



# Industry 4.0 technologies and green creativity: Mediating roles of playful work design and leisure crafting

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## ABSTRACT

Adopting conservation of resources (COR) theory, we propose that Industry 4.0 technologies (I40Ts) perceived as useful and easy to use by employees may supply workplace resources. These extra resources may promote the proactive work/non-work activities of employees for further resource acquisition, which predicts their green creativity, particularly for those with strong green personal values. We empirically validate our propositions using three-wave, multi-source data collected from 282 employees and their managers. Results confirm the positive relationship between the I40T perceptions (usefulness and ease of use) and green creativity, and this relationship is mediated by playful work design and leisure crafting. Additionally, the green personal values of employees amplify the indirect effects of I40T perceptions on green creativity. Drawing on COR, this study reveals the way employees can gain extra resources for work- and non-work-related proactivity in the context of innovation implementation.

## 1. Introduction

Increasing adaptive demands from disruptive changes highlight the significance of adopting and implementing innovations (Mubarik et al., 2021). A dominant view on innovation implementation underscores the resource-intensive nature of such efforts, often exhausting workplace resources, thereby causing burnout and fatigue among employees (Chung et al., 2017). Moreover, studies based on conservation of resources (COR) theory (Hobfoll, 1989) neglect the resource implications of innovations with their prevailing focus on work-related resources (e.g., job autonomy), social resources (e.g., leader and coworker support), and personal resources (e.g., resilience and optimism). Unlike the proven benefits of these workplace resources toward employee well-being and performance (Hobfoll et al., 2018), the resource implications of innovations remain to be negative or, at best, unclear. This unilateral positioning or the neglect of potential resources associated with workplace innovation can be limiting. It unduly overlooks the possibility of innovation functioning as a source of new workplace resources that can be mobilized by employees.

In this study, we challenge the extant view and examine the potential resource gain, rather than resource depletion, from workplace innovations that energize the proactivity and extra contribution of

employees. To explore this possibility, we focus on a set of recently emerged advanced technologies, often referred to as Industry 4.0 technologies (I40Ts) (e.g., Bai et al., 2020; Feroz et al., 2021). Industry 4.0 refers to “the fourth industrial revolution applying the principles of cyber-physical systems (CPS), internet and future-oriented technologies, and smart systems with enhanced human–machine interaction paradigms” (Sanders et al., 2016, p. 816). For example, various human resource functions are now supported by artificial intelligence for recruitment, human resource chatbots for onboarding, and blockchain use for verifying employee backgrounds (Aiswarya et al., 2023). Deploying intelligent robots to perform tedious and dangerous tasks or providing healthcare services via virtual reality reduces injuries among employees and improves their well-being (Warland, 2023; Wilkins, 2018). Empirical evidence demonstrates that I40Ts enhance employee performance and promote learning by assisting and enriching task activities, which can then elicit positive reactions from the employees (e.g., Tapia-Andino & Barcellos-Paula, 2023; Tortorella et al., 2023).

Accordingly, despite the often-observed employee resistance to the implementation of I40Ts (e.g., Karadayi-Usta, 2019; Surange et al., 2022), some employees may appreciate its positive sides. As COR theory suggests, a target object may be perceived as a resource that can be utilized when individuals find them beneficial (e.g., Chen & Fellenz,

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2023). To theorize this possibility, we focus on perceived usefulness and ease of use as critical factors that motivate employees to accept and use a new technology such as I40T (cf., technology acceptance model [TAM], Davis, 1989; King & He, 2006). These innovation perceptions are used to explain individual acceptance and rejection of various forms of technological innovations in diverse contexts (for recent reviews, see Al-Qaysi et al., 2020; Granić & Marangunić, 2019). When employees evaluate I40Ts as useful and easy to use, they may perceive them as newly available resources that can be capitalized on for their benefit. Drawing on COR theory, we propose that positive perceptions of I40Ts may supply additional resources that enable the proactive behavior of employees, thereby promoting their creative performance.

We focus on a particular form of employee creativity targeted at green issues in the workplace. This focus helps address the increasing emphasis on environmental management given the urgent climate crises and the global emergence of environmental, social, and governance (ESG) management (Feroz et al., 2021). This trend supports and likely stimulates the bottom-up efforts of employees toward environmentally friendly actions, such as green creativity. Inspired by the crucial function of I40Ts in performance and business optimization, recent studies have called for the exploration of their potential contribution to sustainability and environmental issues (e.g., Bai et al., 2020; Mubarak et al., 2021). Organizations have started to integrate I40Ts into their green effort. These theoretical and practical impetuses urge researchers to investigate domain-specific creativity targeted at environmental issues (Riva et al., 2021). The environmental benefit of I40Ts is also highlighted as a key reason for their implementation (Ministry of Economic Affairs, 2023). We investigate the ways and conditions through which I40Ts improve the environmental performance of employees in the form of green creativity. Accordingly, we ascertain the potential micro-level mechanisms that account for the benefits of I40Ts to the environmental management of a firm suggested in recent studies (Bai et al., 2020; Mubarak et al., 2021).

To elaborate on the mediating mechanism, we theorize that positive innovation perceptions energize the proactive behaviors of employees that ultimately promote their green creativity. Our focus on employee proactivity extends the prevailing focus on the passive role of employees in responding to top-down innovation initiatives to fulfill associated demands (Cimini et al., 2020). Drawing on COR view that individuals are strategic and proactive in investing available resources across multiple domains of life (Hobfoll et al., 2018), we propose that employees who perceive I40Ts as useful and easy to use likely initiate proactive modifications in their work and non-work activities. Specifically, we isolate playful work design and leisure crafting as proactive behaviors that further generate personal resources needed for creativity (Anderson et al., 2014; Scharp et al., 2019). In effect, this study examines how I40T perceptions can foster the green creativity of employees through proactive mechanisms within (via playful work design) and outside (via leisure crafting) the work context. The current framework extends the innovation literature and provides new insights into the role of positive innovation perceptions in shaping employees' proactive behavior and creativity beyond mere acceptance of the innovation.

Finally, we identify the boundary condition in which I40T perceptions enhance green creativity through proactive work and non-work activities. The effect of I40T perceptions on employees' acceptance and use may be straightforward and thus may not invite the consideration of moderators. However, examining the effects of innovation perceptions on outcomes other than innovation-targeted behavior requires considering moderating contingencies that activate or amplify resource-channeling processes. Given that individuals respond to the same situation differently and exhibit distinct behaviors based on personal values (Schwartz, 1992), I40T perceptions likely promote green creativity when employees hold corresponding personal values. Existing studies report that environmental values and green intrinsic motivation are crucial for green creativity (Li et al., 2020). In this regard, the implications of I40T perceptions on green creativity may be shaped by

green personal values because the effect of available resources may be strengthened when personal values are congruent with the way resources are utilized (Morelli & Cunningham, 2012). Thus, we identify green personal values as a favorable contingency that may amplify the effect of I40T perceptions on green creativity via playful work design and leisure crafting.

In summary, this study advances several theoretical and practical contributions to the management literature. First, we explore the workplace implications of emerging technologies in shaping employee proactivity and green creativity. Existing studies discover that innovation perceptions or innovation-related contexts contribute to job satisfaction (Park et al., 2016), affective commitment (Demircioglu, 2023), work motivation (Fernandes et al., 2016), and job performance (Isgiyarta et al., 2019). These findings suggest that innovation perceptions have broader implications beyond innovation acceptance. We enrich this literature by examining the effects of employees' positive I40T perceptions on their proactive behaviors in the work (playful work design) and non-work domains (leisure crafting) and, ultimately, their green creativity.

