modern organisations (Afonasova et al. 2019). Innovation is defined as 'an idea, practice, or object that is perceived as new by an individual or other unit of adoption' (Rogers 2003, 12). Achieving innovation outcomes often requires the deployment of enabling technologies, with Industry 4.0 technologies (I40T) emerging as a key driver of the fourth industrial revolution. These advanced digital innovations have transformed workplaces by reshaping job roles, work processes, and human-technology interactions (Gupta, Wang, and Czinkota 2023). While these technologies offer significant benefits, their successful implementation is frequently challenged by user resistance, as employees may react negatively and obstruct technological initiatives (Kim and Kankanhalli 2009).

To address the challenge of implementation failure, innovation researchers have developed a robust body of literature exploring target users' acceptance and compliance with innovation initiatives (e.g. Chen and Choi 2025). We extend this literature by emphasising individuals' voluntary and proactive support for new technological innovations, known as innovation championing (Howell and Shea 2001). Innovation champions passionately advocate for new technologies, persuade colleagues to adopt them, and proactively address implementation challenges to ensure success (Fugate and Soenen 2018; Walter et al. 2011). Beyond personal acceptance and compliance, these champions exert social influence and normative pressure in favour of innovation. Given that innovation diffusion resembles the contagion of information and behaviours, champions play a critical role in driving these social, normative contagion processes (Burt 2004; Rogers 2003).

Encountering the increasing pace and demands of technological innovation, organisations must identify, develop, and support innovation champions to address these challenges effectively. However, the factors driving innovation championing behaviour remain largely unexplored (Lutfiyya 2021). The organisational change literature provides some insights into employees' championing behaviour, particularly in the context of planned change efforts such as leadership initiatives, strategic transformations, or cultural shifts (Fugate and Soenen 2018;

Kanitz et al. 2023). This line of research typically views employees' championing of organisational change as a response to external factors. Specifically, proactive support for change can be influenced by three key factors: (1) cognitive appraisal, which determines whether employees perceive change initiatives as a threat or a challenge and how they cope with it (Fugate, Prussia, and Kinicki 2012); (2) group influence processes, including social influences, team norms, and the behaviours of colleagues (Fasbender & Gerpott, 2023); and (3) change-related factors, such as leadership, communication, and organisational support for change (Fugate and Soenen 2018).

The current investigation advances this literature in two important ways. First, while previous studies have focused on organisational changes related to leadership, strategy, or cultural transitions, they have largely overlooked employees' championing of technological innovations. This omission is significant given the growing importance of technologies such as I40T and digital transformation tools for firm performance (Bresciani et al. 2021; Frank, Dalenogare, and Ayala 2019). Second, prior research predominantly frames change championing as a response to external forces, such as leader influence, group norms, or persuasive communication (Armenakis and Harris 2009; Oreg and Berson 2011). Complementing this external perspective, we propose an alternative view that employees' innovation championing behaviour can emerge from their own work experiences, which can transform them into champions of technological innovations (Choi 2004).

This study also extends prior work on idea championing, which focused on advocating for new ideas as part of the broader creative process often described as the 'idea journey', encompassing idea generation, elaboration, championing, and implementation (Perry-Smith and Mannucci 2017). In this literature, championing typically refers to early-stage advocacy for novel ideas (De Clercq, Sun, and Belausteguigoitia 2021; Zhang and Bartol 2010). In contrast, our study advances this conversation by shifting the focus to championing during the implementation stage, wherein employees mobilise support for already adopted innovations, rather than promoting ideas for their adoption (Howell and Shea 2001; Walter et al. 2011).

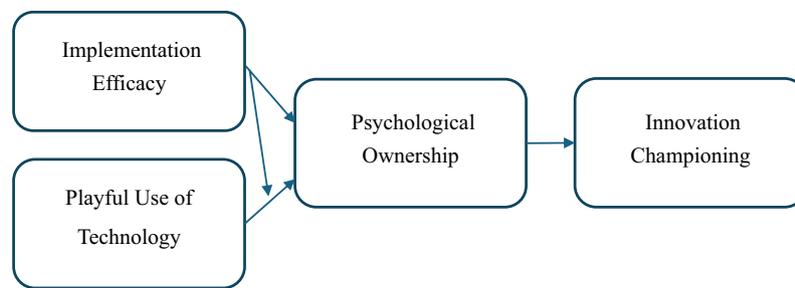
Drawing on extended self theory (Pierce, Kostova, and Dirks 2003), we identify psychological ownership of technological innovations such as I40T as a key psychological mechanism underlying the development of innovation champions. Employees who *own* an innovation and integrate it into their self-concept may naturally emerge as its champions (Avey et al. 2009; Pierce, Kostova, and Dirks 2001). Extended self theory is particularly well suited to the present research because it explains how individuals develop a sense of 'mine' towards external, non-social targets (e.g. tools, technologies, or systems), even in the absence of formal ownership or explicit role expectations (Belk 1988; Pierce, Kostova, and Dirks 2003). This perspective is especially relevant in innovation implementation contexts, where employees are required to engage deeply with workplace technologies that they do not legally own and may not formally identify with as part of a prescribed role.<sup>1</sup>

In line with extended self theory, we further propose two critical predictors of psychological ownership: playful use of technology and implementation efficacy. To conceptualise playful use of technology, we draw on the emerging theory of *playful work design* (PWD), which describes proactive efforts to incorporate playful elements, such as a sense of fun or self-imposed competition, into work tasks (Chen 2020; Scharp et al. 2021). Employees who engage with workplace technologies in a playful manner are likely to develop strong psychological connections to newly adopted technological innovations, such as I40T, thereby increasing their willingness to champion them (Bitrián et al. 2023). In addition, we examine the role of implementation efficacy, i.e. an individual's cognitive belief in their ability to implement the newly adopted technology in question (Latikka, Turja, and Oksanen 2019). We further elaborate on the predictive mechanism by proposing that efficacy beliefs function as an enabling condition that amplifies the effect of playful technology use on psychological ownership.

All in all, this study advances the literature in several important ways. First, complementing prior research mostly focusing on compliant adoption and use of innovations or early-stage advocacy for ideas (De Clercq, Sun, and Belausteguigoitia 2021; Fugate and Soenen 2018; Kanitz et al. 2023; Perry-Smith and Mannucci 2017), we emphasise the critical role of workplace champions who proactively

---

<sup>1</sup>Similar to extended self theory, identity-based perspectives such as role identity theory (Stryker and Burke 2000) and social identity theory (Tajfel and Turner 1986) offer useful explanations for how the self can extend to encompass external targets such as roles and groups. However, these identity-based theories primarily explain internalisation through processes of social categorisation and normative alignment with roles or collectives (i.e. 'who I am' or 'who we are'), whereas extended self theory centres on possession-based attachment to objects or ideas, namely, the sense of 'what is mine.' These perspectives may complement our framework: whereas identity theories emphasise how roles and group affiliations shape individuals' motivation and behaviour, extended self theory uniquely explains how external objects and technologies become integrated into one's self-concept through psychological ownership (Belk 1988; Pierce, Kostova, and Dirks 2003).



**Figure 1.** Research Framework.

promote innovation implementation. Second, we draw on extended self theory and offer novel insights into how employees psychologically appropriate and develop ownership over workplace innovations (Pierce, Kostova, and Dirks 2003). Our most distinctive contribution lies in identifying a novel pathway through which playful use of technology develops psychological ownership, which in turn promotes innovation championing. Third, we shift the focus from traditional external factors, such as group or leader influences, to a person-centred perspective that emphasises how employees' playful use of technologies and their efficacy beliefs jointly shape innovation championing. This perspective broadens PWD theory beyond its conventional focus on work motivation, extending it to the domain of innovation implementation (Bakker et al. 2020; Scharp et al. 2021).

Practically, by examining these mechanisms in the context of I40T, our findings provide valuable managerial insights into how organisations can identify and cultivate innovation champions among employees. In effect, the present analysis isolates critical factors for the successful implementation of I40T initiatives and the broader realisation of digital transformation. The overall theoretical framework is illustrated in Figure 1, and the following sections elaborate on our propositions in detail.

## 1. Literature review and hypothesis development

*Championing* refers to the act of supporting or defending a cause (Balven et al. 2018). In the management literature, championing has been related to supporting the implementation of change or innovation (Balven et al. 2018; Howell and Shea 2001). For successful innovation implementation, champions are crucial because they do not just embrace the development and use of the innovation but also proactively convince others to do the same (Cunningham 2006; Lysova et al. 2015), even if they have to fight bureaucratic, social, and political obstacles (Schon 1963; Simon et al. 2002). Without champions, any innovation efforts may remain dormant (Frost and Egri 1991).

Championing represents an intense form of support for organisational innovation, which is distinct from other forms of support, such as compliance, cooperation, or innovation use behaviour (Fugate and Soenen 2018). In this study, innovation championing is defined as a set of proactive, extra-role behaviours through which employees advocate for, mobilise support around, and mitigate resistance to the implementation of a specific innovation (Herscovitch and Meyer 2002). These behaviours are distinct from implementation itself, which involves the actual execution and integration of the innovation into organisational routines. Thus, innovation championing represents proactive and discretionary supportive actions that complement, but are not equivalent to, implementation behaviours.

Innovation championing represents a form of social influence because it is a discretionary attempt to convince others of the importance and necessity of the innovation at hand (Faupel and Süß 2019). Indeed, empirical studies demonstrated that championing behaviour diminishes co-workers' resistance to a new practice, promotes innovation acceptance both inside and outside the organisation, and improves implementation effectiveness (Chou 2015; Kanitz et al. 2023). Innovation championing may exert positive social influences towards others by reducing the inherent sense of risk and uncertainty associated with innovation, thereby having greater and broader implications beyond one's own

innovation use behaviour (Sergeeva and Zanello 2018). Thus, clearly understanding predictive mechanisms leading to innovation championing has theoretical and practical significance.