Second, the current framework elaborates on how personal values channel the deployment of extra resources from I40T perceptions toward a specific form of creativity (i.e., green creativity). The role of green personal values in shaping green creativity during I40T implementation enriches COR theory in the context of organizational innovation. Previous studies focus on the role of positive perceptions of an innovation in shaping its acceptance and use and overlook boundary conditions (Al-Qaysi et al., 2020; Davis, 1989; Granić & Marangunić, 2019). Answering whether and how innovation perceptions may contribute to non-innovation-related outcomes, such as the green creativity of employees, necessitates a consideration of moderating contingencies.

Third, this study offers timely practical suggestions for organizations encountering rapid technological changes characterized by digital transformation and I40Ts while trying to satisfy the increasing demand for environmentally friendly business practices, such as ESG management. The findings provide insights into how organizations can implement I40Ts to improve employee proactivity and green creativity and thereby enhance their green and operational performance. By challenging the common assumption that innovations primarily create resource demands and instead focusing on the potentially resource gains from innovations, this study advances the view that innovation perceptions are not only a prerequisite for acceptance. They also enhance green performance through proactive mechanisms, such as playful work design and leisure crafting.

## 2. Literature review and theoretical framework

### 2.1. Resource availability from positive I40T perceptions

The core tenet of COR theory states that resource conservation and acquisition represent a basic human nature; that is, individuals naturally maintain, protect, and acquire resources for their disposal (Hobfoll, 1989). In view of this theory on human motivation, available resources that can be invested for further resource acquisition constitutes a critical driver of human behavior (Hobfoll et al., 2018). *Perceived resource availability* reflects individuals' cognitive evaluation of the number of resources they can approach and the degree to which they can dispose them to perform successfully in a given domain (Hochwarter et al., 2007). We argue that positive I40T perceptions may represent a resource that can assist individuals to achieve workplace goals, thereby promoting their sense of resource availability (Halbesleben et al., 2014). From a resource perspective, individuals who perceive I40Ts as useful and easy to use may recognize extra resources at their disposal that can be utilized for further resource gain (Hobfoll et al., 2018).

In contemporary organizations where advanced technologies are continually introduced, employees may evaluate these technologies as

unwanted job demands that increase their workload or as extra resources that assist their goal achievement and flexible adaptation (job demands–resources model, Demerouti et al., 2001). In view of COR theory, we propose that when employees evaluate I40Ts as useful and easy to use, they may appraise them as resources and thus perceive resource availability at work. According to TAM (Davis, 1989), *perceived usefulness* is “the degree to which a person believes that using a particular system would enhance his or her job performance,” whereas *perceived ease of use* is “the degree to which a person believes that using a particular system would be free of effort” (p. 320). Employees with these I40T perceptions may recognize additional resources and opportunities.

## 2.2. I40T perceptions and green creativity

*Creativity* refers to the generation of novel and useful ideas and solutions (Amabile & Mueller, 2008). It relies on the identification of problem, information search, and generation of alternative ideas and solutions (Reiter-Palmon & Illies, 2004), which require the investment of cognitive resources (Chae & Choi, 2019). In view of COR theory (Hobfoll, 1989), positive I40T perceptions represent available resources, which can be deployed to proactive, extra-role behaviors. When recognizing the usefulness of I40Ts, individuals may view them as an additional support (Halbesleben et al., 2014), thereby perceiving a great resource pool. Similarly, in finding I40Ts easy to use, individuals can conserve resources in figuring out how to use them (Saadé, 2007). As a result, individuals can direct saved resources to other aspects of work, such as creative problem solving (Chae & Choi, 2019).

We propose that the resource availability from I40T implementation promotes a particular form of creativity, that is, *green creativity* or “the development of new ideas about green products, green services, green processes, or green practices that are judged to be original, novel, and useful” (Chen & Chang, 2013, p. 113). I40T implementation may increase the green creativity of employees because it is regarded as an organizational effort to promote sustainable, pro-environmental practices (e.g., De Giovanni & Cariola, 2020; Mubarak et al., 2021). Studies show that green creativity improves firm performance in a pro-environmental and sustainable fashion (Mittal & Dhar, 2016).

Although I40T application was initially geared toward optimizing business operations to improve performance (Saucedo-Martínez et al., 2018), it is increasingly serving the purpose of promoting sustainable, pro-environmental, and green practices (De Giovanni & Cariola, 2020; Mubarak & Petraite, 2020). For example, some companies use blockchain to create green supply chain practices and save in material consumption during production processes (Mubarak et al., 2021). Other companies use I40T to implement green process innovations and reduce unnecessary operations (Liu & De Giovanni, 2019). Various advanced technologies comprising I40Ts, such as virtual reality, 3D printing, and blockchain, tend to stimulate the interest of users and assist their creative engagement, thereby promoting idea generation (Liu & Zhu, 2021; Zhou and Lee, 2024). Empirical studies also demonstrate the benefits of implementing these I40Ts toward environmentally friendly ideas and green innovation (Li, 2021; Mamica, 2018). Considering these positive effects of I40T implementation on green innovation, I40Ts may enable employees' green creativity. In sum, employees who gain additional available resources from positive I40T appraisals may engage in proactive green efforts.

**Hypothesis 1(H1).** *I40T perceptions (H1a: perceived usefulness, H1b: perceived ease of use) are positively related to green creativity.*

## 2.3. Playful work design as a work-related mediating mechanism

Although resources gained from I40Ts can directly affect employee creativity, we also consider plausible intervening mechanisms in the work and non-work domains to further elaborate on the function of positive innovation perceptions. In the work domain, we propose playful

work design as a potential mediator. *Playful work design* accounts for individuals' proactivity in changing their experiences in work activities, thereby fostering enjoyment and challenges from their work (Bakker et al., 2020; Scharp et al., 2019). Management research on play underscores organizational interventions to provide playful work experiences for employees (Tews et al., 2014; Tsaor, Hsu, & Lin, 2019; Westat et al., 2016). Yet, whether and how employees proactively generate playful experiences at work by themselves are unclear (Bakker et al., 2020).

Playful work design captures the proactive work strategies of individuals to developing playful experiences characterized by two key elements (Csikszentmihalyi, 1975; Parker & Collins, 2010). First, individuals may engage in ludic plays through which they can make their work activities fun (i.e., designing fun, Barnett, 2007). Ludic play, such as roleplay and joking, involves the use of humor, imagination, and fantasy (Robert & Wilbanks, 2012). Designing fun provides entertainment and amusement during work activities, resulting in positive affective experiences (Lieberman, 2014; Robert & Wilbanks, 2012). Second, individuals engage in agonistic play through which they create internal competitions (i.e., designing competition, Mainemelis & Ronson, 2006). Agonistic play, such as setting goals, creating challenges, and pushing oneself to the limit, involves the use of agonistic framing and self-competition (Csikszentmihalyi, 1975; Scharp et al., 2021). Designing competition generates pleasure via strengthening one's skills and task mastery (Howe, 2008). Accordingly, individuals performing playful work design take proactive initiatives to make their work activities engaging, entertaining, and challenging through fun and competition (Bakker et al., 2020).