### 1.1. Psychological ownership as a critical condition for innovation championing

In this study, we identify psychological ownership as a significant predictor of innovation championing. The core of psychological ownership is the sense of possession over a given target (Pierce, Kostova, and Dirks 2001). It reflects a psychological connection between individuals and a target of ownership (e.g. an object, job, organisation, and innovation) (Morewedge et al. 2009; Pierce, Kostova, and Dirks 2003). Individuals who develop a sense of ownership of their job and organisation tend to exhibit desirable outcomes in terms of job performance, citizenship, voice, and knowledge sharing (Zhang et al. 2021). In addition, psychological ownership enables individuals to absorb the target into their extended self, thus engendering a strong attachment to the target that urges them to ‘protect, care and sacrifice’ for it (Pierce, Kostova, and Dirks 2001, 303).<sup>2</sup>

A useful framework for understanding this phenomenon is extended self theory (Belk 1988), which posits that individuals define their identity not only through their physical selves but also through external objects, possessions, and affiliations that become integral to their self-concept. Similar to other identity-based theories such as role identity theory (Stryker and Burke 2000) and social identity theory (Tajfel and Turner 1986), extended self theory has been used to explain employees’ psychological attachment to their jobs, roles, and technological tools (Brown et al. 2014).

Empirical studies have shown that workplace technologies associated with digital transformation and automation are increasingly becoming integral to employees’ extended selves (Pierce, Kostova, and Dirks 2003). Employees who develop a sense of ownership over these technologies are more likely to advocate for their use, highlight their benefits to colleagues, and actively promote their functionality (J. Liu et al. 2012; Zhang et al. 2021). Unlike mere compliance to external demands, employees who psychologically ‘own’ an innovation feel a heightened sense of personal responsibility for its success (J. Liu et al. 2012; Pierce, Kostova, and Dirks 2001). Importantly, this process of extending one’s self into an innovation does not require actual possession but rather a felt sense of ‘this is mine,’ which shapes employees’ motivation to support and drive its implementation (Zhang et al. 2021). As employees view a given innovation as part of their extended self, they attach significance and become motivated to care about its success (Brasel and Gips 2014; J. Liu et al. 2012), turning them into innovation champions (Dirks, Cummings, and Pierce 1996; O’Driscoll, Pierce, and Coghlan 2006). Therefore, we propose the following relationship:

**Hypothesis 1.** Psychological ownership of a technological innovation is positively related to innovation championing.

### 1.2. Implementation efficacy and psychological ownership

Identifying psychological ownership as a critical driver of innovation championing, we further explore the predictors of psychological ownership in the workplace. People extend their sense of self into objects through three primary routes: (1) control, (2) investment, and (3) knowledge (Belk 1988). Thus, when employees feel a sense of control over an innovation, invest time and effort in understanding it, and develop a deep knowledge of its functionality, they begin to develop psychological ownership that promotes proactive behaviours such as innovation championing (Avey et al. 2009; Pierce, Kostova, and Dirks 2003). These conditions may be fulfilled by individuals’ efficacy belief regarding the use of a target innovation, that is *implementation efficacy*. Studies on innovation implementation have demonstrated the

<sup>2</sup>Importantly, psychological ownership is conceptually distinct from identity internalisation, which involves incorporating roles or social categories into one’s self-concept and motivates behaviour through role-consistent expectations or identity-based norms (Ashforth, Harrison, and Corley 2008; Stryker and Burke 2000). In contrast, psychological ownership reflects a felt sense of possessiveness and responsibility towards a specific target, motivating stewardship, protection, and advocacy even when that target is not central to one’s self-identity (Pierce, Kostova, and Dirks 2001; Van Dyne and Pierce 2004). Accordingly, employees may come to psychologically ‘own’ a technological innovation and feel responsible for its successful implementation without defining themselves as innovators or identifying with a formal innovation-related role. From this perspective, the emergence of psychological ownership towards innovations is more effectively explained by extended self theory, with identity-based approaches offering complementary explanatory value in the present context.

significance of efficacy-related constructs (e.g. perceived ease of use, innovation-related skills and knowledge) in shaping employees' commitment to and actual use of innovation (Bright, Kleiser, and Grau 2015). Implementation efficacy may lead to positive attitudes and behaviours towards innovation based on individuals' positive outcome expectations and accompanying willingness to invest their personal resources (Axboe et al. 2016).

From the perspective of extended self theory, we propose that implementation efficacy strengthens psychological ownership by activating its three foundational routes. First, it enhances perceived control, as employees who feel efficacious gain a sense of mastery over the technology being implemented. Second, this confidence increases willingness to invest personal resources such as time and effort to achieve successful outcomes. Third, it facilitates the development of intimate knowledge by motivating employees to further explore and understand the innovation (Bandura 1997; Pierce, Kostova, and Dirks 2003). Accordingly, implementation efficacy serves as a theoretically grounded antecedent of psychological ownership, establishing the cognitive foundation upon which psychological ownership can emerge. Thus, we propose the following:

**Hypothesis 2.** Implementation efficacy is positively related to psychological ownership of a technological innovation.

### 1.3. Playful use of technology and psychological ownership

In addition to efficacy belief, understanding how employees' daily task behaviours affect their psychological ownership is important to prepare them for future implementation efforts. The conditions for psychological ownership, i.e. control, investment, and knowledge (Pierce, Kostova, and Dirks 2001), can be fulfilled through employees' playful use of technology during their regular work activities, a concept rooted in the PWD theory. PWD represents self-initiated and proactive behaviours, where employees modify their work environment to incorporate elements of play (Bakker et al. 2020; Scharp et al. 2021).

As an intrinsically motivated behaviour, play is something employees engage in voluntarily because it provides experiences of enjoyment, mastery, and growth (Petelczyc et al. 2018; Van Vleet and Feeney 2015). There are two types of play: ludic and agonistic play. *Ludic play* is playful and irrational in nature, emphasising the utilisation of humour and imagination (e.g. joking and making fun; Martin and Ford 2018), whereas *agonistic play* is serious and rational in nature, emphasising challenges and rules (e.g. games and competitions; Abramis 1990). Hence, PWD includes two aspects (Bakker et al. 2020): designing fun (ludic play) and designing competition (agonistic play). When designing fun, individuals adopt a ludic mindset by using humour and spontaneity to shape their work conditions into where they are amused and have fun (Lieberman 2014; Proyer 2012). When designing competition, individuals adopt an agonistic mindset by developing and conquering competitions with themselves, such as setting limited time to complete the tasks, thereby experiencing challenge and self-competition during work activities (Csikszentmihalyi 1975; Strauss and Parker 2014).

Playful use of technology involves employees proactively modifying their tasks to incorporate elements of fun, self-imposed challenges, and active learning, particularly through workplace technologies (Scharp et al. 2021). For instance, employees in data analytics or project management roles might use tools like Asana or Trello to turn workflow tracking into a game-like experience. They can set personal performance benchmarks, earn digital badges, and strive to surpass previous achievements, making their interaction with the technology more stimulating and engaging. Eventually, this personal engagement transforms the technology from a mere organisational tool into something employees perceive as 'their own' (Bakker et al. 2020; Scharp et al. 2021).

In line with extended self theory (Belk 1988; Pierce, Kostova, and Dirks 2003), playful use of technology promotes psychological ownership by enabling employees to internalise new technologies as extensions of their self-concept. When employees engage with workplace technologies for enjoyment or self-imposed challenges (e.g. work gamification), they deepen their familiarity with them and enhance their ability to navigate and control these tools effectively (Padilla-Meléndez, Del Aguila-Obra, and Garrido-Moreno 2013). Consequently, playful use of technology allows individuals to (a) experience a sense of ownership

through increased control over technology use, (b) invest personal resources through devoted and enjoyable experimentation, and (c) acquire relevant knowledge and skills that further reinforce ownership of new technologies (W. Liu et al. 2023; Scharp et al. 2021). This discussion leads to the following hypothesis:

**Hypothesis 3.** Playful use of technology is positively related to psychological ownership of a technological innovation.

#### ***1.4. Psychological ownership as a mediating mechanism***

Based on the above main effect hypotheses, we further propose the indirect effects of implementation efficacy and playful use of technology on innovation championing through psychological ownership. Implementation efficacy represents a favourable innovation perceptions and appraisals that promotes psychological ownership and further leads to proactive advocacy for innovation (Moghavvemi 2015). Similarly, as a proactive behaviour for optimising the technological aspect of their work for playful experiences, such as fun, challenge, and competition, playful use of technology provides positive psychological energy towards proactive championing for a new technological innovation (W. Liu et al. 2023; Scharp et al. 2021). Accordingly, implementation efficacy and playful use of technology at work can increase proactive endorsement of innovation among employees by strengthening their ownership of the given innovation (Avey et al. 2009; Pierce, Kostova, and Dirks 2001). Based on this discussion, we advance the following mediation hypotheses:

**Hypothesis 4.** Psychological ownership mediates the relationship between implementation efficacy and innovation championing.

**Hypothesis 5.** Psychological ownership mediates the relationship between playful use of technology and innovation championing.

#### ***1.5. Interaction between implementation efficacy and playful use of technology***

Finally, we propose that implementation efficacy and playful use of technology interact synergistically to predict employees' psychological ownership and championing of a target innovation. Specifically, employees who engage playfully with technologies are more likely to develop a strong sense of ownership when they also possess high efficacy regarding the newly adopted technology (e.g. I40T). In the current framework, playful use of technology and implementation efficacy serve complementary and synergistic roles. Playful use of technology operates as a proactive behavioural pathway through which employees engage with workplace technologies in their daily work, whereas implementation efficacy functions as a cognitive enabling condition that strengthens this pathway in the context of implementing a specific innovation, such as I40T.

Conceptually, these two constructs are independent and complementary. Employees may feel highly efficacious yet engage with technology in a purely instrumental, rather than playful, manner, or conversely, may engage playfully with various workplace technologies despite initially low confidence in a newly implemented technology. Accordingly, during the implementation of a new technological innovation, playful engagement with technology is more likely to translate into psychological ownership when employees also possess a strong sense of mastery in using the technology at hand. Therefore, the interaction between playful use of technology and implementation efficacy captures the joint activation of behavioural engagement and cognitive readiness that facilitates the development of psychological ownership. Hence, we propose the following hypotheses:

**Hypothesis 6.** Implementation efficacy positively moderates the relationship between playful use of technology and psychological ownership.

**Hypothesis 7.** Implementation efficacy positively moderates the indirect relationship between playful use of technology and innovation championing mediated by psychological ownership.

## 2. Method

### 2.1. Participants and procedure

We tested the current theoretical hypotheses in the context of implementing I40T. Many organisations around the world have introduced I40T to optimise business operations and achieve sustained competitive advantages amidst increasing challenges of global competition and technological developments (Bai et al. 2020; Leong, Chuah, and Tuan 2020). *Industry 4.0* accounts for ‘the fourth industrial revolution applying the principles of cyber-physical systems, internet and future-oriented technologies and smart systems with enhanced human-machine interaction paradigms’ (Sanders, Elangeswaran, and Wulfsberg 2016, 816).

With a three-wave, multisource design, we tested our hypotheses by studying employees of Taiwanese firms that introduced I40T for their employees to implement. In recent years, the Taiwanese government has been actively engaging in promoting I40T for the purpose of becoming a global leader of technology. However, employee support for such corporate initiatives has been lukewarm and approximately half of employees are not willing to accept and use I40T at work (Common Wealth Magazine 2019). This trend reflects the need for Taiwanese firms to explore ways to secure employee support for I40T, which is in line with the current study’s focus on innovation championing. The data collection was conducted in collaboration with a survey company in Taiwan. The company assisted in reaching the participants, informing them of the general aim of this study, and obtaining their and their managers’ permission to administer the survey. The participation was voluntary, and the anonymity and confidentiality of the collected data were ensured.

Participants were drawn from organisations spanning a broad range of jobs, as reflected in the occupational categories reported in Table 1. Most participants worked in manufacturing/operations, engineering/technology, and business/service functions, where the adoption and implementation of Industry 4.0-related technologies are particularly prevalent. Although organisational size and the degree of technology exposure were not measured directly, all participating organisations were engaged in the implementation of digital, automation-, or analytics-enabled technologies. This organisational context therefore provides an appropriate and relevant setting for the present study.

At Time 1, we distributed the questionnaire to 532 employees and received a total of 329 usable questionnaires, yielding a response rate of 62%. Time 1 survey evaluated the participants’ playful use of technology and implementation efficacy. At Time 2 (three weeks later), we distributed another set of questionnaires to the 329 employees who completed the Time 1 survey. This time, we received 286 usable questionnaires, yielding a response rate of 87%. The Time 2 survey evaluated the participants’ psychological ownership. At Time 3 (another three weeks later), we distributed the final questionnaire to the managers of the 286 participants who completed the Time 2 survey. These managers rated the levels of the participants’ innovation championing. We eventually received a total of 255 usable questionnaires, yielding a response rate of 89%.

To evaluate the potential impact of attrition, we compared the demographic characteristics (age, gender, education, and tenure) of participants who dropped out between survey waves with those who remained in the final sample. Chi-square tests (for categorical variables) and independent-sample t-tests (for continuous variables) indicated no statistically significant differences between the two groups (all  $ps > .10$ ). Therefore, the final sample can be considered broadly representative of the initial sample. Nevertheless, consistent with most multi-wave field studies, the possibility of unobserved differences cannot be entirely ruled out.

A majority of the participants were female (60%). Most participants’ ages ranged between 31 and 40 years (48.6%), followed by those who were 41–50 years (28.2%) and 21–30 years (18.8%). Most participants had a bachelor’s degree (67.8%), followed by those with a high school/vocational school diploma (17.3%) and a graduate degree (13.7%). Their functions included professional service or general management (40.4%), engineering or technology (22%), and manufacturing or operation (18%). The majority of the participants

Table 1. Means, Standard Deviations, and Correlations Among Study Variables

Variables	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Age	3.17	.81	-												
2. Gender	1.40	.49	.15*	-											
3. Education	3.94	.60	-.26***	.18**	-										
4. Tenure	4.28	1.64	.58***	.19*	.01	-									
5. Occupation 1	.01	.09	-.02	.11	-.07	-.04	-								
6. Occupation 2	.18	.39	.03	.10	7.11	.10	-.04	-							
7. Occupation 3	.22	.42	.11	.19**	.08	.01	-.05	-.25***	-						
8. Occupation 4	.40	.49	-.06	-.20***	-.11	-.04	-.07	-.39***	-.44***	-					
9. Occupation 5	.04	.20	-.05	.06	.18**	.05	-.02	-.10	-.11	-.18**	-				
10. Occupation 6	.10	.30	-.06	-.09	.14*	-.03	-.03	-.16*	-.18**	-.28***	-.07	-			
11. Playful use of technology	3.17	.84	-.01	-.06	.05	.04	.02	.00	.00	-.03	.11	.06	-		
12. Implementation efficacy	6.08	1.45	.07	.06	.10	.10	-.08	.00	.13*	-.15*	.02	.10	.39***	-	
13. Psychological ownership	3.66	.66	.06	.02	.11	.10	-.02	-.07	.17**	-.11	.04	.06	.29***	.22***	-
14. Innovation championing	4.83	.98	.02	-.05	.08	.05	-.03	.00	-.02	-.03	.06	.04	.34***	.42***	.40***

Note: \*,  $p < .05$ ; \*\*,  $p < .01$ ; \*\*\*,  $p < .001$  ( $N = 255$  participants) Age: 1 = 20 years old or under, 2 = 21–30 years old, 3 = 31–40 years old, 4 = 41–50 years old, 5 = 51–60 years old, 6 = 61 years old or over; Gender: 1 = Female, 2 = Male; Education: 1 = Elementary/Primary school and under, 2 = Junior high school, 3 = Senior high/vocational school, 4 = Bachelor's degree, 5 = Master's degree, 6 = Doctoral degree and above; Tenure: 1 = Less than a year, 2 = 1–3 years, 3 = 3–5 years, 4 = 5–7 years, 5 = 7–9 years, 6 = More than 10 years; Occupation: 1 = Agriculture and Forestry/fishery and animal husbandry, 2 = Manufacturing/operation, 3 = Engineering/technology, 4 = Business/service, 5 = Medical law/Professional, 6 = Military/Education, 7 = Others.

worked for more than 10 years (38%), followed by those who worked for 3–5 years (18.8%), 5–7 years (14.1%), 1–3 years (13.7%), and 7–9 years (11%).

## 2.2. Measures

Prior to the survey, we used the professional translation service to translate and back-translate all items from English to Mandarin, thus ensuring that the original meanings of those items were maintained (Brislin 1980). Except for playful use of technology, all scale items contained the notion of I40T. To highlight the focus of the survey and obtain consistent participant responses, we briefly explained the term to the participants by providing the below statement on top of the questionnaire: ‘Industry 4.0 technologies (I40T) encompass artificial intelligence, blockchain, additive manufacturing, system integration, automation, cloud, cyber security, Internet of Things, big data and analytics, virtual reality, and simulation.’ Participants were then instructed to recall a specific technological innovation falling within the I40T definition that they are expected to implement at work and to focus on this experience when responding to the survey items. This procedure ensured that their responses were grounded in a consistent and concrete experience with a particular I40T, thereby reducing ambiguity and enabling more reliable measurement of the study variables. All measurement items are reported in Appendix.

### 2.2.1. Playful use of technology (T1, employee)

We measured playful use of technology using a 12-item scale ( $\alpha = .95$ ) adapted from the PWD measure developed by Scharp et al. (2021). The original PWD items were adapted to capture employees’ use of workplace technologies as vehicles for infusing playfulness into their tasks, rather than their general tendency to engage in play at work. For example, the original item ‘I approach my work in a playful way’ was revised to ‘I approach my use of technology in a playful way’ (designing fun), and the original item ‘I compete with myself at work, not because I have to, but because I enjoy it’ was modified to ‘I compete with myself when using technology, not because I have to, but because I enjoy it’ (designing competition).<sup>3</sup> All items were rated on a 5-point Likert scale (1 = Never, 5 = Very Often).

To validate the adapted measure, we conducted confirmatory factor analyses, which showed excellent fit for the two subdimensions (designing fun:  $\chi^2$  (35.008),  $df = 9$ ,  $\chi^2/df = 3.90$ ; CFI = .97; NFI = .97; SRMR = .02, designing competition:  $\chi^2$  (53.297),  $df = 9$ ,  $\chi^2/df = 5.92$ ; CFI = .96; NFI = .95; SRMR = .03). We further compared a two-factor model distinguishing designing fun and designing competition with a one-factor model representing an overall playful use of technology construct. The model comparison indicated that the two-factor model did not provide a statistically significant improvement in fit over the one-factor model ( $\Delta\chi^2 = 1.16$ ,  $\Delta df = 1$ ,  $p > .05$ ), suggesting that the additional complexity associated with separating the two dimensions was not empirically warranted. Accordingly, in line with previous research (Bakker et al. 2020; Petelczyc et al. 2018), we combined the two dimensions into a single factor to create an overall measure of playful use of technology.<sup>4</sup>

### 2.2.2. Implementation efficacy (T1, employee)

To measure implementation efficacy, we adopted a 10-item scale ( $\alpha = .91$ ) developed by Compeau and Higgins (1995), which was initially designed to evaluate individuals’ efficacy in using technology. We replaced ‘technology’ with ‘I40T’ in each item to specify the target innovation in the present study. The

<sup>3</sup>Regarding conceptual validity, we emphasise that the adaptation of the PWD items was theory driven rather than exploratory. Consistent with the original definition of PWD as employees’ self-initiated efforts to incorporate fun and challenge into their work tasks (Bakker et al. 2020; Scharp et al. 2021), we retained the core dimensions of designing fun and designing competition and modified item wording only to specify workplace technologies as the medium through which playfulness was enacted. This adaptation followed established principles of scale adaptation and content validity by preserving the original dimensional structure of PWD while altering only the contextual referent of the items. Each adapted item was evaluated against the theoretical definition of PWD to ensure that it continued to capture self-initiated playfulness and challenge embedded in work tasks, rather than technology enjoyment or gamification per se.

<sup>4</sup>From a theoretical perspective, although ludic play (designing fun) and agonistic play (designing competition) reflect conceptually distinct play motives, playful work design theory conceptualises them as complementary behavioural expressions of a shared higher-order orientation towards self-initiated, intrinsically motivated engagement with work tasks (Bakker et al. 2020; Scharp et al. 2021). At this higher level of abstraction, the distinction between fun-based and challenge-based play becomes secondary to their common function of fostering active involvement, experimentation, and personal investment in work activities. Accordingly, modelling playful use of technology as a unidimensional construct captures this overarching motivational orientation while preserving theoretical parsimony, without denying the conceptual distinctiveness of its constituent play forms.

participants were instructed to rate items, such as ‘I could complete my job using I40T if there was no one around to tell me what to do as I go.’ The response format was a 10-point Likert scale (1 = *Not at all confident*, 10 = *Totally confident*).