In view of COR theory (Hobfoll, 1989), positive I40T perceptions may supply additional resources for employees to redesign their work to be enjoyable (Hobfoll et al., 2018). Specifically, humans naturally seek playful activities to balance challenges at work and the level of resources such as skills to further improve their sense of control and relief (e.g., Csikszentmihalyi, 1975; DesCamp & Thomas, 1993). When perceiving I40Ts as easy to use and useful, individuals may be intrinsically motivated to engage in playful work design owing to additional resources that can be used for reshaping work experiences as playful. Moreover, playful work design enables employees to acquire additional resources, such as emotional resources (e.g., enjoyment and positive affect, Lieberman, 2014; Robert & Wilbanks, 2012), personal resources (e.g., self-efficacy, Csikszentmihalyi, 1975; Scharp et al., 2021), and work-related resources (e.g., task skills, Howe, 2008). Given that individuals are inherently motivated to acquire additional resources, especially when they perceive having resources available at their disposal, resource availability based on I40T perceptions may urge employees to invest their resources in playful work design.

**Hypothesis 2(H2).** *I40T perceptions (H2a: perceived usefulness, H2b: perceived ease of use) are positively related to playful work design.*

Playful work design may translate the effect of I40T perceptions into green creativity. Playfulness increases work-related flow and allow employees to shift their attention flexibly to perform creatively (Liu et al., 2023). Play facilitates creativity because it enables individuals to be imaginative and juggle different possibilities (Lieberman, 2014; Proyer et al., 2019). It is a stimulus-seeking behavior that individuals use to increase enjoyment and challenge by raising their level of cognitive and emotional stimulation (Petelczyc et al., 2018). Through playful work design, employees may not only experience enjoyment and self-competition at work but also shift their focus and seek broad stimuli, which promote creativity at work (Yeh, 2015).

We propose that playful work design may contribute to green creativity in contemporary organizations that emphasize pro-environmental and sustainable performance as a core management priority (Mittal & Dhar, 2016). In the context of environmental management, individuals require various resources to perform pro-environmental behaviors such as green creativity. For example, Carter (2011) found that positive emotions foster employees' environmentally responsible creative

behaviors. Thus, green creativity can be promoted when employees adopt playful work design that generates psychological resources needed for creativity, such as positive affect and humor (Li et al., 2019). Moreover, a recent study reveals that personal attributes such as self-efficacy facilitate employees to engage in green creativity (Farooq et al., 2022). Therefore, employees who have accrued self-efficacy and improved skills by designing competition likely cultivate and present new green ideas (Anderson et al., 2014). In other words, playful work design contributes to producing needed resources for green creativity, thereby functioning as a mechanism through which I40T perceptions boost green creativity.

**Hypothesis 3 (H3).** (H3). *Playful work design mediates the relationship between I40T perceptions (H3a: perceived usefulness, H3b: perceived ease of use) and green creativity.*

#### 2.4. Leisure crafting as a non-work-related mediating mechanism

The current framework also identifies how workplace innovation shapes the non-work activities of employees to ultimately affect their green creativity. To this end, we focus on leisure crafting, which refers to individuals' proactive pursuit of personal leisure activities targeted at goal setting, human connection, and learning (Petrou & Bakker, 2016). Specifically, through leisure crafting, (a) individuals may strive to set and pursue new goals, becoming intrinsically motivated and pushing their limit (Petrou & Bakker, 2016). (b) They may connect with people outside the work context, improving their interpersonal relationships and broadening their social networks (Brajša-Žganec et al., 2011). (c) They may acquire new knowledge and skills, continuously learning and developing themselves (Berg et al., 2010; Sonnentag & Fritz, 2014).

Studies show that leisure crafting helps individuals thrive in work and personal domains by providing them with psychological, social, and intellectual resources (Chen, 2020). On the basis of COR theory (Hobfoll et al., 2018), we propose that resource availability from I40Ts may increase leisure crafting because individuals invest available resources across domains to acquire additional ones (Chen & Fellenz, 2020; Kruglanski et al., 2013). When perceiving a new technology as useful during their work, individuals find ways to use or apply the technology in their non-work domain as well, which can enhance their performance in the work domain (Bauwens et al., 2020). Employees engage in this cross-domain application of workplace innovation particularly when they perceive it as easy to use, thereby boosting their sense of efficacy (Al-Qaysi et al., 2020; Granić & Marangunić, 2019). This cross-domain flow of resources suggests that I40T perceptions may motivate employees to invest newly available resources toward making their personal lives meaningful. Empirical studies suggest that the perceived usefulness and ease of use of a technology promote the learning behavior of employees and their connection with others (Luo & Du, 2022). Likewise, positive I40T perceptions may fuel leisure crafting among employees to set new goals, meet new people, and pursue learning through non-work activities.

**Hypothesis 4(H4).** *I40T perceptions (H4a: perceived usefulness, H4b: perceived ease of use) are positively related to leisure crafting.*

Increased leisure crafting may mediate the relationship between I40T perceptions and green creativity. Similar to playful work design, leisure crafting can mobilize individuals to shift their attention freely and broaden their perspective (Liu et al., 2023). By crafting their personal life, individuals can acquire cognitive and emotional resources conducive to creativity, which is a resource-intensive performance domain (Chae & Choi, 2019). Specifically, through leisure crafting, individuals learn new things, enabling them to look at tasks or problems in various ways (Soroohan, 1993). Leisure crafting expands the informal, personal social network of individuals, allowing them to draw on different ideas from others (Perry-Smith & Mannucci, 2017). Individuals can encounter new challenges and opportunities while pursuing new

goals that may allow them to think out of the box to solve problems (Latham, 2007). In sum, leisure crafting promotes the acquisition of personal, relational, and intellectual resources, which may inspire creative endeavors at work (Chen, 2020).

Although the contribution of leisure crafting toward green creativity beyond its contribution to general creativity is yet to be examined, we expect such a domain-specific effect to be plausible. For example, a recent study suggests that the role of leisure crafting may extend to environment management. Chen and Wu (2022) revealed that leisure crafting enables employees to make positive environmental impacts beyond what is required at work, perhaps because it supplies employees additional resources to behave responsibly and contribute to the environment while working. In this vein, leisure crafting can boost employees' positive, constructive energy and motivate their green creativity at work. Accordingly, leisure crafting may fuel employees to perform green creativity at work, which is highly valued and encouraged in contemporary organizations and society in general.

**Hypothesis 5(H5).** (H5). *Leisure crafting mediates the relationship between I40T perceptions (H5a: perceived usefulness, H5b: perceived ease of use) and green creativity.*

It is important to note that playful work design and leisure crafting contribute to green creativity in distinct yet complementary ways. Playful work design enhances green creativity in the workplace by fostering innovation and resourcefulness through engaging in fun, task-based challenges, and encouraging employees to devise creative solutions for environmental objectives within their work tasks. Conversely, leisure crafting nurtures green creativity from a broader perspective by enabling employees to develop diverse skills, build strong social networks, and enhance self-motivation in their personal lives. These personal gains can then be applied to pro-environmental initiatives at work. Together, these two constructs provide unique and synergistic pathways through which I40T promotes green creativity, spanning both work and non-work domains.

#### 2.5. Green personal values as a moderating contingency

Thus far, we specify playful work design and leisure crafting as intervening mechanisms that explain the relationship between I40T perceptions and green creativity. This unfolding effect of resource availability from I40Ts may not occur for everyone, and some employees may not exhibit the proposed effect. Further drawing on the COR literature (e.g., Halbesleben et al., 2014; Morelli & Cunningham, 2012), we identify personal values as a potential boundary condition for the current mediation hypotheses. Personal values refer to individuals' beliefs regarding what is right and desirable and how they fundamentally see the world and themselves (Schwartz, 1992). They are relatively stable and thus influence the judgments and behavioral choices of individuals over time and across different contexts (Morgan et al., 2010). The effect of resources on behavior differs among individuals because each person holds different values, affecting how they perceive and use resources (Morelli & Cunningham, 2012). Considering the strategic nature of resource investment (Hobfoll et al., 2018), individuals likely allocate available resources toward promoting what they perceive as important and valuable.

In the current model, we isolate green personal values as a potential moderator because they reflect individuals' conviction in environmental sustainability and willingness to act accordingly (Dumont et al., 2017). As suggested by COR theory (Hobfoll, 1989), green personal values may accentuate the allocation of available resources toward pro-environmental, green activities. The additional resources accrued from playful work design and leisure crafting, such as positive affect, task motivation, increased skills and efficacy, and diverse interpersonal relations, may be channeled to activities that are consistent with the personal values and convictions of individuals (e.g., Berg et al., 2010; Scharp et al., 2019). Thus, green personal values likely amplify the

contribution of available resources gained from I40T perceptions to green creativity through playful work design and leisure crafting. These considerations lead to the following moderated mediation hypotheses.

**Hypothesis 6(H6).** *Green personal values positively moderate the indirect relationships between I40T perceptions (H6a: perceived usefulness, H6b: perceived ease of use) and green creativity mediated by playful work design.*

**Hypothesis 7(H7).** *(H7). Green personal values positively moderate the indirect relationships between I40T perceptions (H7a: perceived usefulness, H7b: perceived ease of use) and green creativity mediated by leisure crafting.*

Fig. 1 summarizes the overall theoretical framework of our study, which is empirically validated by multi-wave, multi-source field data.

### 3. Method

To test the current hypotheses, we adopted a multi-wave, multi-source design and collected field data from employees and their managers in Taiwan. To test the current hypotheses, we adopted a multi-wave, multi-source design and collected field data from employees and their managers in Taiwan. The Taiwanese government has been promoting I40Ts across industries and is striving to develop its own I40T program, referred to as Productivity 4.0, leveraging its globally competitive capabilities and talents in advanced electronics, semiconductor, and information technologies (Sci-Tech Vista, 2018). This nationwide effort aims to optimize the smart supply chain ecosystem for leading industries in Taiwan, which is expected to stimulate overall economic growth and competitive advantages. In recent years, the Taiwanese government has urged companies to explore ways to utilize I40Ts to support ESG management (Ministry of Economic Affairs, 2023), seeking a leading position in ESG on a global scale. Consequently, green issues have been identified as one of the essential goals for companies implementing I40Ts. Therefore, Taiwanese employees tend to perceive I40Ts as a firm's effort to increase environmental performance along with operational efficiency. These trends and initiatives render Taiwan an appropriate setting for validating the current research framework.

We conducted data collection in collaboration with a survey company in Taiwan. The company assisted us in reaching participants and obtaining their consent. Before participation, we informed the participants about the anonymity and confidentiality of their responses and reminded them that participation was voluntary and that they could withdraw from the study at any time.

We administered questionnaires at three different time points. At Time 1, participants reported their perceptions of the usefulness and ease of use of I40Ts, green personal values, and demographic information. We initially distributed the Time 1 survey to 711 employees and received 535 usable questionnaires (response rate = 75 %). Two weeks later, at Time 2, we distributed the second questionnaire to the 535 participants who completed the Time 1 survey. This questionnaire

assessed the extent to which participants engaged in playful work design and leisure crafting. A total of 308 usable questionnaires were returned (response rate = 58 %). Finally, two weeks after Time 2, we collected the Time 3 data. At this final stage, we asked the managers of the 308 employees who completed the Time 1 and Time 2 surveys to evaluate the green creativity of these employees. We obtained usable responses from 282 managers (response rate = 92 %).

Due to some sample attrition over the three waves of data collection, we checked for systematic bias that might explain the pattern of non-responses in our sample. A series of paired-sample t-tests were conducted, all of which were nonsignificant, indicating that non-response bias did not significantly affect the measures and findings in our study.

The final analysis sample comprised 282 participants and their managers who provided three-wave, multi-source data. Most of the participating employees were female (60.6 %). The age distribution of the employees was as follows: 21–30 years old (33 %), 31–40 years old (42.21 %), and 41–50 years old (16.3 %). Regarding education levels, participants held a high school/vocational diploma (14.9 %), a bachelor's degree (67.7 %), or a master's degree (14.5 %). The participants worked primarily in management/administration (39 %), followed by engineering/technology (22.7 %) and manufacturing/operations (15.6 %). Their work experience ranged from 1–3 years (12.1 %), 3–5 years (14.9 %), 5–7 years (21.6 %), 7–9 years (19.5 %), to more than 10 years (24.1 %). The majority of the managers were male (61.7 %), with the most common age range being 41–50 years (40.3 %), followed by 51–60 years (32.5 %). Most managers reported holding a bachelor's degree (75.3 %) or a master's degree (16.2 %).

#### 3.1. Measures

We collaborated with a professional translation company to perform a back-translation of all the survey items from English to Mandarin, ensuring the original meaning of the items was maintained (Brislin, 1980). We also retained the original response format for each measure, as changes in response scales could lead to arbitrary changes in response patterns (Johns, 2005). Adjusting the response format of the scales requires a convincing justification (Guy & Norvell, 1977). Since there is no methodological basis in the literature necessitating such changes for our current measures, we used the original five- or six-point Likert-type scales.

At the beginning of the survey, we clarified the conceptualization of Industry 4.0 and the related technologies that represent I40Ts to ensure participants developed a shared understanding of the construct. We provided the following explanation: "Industry 4.0 refers to the fourth industrial revolution, which applies the principles of cyber-physical systems, the internet, future-oriented technologies, and smart systems with enhanced human-machine interaction paradigms. I40Ts are associated with technologies such as artificial intelligence, blockchain, the

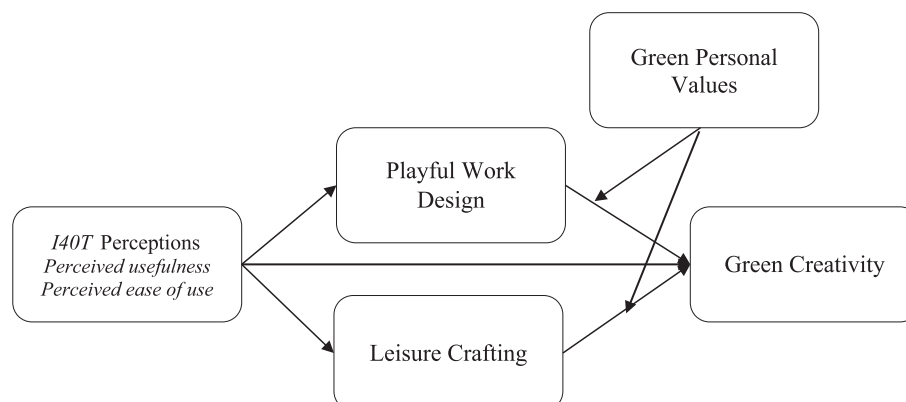


Fig. 1. Research model.

Internet of Things, big data, virtual reality, and simulation.”

**Perceived usefulness and ease of use of I40Ts (Time 1).** We assessed participants' perceptions of I40Ts using the measures developed by Choi et al. (2011). To align with the current research context, we modified the items by replacing “the innovation” with “I40Ts.” For example, in the perceived usefulness dimension, we revised the original item “The innovation would enable me to accomplish my tasks more effectively” to “I40Ts would enable me to accomplish my tasks more effectively.” Similarly, for the perceived ease of use dimension, we changed “I find it easy to use the innovation in my job” to “I find it easy to use I40Ts in my job.” The I40T perception items were evaluated using a six-point Likert scale (1 = Strongly disagree; 6 = Strongly agree).