### 2.2.3. Psychological ownership of innovation (T2, employee)

The participants reported their psychological ownership regarding the target innovation (i.e. I40T) by responding to a 7-item scale ( $\alpha = .81$ ) based on Van Dyne and Pierce (2004). The scale was initially designed to evaluate employees’ psychological ownership towards their organisation. A sample item is ‘I feel a very high degree of personal ownership for this organization.’ For this study, we changed the target of psychological ownership by replacing organisation with I40T. For example, we revised the above item as ‘I feel a very high degree of personal ownership for this technology (I40T).’ To clarify the target, we provided the following statement before the psychological ownership items: ‘The following questions deal with the sense of ownership that you feel for Industry 4.0 technologies (I40T) that you use at work. Please indicate the degree to which you personally agree or disagree with the following statements.’ All items were rated on a 5-point Likert scale (1 = *Strongly disagree*, 5 = *Strongly agree*).

### 2.2.4. Innovation championing (T3, manager)

We measured participants’ innovation championing by using a 3-item scale ( $\alpha = .85$ ) developed by Herscovitch and Meyer (2002). The scale was initially designed to measure the change championing behaviours of employees through their self-reports. For this study, we adapted the items to evaluate employees’ innovation championing behaviour through their managers’ evaluation in line with the purpose of the current research and to avoid the same source bias. For example, we revised the original item ‘I tried to overcome my coworkers’ resistance towards the change initiative’ into ‘This employee tried to overcome coworkers’ resistance towards the use of I40T.’ All items were rated using a 7-point Likert scale (1 = *Strongly disagree*; 7 = *Strongly agree*). This operationalisation captures managers’ evaluations of employees’ discretionary support for innovation (e.g. persuading co-workers, overcoming resistance) rather than the act of implementation itself, aligning with our definition of championing as proactive behaviours that facilitate – but are distinct from – implementation.

### 2.2.5. Control variables

To address potential sources of confounding in our analysis results, we identified and included a set of demographic variables, namely, age, gender, education, occupation, and tenure, as control variables based on previous studies. In their study on innovation implementation, Venkatesh, Morris, and Ackerman (2000) reported that age and gender differences significantly affected technology adoption. Abu-Shanab (2011) discovered a significant role of education in view of the unified theory of acceptance and use of technology. Su and Li (2010) revealed that occupation is a significant predictor of individuals’ adoption of technology. Along with these demographic variables, we included tenure as a control given the possibility that it indicates one’s experience and familiarity with existing routines and technologies, which in turn can shape their attitudes and readiness towards a new technological innovation. The current set of control variables was included to address the theoretical possibilities and the potential confounding effects. We performed the same analysis with and without those control variables and achieved results with the same significance patterns.

## 3. Results

Before testing the current hypotheses, we verified the empirical distinctiveness of the study variables by conducting a series of confirmatory factor analyses (CFA). The hypothesised four-factor model exhibited acceptable model fit indexes ( $\chi^2$  (285.66),  $df = 114$ ,  $\chi^2/df = 2.51$ ; CFI = .94; NFI = .90; SRMR = .07). We further tested several alternative measurement models.

A five-factor model that separated playful use of technology into *designing fun* and *designing competition* did not produce a better fit ( $\chi^2 = 280.40$ ,  $df = 113$ ,  $\chi^2/df = 2.48$ ; CFI = .94; NFI = .90; SRMR = .07), and model comparison indicated no significant improvement ( $\Delta\chi^2 = 5.26$ ,  $\Delta df = 1$ , *ns.*). Additional alternative models exhibited substantially poorer fit: a three-factor model combining playful use of technology and

implementation efficacy into a single factor ( $\chi^2 = 605.17$ ,  $df = 116$ ,  $\chi^2/df = 5.22$ ; CFI = .82; NFI = .79; SRMR = .10); a two-factor model collapsing playful use of technology, implementation efficacy, and psychological ownership into one factor ( $\chi^2 = 748.86$ ,  $df = 118$ ,  $\chi^2/df = 6.35$ ; CFI = .76; NFI = .73; SRMR = .10); and a single-factor model ( $\chi^2 = 862.69$ ,  $df = 119$ ,  $\chi^2/df = 7.25$ ; CFI = .72; NFI = .69; SRMR = .11), all of which fit significantly worse ( $p < .001$  for all chi-square difference tests). These results support the empirical distinctiveness of our focal constructs, and the very high correlation between the two playful use facets ( $r = .84$ ,  $p < .001$ ) justifies treating them as a composite construct for parsimony in subsequent analyses.<sup>5</sup>

To further address potential concerns regarding omitted variable bias, we conducted an Impact Threshold of a Confounding Variable (ITCV) analysis (Frank 2000; Lonati and Wulff 2024). This analysis estimates the minimum correlation that an unmeasured confounder would need to have with *both* the predictor and the outcome to completely explain away the observed effect. Across our key relationships, the ITCV values ranged from .29 to .40, indicating that an unmeasured confounding variable would need to have quite high correlations with both constructs to fully account for the observed effects, thereby strengthening confidence in the validity and stability of our conclusions. We report the means, standard deviations, and correlations of the study variables in Table 1.

### 3.1. Main and mediation effects

To test the hypotheses, we adopted SPSS Process Macro. The three main-effect hypotheses proposed the relationships between psychological ownership and innovation championing (Hypothesis 1), between implementation efficacy and psychological ownership (Hypothesis 2), and between playful use of technology and psychological ownership (Hypothesis 3). The hypothesis test results are presented in Table 2. Consistent with Hypothesis 1, employees' psychological ownership was a positive predictor of innovation championing as rated by their supervisors ( $b = .49$ ,  $p < .001$ ). However, Hypothesis 2 was not supported because implementation efficacy was not positively associated with psychological ownership ( $b = .04$ ,  $p$

**Table 2.** Results for the Moderated Mediation Model: Main and Moderating Effects

Predictors	Outcome: Innovation championing	Outcome: Psychological ownership	Outcome: Innovation championing	Outcome: Innovation championing
Constant	3.04 (.63)***	3.13 (.40)***	2.58 (.45)***	2.77 (.74)***
Age	.04 (.10)	-.01 (.07)	.02 (.07)	.02 (.09)
Gender	-.11 (.13)	.00 (.09)	-.06 (.10)	-.10 (.13)
Education	.12 (.11)	.05 (.08)	.08 (.08)	.07 (.11)
Tenure	.02 (.05)	.03 (.03)	.03 (.03)	.01 (.04)
Occupation 1	-.19 (.73)	.13 (.45)	.20 (.47)	-.16 (.53)
Occupation 2	.10 (.32)	.09 (.24)	.06 (.28)	.13 (.35)
Occupation 3	.11 (.32)	.35 (.24)	.33 (.28)	-.01 (.36)
Occupation 4	.05 (.30)	.11 (.24)	.08 (.28)	.06 (.34)
Occupation 5	.12 (.42)	.18 (.30)	.22 (.34)	.11 (.43)
Occupation 6	.09 (.35)	.23 (.24)	.22 (.29)	.04 (.36)
Playful use of technology	.39 (.07)***	.18 (.07)*		.28 (.10)**
Implementation efficacy		.04 (.04)	.08 (.04)***	.25 (.05)***
Psychological ownership				.49 (.14)***
Playful use of technology		.13 (.07)*		
Implementation efficacy				
R <sup>2</sup>	.13	.22	.09	.22

Note:  $N = 255$  participants. \*  $p < .05$ ; \*\*  $p < .01$ ; \*\*\*  $p < .001$ . Occupation: 1 = Agriculture and Forestry/fishery and animal husbandry, 2 = Manufacturing/operation, 3 = Engineering/technology, 4 = Business/service, 5 = Medical law/Professional, 6 = Military/Education, 7 = Others. Values in parentheses are standard errors.

<sup>5</sup>This high correlation indicates substantial shared variance but does not, by itself, imply a lack of discriminant validity; rather, it suggests that the two dimensions reflect closely related facets of a higher-order construct. Moreover, consistent hypothesis-testing results were obtained using both the overall measure of playful use of technology and the separate measures of the two dimensions. Taken together, the CFA results, model comparisons, and theoretical considerations provide strong evidence for the validity and reliability of the adapted PWD measure within the technological context.

> .05). Our analysis supported Hypothesis 3 because playful use of technology was positively related to psychological ownership ( $b = .18, p < .05$ ).

Hypotheses 4 and 5 state that psychological ownership mediates the effects of implementation efficacy and playful use of technology on innovation championing. As reported in Table 3, the indirect effect of implementation efficacy on innovation championing through psychological ownership was not statistically significant ( $b = .04, 95\%$  confidence interval (CI) =  $[-.002, .10]$ ). Thus, Hypothesis 4 was not supported. In comparison, the indirect effect of playful use of technology on innovation championing through psychological ownership was significant ( $b = .09, 95\%$  CI =  $[.03, .18]$ ), thereby supporting Hypothesis 5.

### 3.2. Moderation and moderated mediation effects

Hypothesis 6 posits that implementation efficacy positively moderates the relationship between playful use of technology and psychological ownership. We centred all predictors, including implementation efficacy and playful use of technology, to mitigate multicollinearity concerns and tested their interactions within the regression models. Collinearity diagnostics confirmed that the variance inflation factors were within acceptable ranges, indicating that the predictors did not excessively influence one another.

As shown in Table 2, the effect of the interaction between playful use of technology and implementation efficacy on psychological ownership was positive and significant ( $b = .13, p < .05$ ), confirming that these variables interact synergistically. This significant interaction was further explored through a simple slope analysis. As shown in Figure 2, the relationship between playful use of technology and psychological ownership was stronger for individuals with high implementation efficacy (1SD above the mean;  $b = .31, p < .001$ ) than their counterparts with low implementation efficacy (1SD below the mean;  $b = .18, p < .01$ ), thereby supporting Hypotheses 6 for the moderating effect of implementation efficacy. The observed variability in implementation efficacy ( $SD = 1.45$ ) indicates that a  $\pm 1$  SD range captures substantial differences in employees' confidence levels. This dispersion highlights the practical significance of the moderation effect, showing that employees in our sample exhibited a wide range of efficacy beliefs rather than clustering closely around the mean.