We evaluated the two dimensions of innovation perception using three items each for perceived usefulness ( $\alpha = 0.96$ ) and perceived ease of use ( $\alpha = 0.94$ ). Previous studies have revealed high correlations between these two dimensions, often finding them empirically indistinguishable (e.g., Choi et al., 2011; King & He, 2006). In our study, the correlation between these dimensions was also quite high ( $r = 0.95$ ,  $p < 0.001$ ). Consequently, we followed the practice of existing studies and merged these two dimensions into a single scale comprising six items ( $\alpha = 0.97$ ; CR = 0.98; AVE = 0.89;  $\chi^2(df = 9) = 19.50$ ,  $\chi^2/df = 2.17$ ; CFI = 0.99; NFI = 0.99; SRMR = 0.01) to measure I40T perceptions representing both usefulness and ease of use. This single-factor measurement model performed significantly better than the two-factor model ( $\Delta\chi^2(\Delta df = 1) = 656.48$ ,  $p < 0.001$ ), which provided a worse model fit ( $\chi^2(df = 10) = 675.98$ ,  $\chi^2/df = 67.60$ ; CFI = 0.72; NFI = 0.72; SRMR = 0.57).

Given the very high correlation between the two perceptions and the adequacy of the single-factor model, we tested the current hypotheses using a unified variable of I40T perceptions that combines I40T usefulness and ease of use into a single construct. Despite this empirical testing approach, our original hypotheses treated I40T usefulness and ease of use as separate dimensions of innovation perceptions. Consequently, we conducted the same hypothesis-testing analyses for the usefulness and ease of use dimensions separately. The results are presented in the Online Supplemental Materials (OSM). As shown in the OSM, the analysis results were identical for both I40T usefulness and ease of use, confirming the findings of the current hypothesis testing based on the single, combined measure of I40T perceptions.

**Green personal values (Time 1).** Participants' green values were assessed using a scale developed by Steg et al. (2005). This scale contains five items ( $\alpha = 0.92$ ; CR = 0.94; AVE = 0.76;  $\chi^2(df = 2) = 4.33$ ,  $\chi^2/df = 2.16$ ; CFI = 0.99; NFI = 0.99; SRMR = 0.01). A sample item is, “I feel personally obliged to save as much energy as possible.” Responses for these items were measured on a five-point Likert scale (1 = Strongly disagree; 5 = Strongly agree).

**Playful work design (Time 2).** Playful work design was measured using the scale developed by Scharp et al. (2021), which includes two dimensions: designing fun and designing competition, each measured with six items. Sample items for these dimensions are “I approach my work in a playful way” (designing fun) and “I try to make my job a series of exciting challenges” (designing competition). Participants rated these items on a five-point Likert scale (1 = Never; 5 = Very often). Consistent with prior studies (Scharp et al., 2021), designing fun and designing competition are highly correlated ( $r = 0.89$ ,  $p < 0.001$ ) and may represent a single overarching construct. Therefore, we combined the two subscales into a single scale with 12 items ( $\alpha = 0.94$ ; CR = 0.95; AVE = 0.65;  $\chi^2(df = 20) = 72.97$ ,  $\chi^2/df = 3.65$ ; CFI = 0.97; NFI = 0.96; SRMR = 0.03) representing playful work design.

**Leisure crafting (Time 2).** We used the leisure crafting scale developed by Petrou and Bakker (2016), which contains nine items ( $\alpha = 0.95$ ; CR = 0.96; AVE = 0.70;  $\chi^2(df = 9) = 32.24$ ,  $\chi^2/df = 3.58$ ; CFI = 0.98; NFI = 0.98; SRMR = 0.02). Sample items include, “I try to build relationships through leisure activities” and “My leisure time is a chance for me to grow and develop.” Responses were measured on a five-point Likert scale (1 = Not at all; 5 = Very much).

It is important to note that leisure crafting and playful work design are conceptually and operationally distinct. Leisure crafting involves activities that are leisure-based and target non-work-related purposes such as goal-setting, human connection, and personal growth and development in private life domains. In contrast, playful work design involves work-based activities aimed at shaping individuals' work experiences in a playful manner. Therefore, the concepts and measures of leisure crafting and playful work design are fundamentally different and do not overlap in nature.

**Green creativity (Time 3).** We instructed the managers to evaluate the green creativity of participants using a six-item measure ( $\alpha = 0.91$ ; CR = 0.94; AVE = 0.72;  $\chi^2(df = 5) = 13.97$ ,  $\chi^2/df = 2.80$ ; CFI = 0.99; NFI = 0.98; SRMR = 0.02) adopted from Chen and Chang (2013). Sample items include, “This employee suggests new ways to achieve environmental goals” and “This employee promotes and champions new green ideas to others.” Managers rated these items on a five-point Likert scale (1 = Strongly disagree; 5 = Strongly agree).

**Control variables.** Following the recommendation for including control variables that may affect the proposed relationship (Bernierth & Aguinis, 2016), we identified and included demographic characteristics such as age, gender, and education, which are significant in explaining individual creativity (Binnewies et al., 2008; Fasko, 2001). Additionally, we controlled for employees' professional characteristics, including tenure and occupation, which have implications for creativity (Liu et al., 2016).

Furthermore, we controlled for work overload reported by employees due to its potential impact on their workplace resources and creative performance (Pluta & Rudawska, 2021). Given the central role of employee resources in our theoretical framework based on COR theory, including a resource-related factor is crucial to reduce confounding from alternative explanations. We assessed perceived work overload using a four-item index ( $\alpha = 0.90$ , Schlotz et al., 2004) that evaluated both quantitative and qualitative aspects of overload, with sample items such as “I constantly work under increasing time pressure” and “I frequently feel that I am working at the limit of my capabilities.”

#### 4. Results

Before conducting hypothesis-testing analyses, we performed confirmatory factor analysis (CFA) to verify the empirical distinctiveness of the hypothesized measurement model. The CFA of the current data, comprising five study variables measured by 38 items, included 703 parameters to be estimated [ $38 \times (38-1)/2$ ], which was much larger than the sample size (i.e., 282 employees). Given the recommended sample-to-parameter ratio of 5:1 (Bentler & Chou, 1987), we employed the item parcel technique. By creating two item parcels for each of the five variables, we reduced the number of parameters for CFA to 45 [ $10 \times (10-1)/2$ ] (Bagozzi & Edwards, 1998).

The five-factor model exhibited an acceptable fit ( $\chi^2(df = 29) = 107.87$ ,  $\chi^2/df = 3.72$ ; CFI = 0.97; NFI = 0.96; SRMR = 0.08). To further verify the adequacy of the hypothesized model, we tested several plausible alternative measurement models. As summarized in Table 1, the hypothesized model performed better than any alternative four- or three-factor models ( $p < 0.001$  for all  $\chi^2$  difference tests).

We also conducted the same CFA using all 38 items to indicate five latent factors. This CFA with the full set of items also showed an acceptable fit for the five-factor model ( $\chi^2(df = 203) = 864.81$ ,  $\chi^2/df = 4.26$ ; CFI = 0.90; NFI = 0.90; SRMR = 0.08), and it demonstrated a better fit than any alternative measurement models ( $p < 0.001$  for all  $\chi^2$  difference tests). The results of these model fit comparisons through CFAs support the superiority and validity of the proposed five-factor structure over alternative measurement models. Accordingly, we retained the five study variables for the current analyses. The means, standard deviations, and correlations among the study variables are presented in Table 2.