Hypothesis 7 posits that implementation efficacy positively moderates the indirect relationship between playful use of technology and innovation championing through psychological ownership. As shown in Table 3, this indirect effect of playful use of technology was greater for those with high implementation efficacy (1SD above the mean;  $b = .18, 95\%$  CI =  $[.10, .29]$ ) than their counterparts with low implementation efficacy (1SD below the mean;  $b = .01, 95\%$  CI =  $[-.01, .05]$ ). The indirect effect at the low level was nonsignificant because its confidence interval included zero, whereas the effect at the high level was significant. Furthermore, the index of moderated mediation was significant (index =  $.06, 95\%$  CI =  $[.02, .13]$ ), indicating that the indirect effects were significantly different at varying levels of implementation efficacy. Thus, the results confirm the moderated mediation effect, supporting Hypothesis 7.

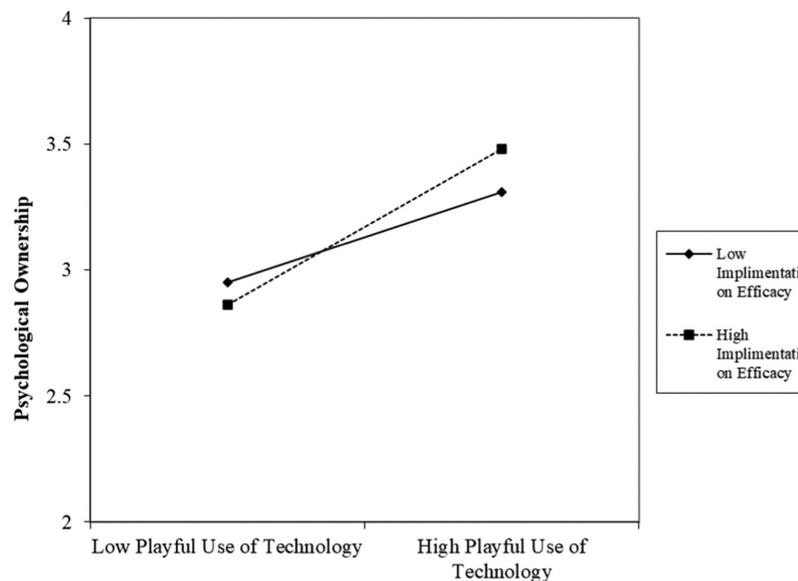
## 4. Discussion

Given the growing importance and complexity of innovation, organisations must identify and support champions who proactively advocate for adopted innovations, persuade colleagues to embrace them, and work to overcome resistance during their implementation (Fugate and Soenen 2018; Walter et al. 2011). Drawing on extended self theory, we developed a theoretical framework focusing on the role of psychological ownership in shaping employees' innovation championing. Using the organisational context of implementing I40T, we tested these hypotheses through an analysis of three-wave, multi-source data. Our results provide strong evidence for both the direct and indirect effects of playful use of technology on employees' innovation championing via psychological ownership. Notably, the bootstrapping results indicate that self-confidence in implementing the new technology amplifies the impact of playful technology use on innovation championing. The following sections discuss the theoretical and practical implications, study limitations, and directions for future research.

**Table 3.** Results for the Mediation and Moderated Mediation Model: Unconditional and Conditional Indirect Effects

Independent variable	Mediator	Dependent variable	Moderator	Moderator level	Indirect effect	Bootstrapping bias-corrected 95% CI	
						Lower limit	Upper limit
<b>Mediation</b>							
Implementation efficacy	Psychological ownership	Innovation championing			.04		.10
<b>Moderated mediation</b>							
Playful use of technology	Psychological ownership	Innovation championing	Implementation efficacy	Low	.01	-.01	.05
				Medium	.09	.03	.18
				High	.18	.10	.29
					.06	.02	.13

Note: N = 255; Bootstrap sample size = 5,000.  
 CI = confidence interval.



**Figure 2.** Moderating Effect of Implementation Efficacy on the Relationship between Playful Use of Technology and Psychological Ownership.

#### 4.1. Theoretical implications

This study makes several important theoretical contributions to the literature. First and foremost, we identify and empirically validate a novel pathway linking playful use of technology to innovation championing through psychological ownership. This pathway illustrates how playful engagement functions as a proactive behavioural mechanism that cultivates employees' sense of ownership over newly introduced technological innovations. By uncovering this pathway, we extend prior research on championing, which has largely concentrated on idea advocacy during the creativity stage or on externally driven compliance with organisational change (De Clercq, Sun, and Belausteguigoitia 2021; Perry-Smith and Mannucci 2017; Zhang and Bartol 2010). Our framework demonstrates that employees' self-initiated playful behaviours at work can foster psychological ownership and emotional attachment to technological innovations, ultimately promoting innovation championing during the implementation stage.

Second, this study demonstrates that playful use of technology is not merely about making work enjoyable; it serves as a strategic mechanism through which employees proactively engage with an upcoming technological innovation, thereby driving their psychological ownership and championing behaviours. Earlier studies exploring the effects of PWD or playfulness at work on task motivation and performance have predominantly drawn on self-determination theory as their theoretical foundation (e.g. Bakker and Van Wingerden 2021; W. Liu et al. 2023; Petelczyc et al. 2018). Departing from this prevailing perspective, which primarily views PWD as a mechanism for satisfying basic psychological needs (Bakker et al. 2021; Scharp, Bakker, and Breevaart 2022), the present study extends the literature by highlighting the *agentic* function of playful technology use. Specifically, we demonstrate how employees' playful engagement with technology enables them to internalise technological innovations as part of their extended self. Our analysis further confirmed that this pathway remains robust whether playful use of technology is modelled as a composite construct or divided into its two dimensions, designing fun and designing competition. Given their high correlation and shared theoretical underpinnings, we retained the composite construct for parsimony; however, future research could investigate if the two facets can exert distinct effects under specific contextual conditions.

Third, our findings advance extended self theory (Pierce, Kostova, and Dirks 2003) by identifying playful technology use as a unique mechanism through which employees develop a sense of ownership over workplace innovations. In earlier studies, psychological ownership has been associated with direct control, long-term investment, and intimate knowledge of a target (Pierce, Kostova, and Dirks 2001, 2003). Challenging this traditional view, our study suggests that ownership of a specific innovation can emerge

through indirect mechanisms, such as playful engagement with workplace technologies. This highlights an alternative way through which employees can form psychological connections to non-physical, digital innovations. By demonstrating that playful behaviour can foster psychological ownership, we provide a more nuanced perspective on how organisational innovations are internalised by employees.

Fourth, our analysis showed that implementation efficacy strengthens the positive relationship between playful use of technology and psychological ownership, thereby demonstrating a boundary condition accentuating innovation championing (Axboe et al. 2016; Bright, Kleiser, and Grau 2015). It should be noted that the conditional indirect effect at low efficacy levels was not significant, indicating that employees low in efficacy did not translate playful technology use into innovation championing via ownership. In contrast, the indirect effect at high efficacy levels was significant, confirming that implementation efficacy amplifies rather than independently drives this psychological process (Bandura 1997). This pattern suggests that efficacy beliefs function as a cognitive enabling condition, laying the groundwork upon which proactive behaviours such as playful engagement with technology can more effectively cultivate psychological ownership and, ultimately, promote innovation championing. Indeed, the literature does not yet provide a clear account of whether and how self-efficacy functions as a direct predictor or as an enabler for psychological ownership, particularly in the context of innovation, which presents a promising avenue for future research.

Finally, our study used I40T as a representative innovation that has garnered significant attention from both academic and industrial communities (Surange et al. 2022). The emerging literature underscores the benefits that I40T offer to organisations but has predominantly concentrated on technical, macro-industrial, or firm-level issues (Dumitrescu and Buzatu 2020). However, recent research has identified employee-related factors, such as lack of motivation and resistance to change, as critical barriers to successful I40T implementation (Herceg et al. 2020; Ito et al. 2021). Building on this trend, we extend the literature by advancing a micro-level perspective that demonstrates how playful use of technology offers organisations a practical means of cultivating innovation champions.

#### **4.2. Practical implications**

The current findings reveal several directions for managerial interventions in the context of innovation implementation. First, to foster innovation championing, organisations may provide employees with opportunities and encourage them to playfully engage with various technologies in their work. To this end, managers can empower employees to use technological tools and devices for enjoyment and self-directed competition where appropriate. This can be achieved by fostering a fun and imaginative work climate in which employees are encouraged to experiment with and apply work-related technologies in playful ways. Managers may also promote continuous engagement with technological tools by encouraging employees to explore new applications that challenge and develop their professional capabilities.

Building on this foundation, broader organisational interventions can further promote playful engagement. For instance, gamification initiatives – such as incorporating points, badges, or leaderboards into workflow platforms – can institutionalise playful interaction with digital tools (Koivisto and Hamari 2019). At the cultural level, organisations can cultivate a climate that values curiosity, experimentation, and humour, thereby normalising playful engagement with technology as part of a broader cultural transformation (Schneider, Ehrhart, and Macey 2013). Together, these interventions illustrate how individual-level playfulness can be scaled into organisational practices that enhance psychological ownership and promote innovation championing.

Second, our findings reveal the value of helping employees develop strong psychological ownership. Hence, while implementing an innovation, apart from informing employees of the benefits of the given innovation, managers may motivate employees to avail themselves of work-related technologies to design for fun and self-competition in their work activities. The interventions implemented at managerial, organisational, and cultural levels, as described above, can help employees strengthen their sense of psychological ownership, thereby motivating them to proactively champion the innovations introduced within their work context.

Third, the current results suggest the need to improve implementation efficacy as it may promote innovation championing and boost the positive impact of playful use of technology on psychological ownership. To achieve this, managers may develop specific goals related to innovations that are easy to

achieve for employees, assisting them to acquire a sense of mastery (Axboe et al. 2016; Bandura 1997). Managers may also provide sufficient information and training programmes to help employees feel comfortable and confident with the innovation. For example, digital literacy training can equip employees with the necessary skills and confidence to experiment with technologies in creative and exploratory ways, thereby enhancing both their implementation efficacy and playfulness (van Laar et al. 2020). Additionally, managers may encourage knowledge sharing wherein employees who possess high levels of implementation efficacy can share their relevant experiences, skills, or tips with others (Safdar, Batool, and Mahmood 2021).

### 4.3. Research limitations and future research directions

The present study has several limitations that must be considered. First, although the present study treated I40T as a collective category of innovation, the specific technologies encompassed within this cluster may vary substantially in their required skill sets and in the extent to which they afford or invite different forms of playful engagement. As noted by Scharp et al. (2021), *designing fun*—which involves humour, social interaction, and light-hearted playfulness – is particularly effective in socially embedded contexts, whereas *designing competition*—which entails self-imposed challenges and personal goal setting – tends to be more beneficial in task-driven environments. This distinction is likely to extend to different types of I40T.

For instance, collaborative technologies such as AI-based systems, digital twins, and cloud-based platforms that rely heavily on teamwork and knowledge sharing may be especially conducive to *designing fun* approaches, whereby employees engage in socially playful interactions and shared humour. In contrast, technologies that emphasise individual cognitive engagement and task efficiency such as automation tools, robotic process automation (RPA), and data analytics systems may be better suited to *designing competition*, where employees challenge themselves to enhance efficiency, create optimised automation scripts, or refine algorithms in game-like ways.

Recognising this potential heterogeneity across different I40T categories may enable researchers to examine whether user responses systematically differ across technologies varying in complexity, skill requirements, and play affordances. Future research should therefore compare distinct types of technologies to determine whether the pathways identified in this study vary depending on the specific characteristics and affordances of the technologies involved. In sum, further investigation is needed to understand how specific forms of playful work design can be tailored to optimise psychological ownership and innovation championing across diverse technological contexts.

Second, although our findings supported the moderating role of implementation efficacy, its direct effect on psychological ownership was not significant, raising potential questions regarding the parsimony of the proposed model. Future research could explore simplified frameworks that focus exclusively on playful use of technology or investigate whether efficacy primarily functions as a boundary condition rather than a direct antecedent of ownership. Alternatively, while our results suggest that implementation efficacy serves more as an enabling condition, future studies could examine the boundary conditions under which efficacy alone may be sufficient to foster ownership – for instance, when innovations are highly task-relevant, competence-threatening, or closely tied to employees' professional identities. Investigating these contingencies would provide a more nuanced understanding of the circumstances under which efficacy can independently generate psychological ownership and innovation championing.

Finally, a further limitation of this study concerns potential endogeneity and omitted variable bias. Unmeasured factors – such as dispositional resistance to change (Oreg 2003) or proactive personality (Bateman and Crant 1993) – may influence both playful use of technology and innovation championing, thereby confounding the observed relationships. In particular, within the current empirical context, employee resistance to I40T may stem from concerns about job displacement, discomfort with rapid technological change, or unfamiliarity with complex systems such as artificial intelligence or cybersecurity (Herceg et al. 2020; Ito et al. 2021). Such resistance could attenuate the positive effects of playful technology use on psychological ownership and subsequent championing behaviours. Future research could address these concerns by explicitly modelling resistance-related or dispositional variables and by adopting research designs that allow for stronger causal inference.

## 5. Conclusion

In this study, we attended to the emerging practical challenges of implementing technological advancements, such as I40T and digital transformation, which require the active participation of employees for their successful implementation. We addressed this challenge by introducing extended self theory and framing the microprocess of innovation implementation as the process of individuals' development of a sense of ownership so that they care about and become willing to proactively endorse and even sacrifice for the sake of innovation (Pierce, Kostova, and Dirks 2001). Our analysis demonstrated the significance of extended self theory as a new theoretical framework to address the recent, but also recurring, business challenges of innovation implementation and provided an in-depth explanation of the microprocesses underlying proactive innovation support among employees. Future research may re-evaluate and further extend the current theoretical framework by taking into account the diversity of cultural contexts, the heterogeneity of technological innovations, and the broader contextual influences arising from meso- and macro-level factors.

## Acknowledgement

This research was partially supported by the Faculty of Business and Law's Pump-Priming Research Funding 2022/23, Anglia Ruskin University, under a broader project on Industry 5.0 and digital innovation. The present study focuses on Industry 4.0 technologies as a foundational component of that research program.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## References

- Abramis, D. J. 1990. "Play in Work: Childish Hedonism or Adult Enthusiasm?" *American Behavioral Scientist* 33 (3): 353–373. <https://doi.org/10.1177/0002764290033003010>.
- Abu-Shanab, E. A. 2011. "Education Level as a Technology Adoption Moderator." In *2011 3rd International Conference on Computer Research and Development*, 324–328. IEEE.
- Afonasova, M., E. Panfilova, M. Galichkina, and B. Ślusarczyk. 2019. "Digitalization in Economy and Innovation: The Effect on Social and Economic Processes." *Polish Journal of Management Studies* 19 (2): 22–32. <https://doi.org/10.17512/pjms.2019.19.2.02>.
- Armenakis, A. A., and S. G. Harris. 2009. "Reflections: Our Journey in Organizational Change Research and Practice." *Journal of Change Management* 9 (2): 127–142. <https://doi.org/10.1080/14697010902879079>.
- Ashforth, B. E., S. H. Harrison, and K. G. Corley. 2008. "Identification in organizations: An examination of four fundamental questions." *Journal of Management* 34 (3): 325–374. <https://doi.org/10.1177/0149206308316059>.
- Avey, J. B., B. J. Avolio, C. D. Crossley, and F. Luthans. 2009. "Psychological Ownership: Theoretical Extensions, Measurement and Relation to Work Outcomes." *Journal of Organizational Behavior* 30 (2): 173–191. <https://doi.org/10.1002/job.583>.
- Axboe, M. K., K. S. Christensen, P. E. Kofoed, and J. Ammentorp. 2016. "Development and Validation of a Self-Efficacy Questionnaire (SE-12) Measuring the Clinical Communication Skills of Health Care Professionals." *BMC Medical Education* 16 (1): 272. <https://doi.org/10.1186/s12909-016-0798-7>.
- Bai, C., P. Dallasega, G. Orzes, and J. Sarkis. 2020. "Industry 4.0 Technologies Assessment: A Sustainability Perspective." *International Journal of Production Economics* 229:107776. <https://doi.org/10.1016/j.ijpe.2020.107776>.
- Bakker, A. B., K. Breevaart, Y. S. Scharp, and J. D. De Vries. 2021. "Daily Self-Leadership and Playful Work Design: Proactive Approaches of Work in Times of Crisis." *The Journal of Applied Behavioral Science* 59 (2): 314–336. <https://doi.org/10.1177/00218863211060453>.
- Bakker, A. B., Y. S. Scharp, K. Breevaart, and J. D. De Vries. 2020. "Playful Work Design: Introduction of a New Concept." *The Spanish Journal of Psychology* 23:e19. <https://doi.org/10.1017/SJP.2020.20>.
- Bakker, A. B., and J. Van Wingerden. 2021. "Rumination About COVID-19 and Employee Well-Being: The Role of Playful Work Design." *Canadian Psychology/Psychologie Canadienne* 62 (1): 73–79. <https://doi.org/10.1037/cap0000262>.
- Balven, R., V. Fenters, D. S. Siegel, and D. Waldman. 2018. "Academic Entrepreneurship: The Roles of Identity, Motivation, Championing, Education, Work-Life Balance, and Organizational Justice." *Academy of Management Perspectives* 32 (1): 21–42. <https://doi.org/10.5465/amp.2016.0127>.
- Bandura, A. 1997. *Self-Efficacy: The Exercise of Control*. Macmillan.