Finally, we performed additional analyses to address potential

**Table 1**  
Model comparison for the confirmatory factor analysis.

Model	$\chi^2 (\delta\phi)$	<i>p</i>	CFI	RMR	RMSEA	AIC
Five-factor model	107.87 (29)	0	0.97	0.06	0.07	159.87
Four-factor model: Innovation perception and playful work design as single constructs	705.64 (31)	0	0.71	0.12	0.18	753.64
Three-factor model: Innovation perception, playful work design, and leisure crafting collapsed as single constructs	1146.15 (33)	0	0.53	0.15	0.35	1190.15
Two-factor model: Innovation perception, playful work design, leisure crafting, and green personal values collapsed as single constructs	1413.89 (35)	0	0.41	0.16	0.37	1453.89
Single-factor model: All study variables as a single construct	1737.44 (44)	0	0.37	0.16	0.37	1781.44

Note. CFI = Comparative Fit Index; RMR = Root Mean-Square Residual; RMSEA = Root Mean Square Error of Approximation; AIC = Akaike's information criterion

common method variance issues. Using Harman's single-factor test as suggested by Podsakoff et al. (2003), we found that the largest factor explained only a small portion of the total variance of focal variables (27.40 %). Following the approach proposed by Iverson and Maguire (2000), we also found that the model fit indices for the single-factor model were unacceptable ( $\chi^2(df = 665) = 8115.90$ ,  $\chi^2/df = 12.20$ ; CFI = 0.33; NFI = 0.31; SRMR = 0.22). Additionally, considering concerns about predictive relevance associated with the focal measures at Time 1 and Time 2, since they were all rated by employees (i.e., same-source bias), we tested another single-factor model by excluding manager-rated green creativity. This model also showed unacceptable fit indices ( $\chi^2(df = 464) = 6447.16$ ,  $\chi^2/df = 13.90$ ; CFI = 0.37; NFI = 0.35; SRMR = 0.24). These results indicate that common method variance is not a serious threat to the validity of our findings.

4.1. Main and mediating effects

We tested the current hypotheses by analyzing a moderated mediation model specified by SPSS PROCESS Macro (Model 15) with all control variables included as covariates. Tables 3 and 4 present the results. H1 states that positive I40T perceptions are positively related to green creativity. As shown in Model 3 in Table 3, positive I40T perceptions, a combined measure of I40T usefulness and I40T ease of use, are a significant positive predictor of green creativity ( $b = 0.12$ ,  $p < 0.01$ ), after controlling the effects of demographic, professional, and work overload factors. Thus, H1 is supported.

H2 and H3 posit that I40T perceptions are positively related to playful work design, which mediates the relationship between I40T perceptions and green creativity. In line with H2, Model 1 in Table 3 shows that I40T perceptions are positively related to playful work design ( $b = 0.25$ ,  $p < 0.001$ ). Table 4 reports the statistically significant indirect effect of I40T perceptions on green creativity through playful work design ( $b = 0.03$ , 95 % CI = [.001, 0.081]). The result confirms H3.

H4 and H5 state that I40T perceptions are positively associated with leisure crafting, which mediates the relationship between I40T perceptions and green creativity. Model 2 in Table 3 reports the significant positive relationship between I40T perceptions and leisure crafting ( $b =$

**Table 2**  
Means, standard deviations, and Pearson correlation results.

Variables	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age	2.69	0.86	—													
2. Gender	1.39	0.49	-0.39**	—												
3. Education	4.00	0.69	-0.05	0.17**	—											
4. Tenure	4.05	1.58	0.48**	0.00	0.17**	—										
5. Occupation 1	0.001	0.06	0.02	-0.05	-0.05	-0.04	—									
6. Occupation 2	0.16	0.36	0.12*	-0.03	0.08	0.08	-0.03	—								
7. Occupation 3	0.23	0.42	-0.02	0.12*	0.13*	-0.17**	-0.03	-0.23**	—							
8. Occupation 4	0.39	0.49	0.03	-0.06	-0.03	0.04	-0.05	-0.34**	-0.43**	—						
9. Occupation 5	0.07	0.26	-0.08	-0.19**	-0.02	0.05	-0.02	-0.12*	-0.15*	-0.22**	—					
10. Work overload	2.44	0.82	0.02	-0.02	-0.03	0.01	0.00	0.06	-0.07	0.06	-0.06	—				
11. I40T perceptions	3.75	1.36	0.18**	-0.15**	0.03	0.02	0.02	0.02	0.13*	0.00	-0.17**	-0.12*	—			
12. Playful work design	3.38	0.73	-0.08	-0.07	-0.01	0.03	0.00	0.04	0.01	-0.01	0.01	-0.16**	0.40**	—		
13. Leisure crafting	3.11	0.84	0.09	0.03	0.08	-0.13*	0.01	-0.02	0.04	0.01	-0.09	-0.06	0.34**	0.20**	—	
14. Green personal values	3.47	0.89	0.23**	-0.08	0.09	0.01	0.04	-0.03	0.03	0.05	-0.08	-0.07	0.43**	0.33**	0.35**	—
15. Green creativity	3.34	0.78	0.09	-0.07	0.05	-0.03	0.00	0.00	0.03	-0.05	0.00	-0.17**	0.35**	0.31**	0.25**	0.31**

Note: N = 282 participants. \*  $p < 0.05$ ; \*\*  $p < 0.01$ .  
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 older; 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 an 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/forestry/fishing, 2 = Manufacturing/operation, 3 = Engineering/technology, 4 = Management/administration, 5 = Medical/Law.

**Table 3**  
Results for the moderated mediation model: main and moderating effects.

Predictors	Outcome: Playful work design <i>b</i> ( <i>SE</i> )	Outcome: Leisure crafting <i>b</i> ( <i>SE</i> )	Outcome: Green creativity <i>b</i> ( <i>SE</i> )
Age	-0.14 (0.06)*	0.09 (0.07)	0.05 (0.06)
Gender	0.06 (0.05)	-0.10 (0.06)	-0.04 (0.05)
Education	-0.03 (0.06)	0.09 (0.07)	0.05 (0.06)
Tenure	0.04 (0.03)	-0.09 (0.04)*	-0.04 (0.03)
Occupation 1	0.09 (0.67)	-0.14 (0.79)	-0.23 (0.68)
Occupation 2	0.15 (0.14)	-0.15 (0.17)	-0.22 (0.15)
Occupation 3	-0.01 (0.13)	-0.14 (0.16)	-0.20 (0.14)
Occupation 4	0.05 (0.12)	-0.08 (0.14)	-0.21 (0.12)
Occupation 5	0.04 (0.19)	0.06 (0.23)	0.02 (0.20)
Work overload	-0.09 (0.05)	-0.02 (0.06)	-0.08 (0.02)
I40T Perceptions	0.25 (0.03)***	0.18 (0.04)***	0.12 (0.05)**
Playful work design			0.14 (0.07)*
Leisure crafting			0.13 (0.06)*
Green personal values			0.10 (0.06)*
Playful work design* Green personal values			0.17 (0.07)*
Leisure crafting* Green personal values			0.15 (0.06)*
R <sup>2</sup>	0.22	0.17	0.30

Note: N = 282 participants. \*  $p < 0.05$ ; \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$ .

0.18,  $p < 0.001$ ), supporting H4. Table 4 shows that the indirect effect of I40T perceptions on green creativity through leisure crafting is positive and significant ( $b = 0.02$ , 95 % CI = [.002, 0.059]). Therefore, our analysis supports H5.