- Bateman, T. S., and J. M. Crant. 1993. "The proactive component of organizational behavior: A measure and correlates." *Journal of Organizational Behavior* 14 (2): 103–118. <https://doi.org/10.1002/job.4030140202>.
- Belk, R. W. 1988. "Possessions and the extended self." *Journal of Consumer Research* 15 (2): 139–168. <https://doi.org/10.1086/209154>.
- Bitrián, P., I. Buil, S. Catalán, and S. Hatfield. 2023. "The Use of Gamification Strategies to Enhance Employees' Attitudes Towards E-Training Systems." *International Journal of Management Education* 21 (3): 100892. <https://doi.org/10.1016/j.ijme.2023.100892>.
- Brasel, S. A., and J. Gips. 2014. "Tablets, Touchscreens, and Touchpads: How Varying Touch Interfaces Trigger Psychological Ownership and Endowment." *Journal of Consumer Psychology* 24 (2): 226–233. <https://doi.org/10.1016/j.jcps.2013.10.003>.
- Bresciani, S., K.-H. Huarng, M. K. Malhotra, and A. Ferraris. 2021. "Digital Transformation as a Springboard for Product, Process and Business Model Innovation." *Journal of Business Research* 128:204–210. <https://doi.org/10.1016/j.jbusres.2021.02.003>.
- Bright, L. F., S. B. Kleiser, and S. L. Grau. 2015. "Too Much Facebook? An Exploratory Examination of Social Media Fatigue." *Computers in Human Behavior* 44:148–155. <https://doi.org/10.1016/j.chb.2014.11.048>.
- Brislin, R. W. 1980. "Translation and Content Analysis of Oral and Written Materials." In *Handbook of Cross-Cultural Psychology: Methodology*, edited by H. C. Triandis and J. W. Berry, 389–444. Allyn and Bacon.
- Brown, G., J. L. Pierce, and C. D. Crossley. 2014. "Toward an Understanding of the Development of Ownership Feelings." *Journal of Organizational Behavior* 35 (3): 318–338. <https://doi.org/10.1002/job.1869>.
- Burt, R. S. 2004. "Structural Holes and Good Ideas." *American Journal of Sociology* 110 (2): 349–399. <https://doi.org/10.1086/421787>.
- Chen, I. S. 2020. "Turning Home Boredom During the Outbreak of COVID-19 into Thriving at Home and Career Self-Management: The Role of Online Leisure Crafting." *International Journal of Contemporary Hospitality Management* 32 (11): 3645–3663. <https://doi.org/10.1108/IJCHM-06-2020-0580>.
- Chen, I. S., and J. N. Choi. 2025. "Industry 4.0 Technologies and Green Creativity: Mediating Roles of Playful Work Design and Leisure Crafting." *Journal of Business Research* 188:115103. <https://doi.org/10.1016/j.jbusres.2024.115103>.
- Choi, J. N. 2004. "Individual and Contextual Predictors of Creative Performance: The Mediating Role of Psychological Processes." *Organizational Behavior and Human Decision Processes* 95 (1): 1–21. <https://doi.org/10.1080/10400419.2004.9651452>.
- Chou, P. 2015. "Transformational Leadership and Employee's Behavioral Support for Organizational Change." *European Journal of Business and Management* 7 (3): 110–122.
- Common Wealth Magazine. 2019. "Industry 4.0 Needs to Be Done Well and Fully? 9 Pictures Showing the Pain Points of Digital Transformation of Taiwanese Companies." <https://www.cw.com.tw/article/5093723?template=transfomers>.
- Compeau, D. R., and C. A. Higgins. 1995. "Application of Social Cognitive Theory to Training for Computer Skills." *Information Systems Research* 6 (2): 118–143. <https://doi.org/10.1287/isre.6.2.118>.
- Csikszentmihalyi, M. 1975. *Beyond Boredom and Anxiety. The Experience of Play in Work and Games*. American Sociological Association.
- Cunningham, G. B. 2006. "Examining the Relationships Among Coping with Change, Demographic Dissimilarity and Championing Behaviour." *Sport Management Review* 9 (3): 253–270. [https://doi.org/10.1016/S1441-3523\(06\)70028-6](https://doi.org/10.1016/S1441-3523(06)70028-6).
- De Clercq, D., W. Sun, and I. Belausteguigoitia. 2021. "When is job control most useful for idea championing? Role conflict and psychological contract violation effects." *Journal of Management & Organization* 27(2): 382–396. <https://doi.org/10.1017/jmo.2018.28>.
- Dirks, K. T., L. L. Cummings, and J. L. Pierce. 1996. "Psychological Ownership in Organizations: Conditions Under Which Individuals Promote and Resist Change." In *Research in Organizational Change and Development*, edited by R. W. T. Woodman and W. A. Pasmore, 1–23. JAI Press.
- Dumitrescu, B. I., and A. I. Buzatu. 2020. "Sustainable Businesses Enhanced Through Digital Transformation and Artificial Intelligence in the Context of Industry 4.0." In *6th BASIQ International Conference on New Trends in Sustainable Business and Consumption*, edited by R. Pamfile, V. Dinu, L. Tăchiciu, D. Pleșea, and C. Vasiliu, 324–328. ASE.
- Fasbender, U., and F. H. Gerpott. 2023. "Designing work for change and its unintended side effects." *Journal of Vocational Behavior* 145:103913. <https://doi.org/10.1016/j.jvb.2023.103913>.
- Faupel, S., and S. Süß. 2019. "The Effect of Transformational Leadership on Employees During Organizational Change – An Empirical Analysis." *Journal of Change Management* 19 (3): 145–166. <https://doi.org/10.1080/14697017.2018.1447006>.
- Frank, A. G., L. S. Dalenogare, and N. F. Ayala. 2019. "Industry 4.0 Technologies: Implementation Patterns in Manufacturing Companies." *International Journal of Production Economics* 210:15–26. <https://doi.org/10.1016/j.ijpe.2019.01.004>.
- Frank, K. A. 2000. "Impact of a confounding variable on a regression coefficient." *Sociological Methods & Research* 29 (2): 147–194. <https://doi.org/10.1177/0049124100029002001>.

- Frost, P. J., and C. P. Egri. 1991. "The Political Process of Innovation." In *Research in Organizational Behaviour*, edited by L. L. Cummings and B. M. Staw, 229–295. Vol. 13. Greenwich, CT: JAI Press.
- Fugate, M., G. E. Prussia, and A. J. Kinicki. 2012. "Managing employee withdrawal during organizational change: The role of threat appraisal." *Journal of Management* 38 (3): 890–914. <https://doi.org/10.1177/0149206309352881>.
- Fugate, M., and G. Soenen. 2018. "Predictors and Processes Related to Employees' Change-Related Compliance and Championing." *Personnel Psychology* 71 (1): 109–132. <https://doi.org/10.1111/peps.12235>.
- Gupta, S., Y. Wang, and M. Czinkota. 2023. "Reshoring: A Road to Industry 4.0 Transformation." *British Journal of Management* 34 (3): 1081–1099. <https://doi.org/10.1111/1467-8551.12731>.
- Herceg, I. V., V. Kuč, V. M. Mijušković, and T. Herceg. 2020. "Challenges and Driving Forces for Industry 4.0 Implementation." *Sustainability* 12 (10): 4208. <https://doi.org/10.3390/su12104208>.
- Herscovitch, L., and J. P. Meyer. 2002. "Commitment to Organizational Change: Extension of a Three-Component Model." *Journal of Applied Psychology* 87 (3): 474–487. <https://doi.org/10.1037/0021-9010.87.3.474>.
- Howell, J. M., and C. M. Shea. 2001. "Individual Differences, Environmental Scanning, Innovation Framing, and Champion Behavior: Key Predictors of Project Performance." *Journal of Product Innovation Management* 18 (1): 15–27. <https://doi.org/10.1111/1540-5885.1810015>.
- Ito, A., T. Ylipää, P. Gullander, J. Bokrantz, V. Centerholt, and A. Skoogh. 2021. "Dealing With Resistance to the Use of Industry 4.0 Technologies in Production Disturbance Management." *Journal of Manufacturing Technology Management* 32 (9): 285–303. <https://doi.org/10.1108/JMTM-12-2020-0475>.
- Kanitz, R., K. Gonzalez, S. Berger, M. Reinwald, H. Huettermann, and J. Franczak. 2023. "Am I the Only One? Consequences of Change Championing (A) Symmetry on Group- and Individual-Level Change Outcomes." *Journal of Organizational Behavior* 44 (7): 1048–1065. <https://doi.org/10.1002/job.2683>.
- Kim, H. W., and A. Kankanhalli. 2009. "Investigating User Resistance to Information Systems Implementation: A Status Quo Bias Perspective." *MIS Quarterly* 33 (3): 567–582. <https://doi.org/10.2307/20650309>.
- Koivisto, J., and J. Hamari. 2019. "The rise of motivational information systems: A review of gamification research." *International Journal of Information Management* 45:191–210. <https://doi.org/10.1016/j.ijinfomgt.2018.10.013>.
- Latikka, R., T. Turja, and A. Oksanen. 2019. "Self-Efficacy and Acceptance of Robots." *Computers in Human Behavior* 93:157–163. <https://doi.org/10.1016/j.chb.2018.12.017>.
- Leong, W. Y., J. H. Chuah, and T. B. Tuan. 2020. *The Nine Pillars of Technologies for Industry 4.0*. Institution of Engineering and Technology.
- Lieberman, J. N. 2014. *Playfulness: Its Relationship to Imagination and Creativity*. Academic Press.
- Liu, J., H. Wang, C. Hui, and C. Lee. 2012. "Psychological Ownership: How Having Control Matters." *Journal of Management Studies* 49 (5): 869–895. <https://doi.org/10.1111/j.1467-6486.2011.01028.x>.
- Liu, W., A. B. Bakker, B. T. Tse, and D. Van Der Linden. 2023. "Does Playful Work Design 'Lead to' More Creativity? A Diary Study on the Role of Flow." *European Journal of Work and Organizational Psychology* 32 (1): 107–117. <https://doi.org/10.1080/1359432X.2022.2104716>.
- Lonati, S., and J. N. Wulff. 2024. "Hic Sunt Dracones: On the Risks of Comparing the ITCV with Control Variable Correlations." *Journal of Management*: 01492063241293126. <https://doi.org/10.1177/01492063241293126>.
- Lutfiyya, I. 2021. *Emotional Intelligence as an Antecedent to Innovation Championing Behavior and the Moderating Effects of Cultural Tightness–Looseness*. University of Wisconsin-Whitewater.
- Lysova, E. I., J. Richardson, S. N. Khapova, and P. G. W. Jansen. 2015. "Change-Supportive Employee Behavior: A Career Identity Explanation." *Career Development International* 20 (1): 38–62. <https://doi.org/10.1108/CDI-03-2014-0042>.
- Martin, R. A., and T. Ford. 2018. *The Psychology of Humor: An Integrative Approach*. Academic Press.
- Moghavvemi, S. 2015. "Impact of Perceived Self-Efficacy and Capability to Use IT Innovation on Individual Use Behaviour." *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.2561739>.
- Morewedge, C. K., L. L. Shu, D. T. Gilbert, and T. D. Wilson. 2009. "Bad Riddance or Good Rubbish? Ownership and Not Loss Aversion Causes the Endowment Effect." *Journal of Experimental Social Psychology* 45 (4): 947–951. <https://doi.org/10.1016/j.jesp.2009.05.014>.
- O'Driscoll, M. P., J. L. Pierce, and A. M. Coghlan. 2006. "The Psychology of Ownership: Work Environment Structure, Organizational Commitment, and Citizenship Behaviors." *Group & Organization Management* 31 (3): 388–416. <https://doi.org/10.1177/1059601104273066>.
- Oreg, S. 2003. "Resistance to change: Developing an individual differences measure." *Journal of Applied Psychology* 88 (4): 680–693. <https://doi.org/10.1037/0021-9010.88.4.680>.
- Oreg, S., and Y. Berson. 2011. "Leadership and Employees' Reactions to Change: The Role of Leaders' Personal Attributes and Transformational Leadership Style." *Personnel Psychology* 64 (3): 627–659. <https://doi.org/10.1111/j.1744-6570.2011.01221.x>.
- Padilla-Meléndez, A., A. R. Del Aguila-Obra, and A. Garrido-Moreno. 2013. "Perceived Playfulness, Gender Differences and Technology Acceptance Model in a Blended Learning Scenario." *Computers & Education* 63:306–317. <https://doi.org/10.1016/j.compedu.2012.12.014>.
- Perry-Smith, J. E., and P. V. Mannucci. 2017. "From Creativity to Innovation: The Social Network Drivers of the Four Phases of the Idea Journey." *Academy of Management Review* 42 (1): 53–79. <https://doi.org/10.5465/amr.2014.0462>.