4.2. Moderation and moderated mediation effects

We also proposed that green personal values positively moderate the indirect relationships between I40T perceptions and green creativity mediated by playful work design (H6) and leisure crafting (H7). Model 3 in Table 3 shows the significant main effect of green personal values on green creativity ( $b = 0.10$ ,  $p < 0.05$ ). Before testing the moderated mediation effects, we checked the significance of simple moderation effects (Edwards & Lambert, 2007).

First, the interaction between playful work design and green personal values is a significant positive predictor of green creativity ( $b = 0.17$ ,  $p < 0.05$ ). A simple slope analysis was performed to probe this significant interaction. As presented in Fig. 2, the relationship between playful work design and green creativity is stronger for participants with high green values (1 SD above the mean) ( $b = 0.31$ ,  $p < 0.01$ ) compared to those with low green values (1 SD below the mean) ( $b = 0.14$ ,  $p < 0.01$ ). These patterns are consistent with the expected positive moderating effect of green personal values.

Second, the interaction between leisure crafting and green personal values is a significant positive predictor of green creativity ( $b = 0.15$ ,  $p < 0.05$ ). The simple slopes depicted in Fig. 3 indicate that the

**Table 4**  
Results for the moderated mediation model: conditional indirect effects.

Independent variable	Mediator	Dependent variable	Moderator	Moderator level	Conditional indirect effect	Bootstrapping bias-corrected 95 % CI	
						Lower limit	Upper limit
I40T Perceptions	Playful work design	Green creativity	Green personal values	Low	0.01	0.001	0.043
				Medium	0.03	0.001	0.081
				High	0.07	0.007	0.143
Index of moderated mediation					0.04	0.001	0.085
I40T Perceptions	Leisure crafting	Green creativity	Green personal values	Low	0.01	0.001	0.040
				Medium	0.02	0.002	0.059
				High	0.05	0.015	0.104
Index of moderated mediation					0.03	0.003	0.066

Note: N = 282. Bootstrap sample size = 5000. CI = confidence interval.

relationship between leisure crafting and green creativity is stronger for participants with high green values ( $b = 0.30$ ,  $p < 0.01$ ) compared to those with low green values ( $b = 0.13$ ,  $p < 0.01$ ), which aligns with our theoretical expectation.

Based on these significant simple interactions, we directly tested the hypothesized moderated mediation by comparing the conditional indirect effects at different levels of green personal values. As shown in Table 4, the indirect effect of I40T perceptions on green creativity through playful work design is greater for participants with high green values (1 SD above the mean) ( $b = 0.07$ , 95 % CI = [.007, 0.143]) compared to those with low green values (1 SD below the mean) ( $b = 0.01$ , 95 % CI = [.001, 0.043]). The index of moderated mediation is significant (index = 0.04, 95 % CI = [.001, 0.085]), indicating that the indirect effects differ significantly across varying levels of green values.

Additionally, the bootstrapping analysis results reported in Table 4 show that the indirect effect of I40T perceptions on green creativity through leisure crafting is greater when green values are high ( $b = 0.05$ , 95 % CI = [.015, 0.104]) compared to when they are low ( $b = 0.01$ , 95 % CI = [.001, 0.040]). The index of moderated mediation is significant (index = 0.03, 95 % CI = [.003, 0.066]). These results support H6 and H7.

5. Discussion

Based on COR theory, we identified the usefulness and ease of use of I40Ts as workplace resources available to employees. We further theorized that the availability of these resources from I40T perceptions

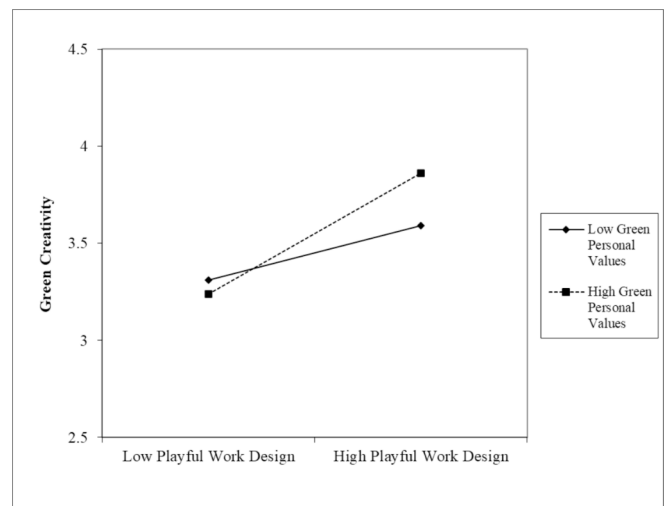


Fig. 2. Moderating effect of green personal values on the relationship between playful work design and green creativity.



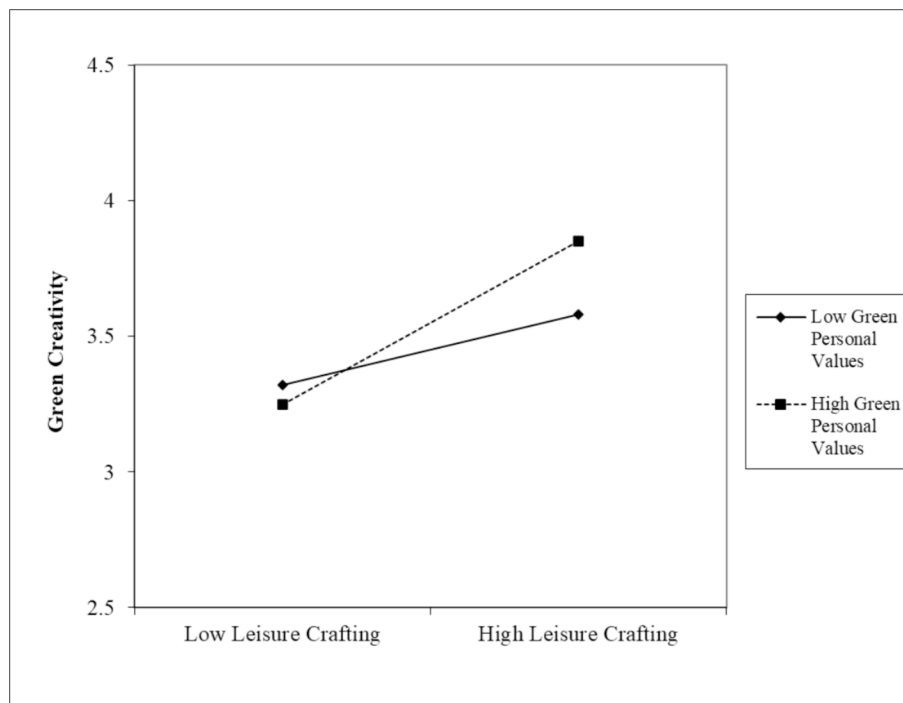


Fig. 3. Moderating effect of green personal values on the relationship between leisure crafting and green creativity.

contributes to green creativity by enhancing playful work design and leisure crafting. We empirically validated these propositions using a multi-wave, multi-source dataset collected from employees of Taiwanese organizations and their managers. Our analysis supports the hypothesized direct and indirect effects of I40T perceptions on green creativity, which are stronger when green personal values are high rather than low. This work contributes to the literature on innovation implementation and employee proactive behaviors in both work and non-work domains concerning an emerging form of creativity. Below, we discuss the theoretical and practical implications, study limitations, and avenues for future research.