- Petelczyc, C. A., A. Capezio, L. Wang, S. L. D. Restubog, and K. Aquino. 2018. "Play at Work: An Integrative Review and Agenda for Future Research." *Journal of Management* 44 (1): 161–190. <https://doi.org/10.1177/0149206317731519>.
- Pierce, J. L., T. Kostova, and K. T. Dirks. 2001. "Toward a Theory of Psychological Ownership in Organizations." *The Academy of Management Review* 26 (2): 298–310. <https://doi.org/10.2307/259124>.
- Pierce, J. L., T. Kostova, and K. T. Dirks. 2003. "The State of Psychological Ownership: Integrating and Extending a Century of Research." *Review of General Psychology* 7 (1): 84–107. <https://doi.org/10.1037/1089-2680.7.1.84>.
- Proyer, R. T. 2012. "Development and Initial Assessment of a Short Measure for Adult Playfulness: The SMAP." *Personality and Individual Differences* 53 (8): 989–994. <https://doi.org/10.1016/j.paid.2012.07.018>.
- Rogers, E. M. 2003. *Diffusion of Innovations*. 5th ed. Free Press.
- Safdar, M., S. H. Batool, and K. Mahmood. 2021. "Relationship Between Self-Efficacy and Knowledge Sharing: Systematic Review." *Global Knowledge, Memory and Communication* 70 (3): 254–271. <https://doi.org/10.1108/GKMC-11-2019-0139>.
- Sanders, A., C. Elangeswaran, and J. Wulfsberg. 2016. "Industry 4.0 Implies Lean Manufacturing: Research Activities in Industry 4.0 Function as Enablers for Lean Manufacturing." *Journal of Industrial Engineering and Management* 9 (3): 811–833. <https://doi.org/10.3926/jiem.1940>.
- Scharp, Y. S., A. B. Bakker, and K. Breevaart. 2022. "Playful Work Design and Employee Work Engagement: A Self-Determination Perspective." *Journal of Vocational Behavior* 134:103693. <https://doi.org/10.1016/j.jvb.2022.103693>.
- Scharp, Y. S., A. B. Bakker, K. Breevaart, K. Kruup, and A. Uusberg. 2021. "Playful Work Design: Conceptualization, Measurement, and Validity." *Human Relations* 76 (4): 509–550. <https://doi.org/10.1177/00187267211070996>.
- Schneider, B., M. G. Ehrhart, and W. H. Macey. 2013. "Organizational climate and culture." *Annual Review of Psychology* 64:361–388. <https://doi.org/10.1146/annurev-psych-113011-143809>.
- Schon, D. 1963. "Champions for Radical New Inventions." *Harvard Business Review* 41 (2): 77–86.
- Sergeeva, N., and C. Zanello. 2018. "Championing and Promoting Innovation in UK Megaprojects." *International Journal of Project Management* 36 (8): 1068–1081. <https://doi.org/10.1016/j.ijproman.2018.09.002>.
- Simon, M., B. Elango, S. M. Houghton, and S. Savelli. 2002. "The Successful Product Pioneer: Maintaining Commitment While Adapting to Change." *Journal of Small Business Management* 40 (3): 187–203. <https://doi.org/10.1111/1540-627X.00050>.
- Strauss, K., and S. K. Parker. 2014. "Effective and Sustained Proactivity in the Workplace: A Self-Determination Theory Perspective." In *The Oxford Handbook of Work Engagement, Motivation, and Self-Determination Theory*, edited by M. Gagné, 50–71. Oxford University Press.
- Stryker, S., and P. J. Burke. 2000. "The past, present, and future of an identity theory." *Social Psychology Quarterly* 63 (4): 284–297. <https://doi.org/10.2307/2695840>.
- Su, Q. Y., and X. W. Li. 2010. "Age/Gender/Occupation and Mobile Phone Technology Adoption: A Cross-Cultural Study in China (Beijing) and the UK (Portsmouth)." In *2010 International Conference on Management and Service Science*, 1–4. IEEE.
- Surange, V. G., S. U. Bokade, A. K. Singh, and S. N. Teli. 2022. "Prioritization of Roadblocks to Adoption of Industry 4.0 Technologies in Manufacturing Industries Using VIKOR." *Materials Today: Proceedings* 50:2194–2200. <https://doi.org/10.1016/j.matpr.2021.09.448>.
- Tajfel, H., and J. C. Turner. 1986. "The social identity theory of intergroup behavior." In *Psychology of intergroup relations*, edited by S. Worchel and W. G. Austin, 7–24. 2nd ed. Nelson-Hall.
- Van Dyne, L., and J. L. Pierce. 2004. "Psychological Ownership and Feelings of Possession: Three Field Studies Predicting Employee Attitudes and Organizational Citizenship Behavior." *Journal of Organizational Behavior* 25 (4): 439–459. <https://doi.org/10.1002/job.249>.
- van Laar, E., A. J. A. M. van Deursen, J. A. G. M. van Dijk, and J. de Haan. 2020. "Determinants of 21st-Century Digital Skills: A Large-Scale Survey Among Working Professionals." *Computers in Human Behavior* 100:93–104. <https://doi.org/10.1016/j.chb.2019.06.017>.
- Van Vleet, M., and B. C. Feeney. 2015. "Play Behavior and Playfulness in Adulthood." *Social and Personality Psychology Compass* 9 (11): 630–643. <https://doi.org/10.1111/spc3.12205>.
- Venkatesh, V., M. G. Morris, and P. L. Ackerman. 2000. "A Longitudinal Field Investigation of Gender Differences in Individual Technology Adoption Decision-Making Processes." *Organizational Behavior and Human Decision Processes* 83 (1): 33–60. <https://doi.org/10.1006/obhd.2000.2896>.
- Walter, A., K. P. Parboteeah, F. Riesenhuber, and M. Hoegl. 2011. "Championship Behaviors and Innovations Success: An Empirical Investigation of University Spin-offs." *Journal of Product Innovation Management* 28 (4): 586–598. <https://doi.org/10.1111/j.1540-5885.2011.00826.x>.
- Zhang, X., and K. M. Bartol. 2010. "Linking Empowering Leadership and Employee Creativity: The Influence of Psychological Empowerment, Intrinsic Motivation, and Creative Process Engagement." *Academy of Management Journal* 53 (1): 107–128. [10.5465/amj.2010.48037118](https://doi.org/10.5465/amj.2010.48037118).
- Zhang, Y., G. Liu, L. Zhang, S. Xu, and M. W. L. Cheung. 2021. "Psychological Ownership: A Meta-Analysis and Comparison of Multiple Forms of Attachment in the Workplace." *Journal of Management* 47 (3): 745–770. <https://doi.org/10.1177/0149206320917195>.

## Appendix

### ***Playful Use of Technology***

#### Designing Fun

- (1) I look for humor in how I use workplace technologies.
- (2) I approach my use of technology in a playful way.
- (3) I look for ways to make technology-supported tasks more fun for myself and others.
- (4) I use workplace technologies to make my work more engaging and enjoyable.
- (5) I look for ways to make my technology use more enjoyable.
- (6) I use my imagination to make technology-based aspects of my work more interesting.

#### Designing Competition

- (1) I try to set personal records when completing technology-based tasks.
- (2) I keep track of my performance when using workplace technologies.
- (3) I compete with myself when using technology, not because I have to, but because I enjoy it.
- (4) I integrate technological tools into my tasks to create playful challenges for myself.
- (5) I push myself to improve my use of technology, even when it isn't required.
- (6) I approach my technology-based tasks as opportunities to challenge myself.

### ***Original Measure of Playful Work Design\****

#### Designing Fun

- (1) I look for humor in the things I need to do.
- (2) I approach my work in a playful way.
- (3) I look for ways to make tasks more fun for everyone involved
- (4) I approach my tasks creatively to make them more interesting.
- (5) I look for ways to make my work more fun.
- (6) I use my imagination to make my job more interesting.

#### Designing Competition

- (1) I try to set time records in my work tasks.
- (2) I try to keep score in all kinds of work activities.
- (3) I compete with myself at work, not because I have to, but because I enjoy it.
- (4) I try to make my job a series of exciting challenges
- (5) I push myself to do better even when it isn't expected.
- (6) I approach my job as a series of exciting challenges.

\* Scharp, Y. S., Bakker, A. B., Breevaart, K., Kruup, K., & Uusberg, A. (2021). EXPRESS: Playful Work Design: Conceptualization, Measurement, and Validity. *Human Relations*, 00187267211070996.

### **Implementation Efficacy**

Stem:

“I could complete my job using the newly introduced Industry 4.0 technologies (I40T) if . . . ”

- (1) . . . there was no one around to tell me what to do as I go.
- (2) . . . I had never used this type of I40T before.
- (3) . . . I only had the manuals or documentation for reference.
- (4) . . . I had observed someone else using I40T before trying it myself.
- (5) . . . I could contact someone for help if I got stuck.
- (6) . . . someone initially helped me get started with I40T.
- (7) . . . I had plenty of time to complete the task for which I40T was provided.
- (8) . . . I only had the built-in help functions or guidance tools for assistance.
- (9) . . . someone demonstrated how to use I40T before I tried it on my own.
- (10) . . . I had previously used similar I40T applications to perform work tasks.

### **Psychological Ownership of Innovation (I40T)**

#### **Instruction**

“The following questions deal with the sense of ownership that you feel for Industry 4.0 technologies (I40T) that you use at work. Please indicate the degree to which you personally agree or disagree with the following statements.”

- (1) This is my technology.
- (2) I sense that this technology is our technology.
- (3) I feel a very high degree of personal ownership for this technology.
- (4) I sense that this is my innovation.
- (5) This is our innovation.
- (6) Most of the people that work with this technology feel as though they own it.
- (7) It is hard for me to think about this technology as mine. (*reverse-coded*)

#### **Innovation Championing**

- (1) This employee spoke positively to others about the use of Industry 4.0 technologies in the workplace.
- (2) This employee tried to overcome coworkers’ resistance toward the use of Industry 4.0 technologies.

This employee embraced the new technologies and actively “sold” their value to others.