### 5.1. Theoretical implications

This study makes several theoretical contributions. First, we enriched the innovation implementation literature by applying the core ideas of TAM to a recent technological trend, namely, I40Ts. In doing so, we explored the broader implications of the two key innovation perceptions in shaping employee outcomes (Davis, 1989). Although TAM has been validated to explain the acceptance and use of specific technologies (Al-Qaysi et al., 2020; Choi et al., 2011; Granić & Marangunić, 2019), it remains unclear whether its two core perceptions impact employees beyond their innovation-related behaviors. Indeed, a recent meta-analysis of 693 studies revealed that most of these studies focused on the effects of perceived usefulness and ease of use on technology acceptance (Marikyan et al., 2023). This pattern was similarly observed in a comprehensive systematic review of the TAM literature (Davis & Granić, 2023). Such a narrow focus may limit our understanding of the impact of workplace technologies on broader human behaviors beyond technology use.

This study demonstrates the benefits of positive innovation perceptions on various employee outcomes, such as designing work and non-work activities in playful and meaningful ways, which can enhance work performance such as green creativity. Our framework and empirical findings suggest that existing TAM studies fall short in fully capturing the organizational advantages and employee benefits offered by innovations. We propose a broader application of TAM, where

innovations can create a favorable context for employee proactivity, akin to the supportive and resourceful environments fostered by favorable HR practices or other employee inducements. Our findings encourage researchers to explore a wider range of employee behaviors beyond mere innovation use when investigating the potential effects of innovation perceptions.

Second, this study theorized and demonstrated the positive effects of I40T perceptions on green performance in the workplace. Research on I40Ts often highlights concerns regarding its potential detriments for employees, such as increased alienation from work and anxiety or stress due to new demands and challenges (e.g., Feroz et al., 2021; Karadayi-Usta, 2019; Surange et al., 2022). We identified a solution to motivate employees to accept I40Ts: promoting their perception of usefulness and ease of use. This study further reveals that when employees perceive I40Ts positively, their implementation can lead to desirable behaviors and outcomes beyond mere innovation use.

In addition to operational efficiency and performance improvement, I40Ts aim to achieve environmental goals such as waste reduction and promoting green efforts (De Giovanni & Cariola, 2020; Mubarak & Petraite, 2020; Mubarak et al., 2021). By investigating the mechanisms underpinning the impact of I40Ts on green creativity, our analysis shows the conducive role of I40Ts in addressing environmental issues and achieving their intended goals through fostering employee green behaviors.

Third, the current findings on playful work design offer novel insights into the implications of advanced technologies on proactive and pro-environmental behaviors. The concept of playful work design has been recently introduced in the literature, with its role in the workplace largely unexplored beyond its positive effects on job engagement and performance (Bakker et al., 2020). While existing research has primarily focused on top-down managerial interventions to encourage playfulness in the workplace (Tews et al., 2014; Tsaor et al., 2019), we propose that employees can proactively initiate the process of making their work fun and challenging.

From the perspective of COR theory, I40T perceptions can facilitate this process by providing resources that employees can use to design their work, leading to further resource acquisition (Halbesleben et al.,

2014; Hobfoll et al., 2018). Our analysis thus advances a proactive view on the development of playful work design from a resource perspective. This enriched approach may pave the way for new research directions, exploring additional proactive or intrinsically motivated factors and their roles in developing playfulness in the workplace.

Fourth, we explored the implications of workplace innovation for employee behaviors in the non-work domain of leisure and personal life. The concept of leisure crafting was initially grounded in self-determination theory (Petrou et al., 2017), which posits it as an alternative approach that individuals adopt to fulfill basic needs unmet in the work domain (e.g., Berg et al., 2010; Petrou & Bakker, 2016). Extending this research, our analysis reveals that, in addition to addressing unfulfilled needs at work, the extra resources provided by workplace innovation can also promote leisure crafting.

We further enrich the existing view of leisure crafting as a coping strategy to fulfill employees' unsatisfied needs, which benefits them through increased meaning-making, work engagement, and career self-management (Chen, 2020; Petrou et al., 2017). Our analysis shows that leisure crafting can also supply resources for environmental management and green creativity, beyond self-focused motivational outcomes. These findings broaden the scope of leisure crafting, suggesting that it is not only initiated by needs satisfaction but can also be driven by the additional resources from workplace innovations, expanding its potential outcome domains.

Fifth, we advance COR theory by specifying a boundary condition that channels the flow of resource investment toward green creativity. The role of personal values within COR theory is unclear (Hobfoll et al., 2018), partly because personal values have not gained sufficient attention in studies grounded in resource-based theories (e.g., COR, job demands-resources model, work-home resource model, Ten Brummelhuis & Bakker, 2012). This oversight presents a significant gap in the COR literature since individuals' resource investments are strategically directed to achieve what they value, which may explain the differentiated effects of available resources across individuals (Schwartz, 1992).

Our analysis addresses this theoretical gap by demonstrating that green personal values amplify the indirect effects of I40T perceptions on green creativity. This pattern underscores the significance of personal values in shaping how available resources are utilized. Consequently, the environmental benefits of I40Ts may be more effectively achieved in firms where employees share green values. Additionally, this work clarifies the extent to which individuals strategically dispose of resources and how they acquire and invest them in accordance with their personal values, which has been an underexplored area in COR theory (Halbesleben et al., 2014).

Finally, the constructs of playful work design and leisure crafting have primarily been examined in the European context (Bakker et al., 2020). Our study contributes to both strands of literature by empirically testing their effects in an Asian context (Taiwan). Cultural values and work philosophies differ significantly between European and Asian workers (Bui et al., 2017; Chen, 2024). Therefore, what proves effective in a European work context may not yield the same results in Asia. Our findings on the mediating roles of playful work design and leisure crafting in the relationship between innovation perceptions and green creativity in the Taiwanese work context enhance the generalizability of these constructs. Future research can explore their joint effects in combination with other Asian-specific work elements (e.g., guanxi, Hu et al., 2016) or cultural values, such as high power distance.

## 5.2. Practical implications

The current findings have several practical implications. First, consistent with recommendations from TAM studies (Davis, 1989; Granić & Marangunić, 2019), organizations should promote perceptions of usefulness and ease of use among employees when implementing I40Ts. These perceptions not only increase innovation-targeted behaviors (Al-Qaysi et al., 2020) but also enhance proactive behaviors in both

work and non-work domains, as shown in this study.

To increase perceived usefulness, managers should communicate the benefits of I40Ts for employees' well-being and performance, in addition to the competitive advantages and environmental benefits for the company. To increase perceived ease of use, organizations should offer user-friendly I40T-related training programs, provide technical support, and allow sufficient time for trial-and-error learning (Choi et al., 2011; Granić & Marangunić, 2019). These organizational interventions should enhance employees' I40T perceptions and associated resource availability, thereby improving their proactive activities and performance.

Second, our analysis highlights the importance of motivating employees to engage in playful work activities and craft meaningful leisure activities, which can generate creative benefits for the organization. To achieve this, organizations can foster a playful culture and managers can offer opportunities that encourage employees to design fun and competitive elements into their work activities. Additionally, providing financial support and relevant information can help employees enrich and diversify their leisure activities outside of work. By supporting employees in engaging in playful work design and leisure crafting, organizations can enhance their potential to make creative contributions.

Third, organizations can more effectively accrue environmental benefits from I40T implementation when they have employees with green personal values who can channel the resources gained from I40Ts into green creativity. To enhance environmental performance and respond to challenges such as ESG management (Feroz et al., 2021), organizations may consider green personal values as a criterion during recruitment and hiring. For instance, job applicants can be encouraged to state their green values and experiences in their applications, and interview questions can be designed to assess awareness, sensitivity, and knowledge of environmental issues to evaluate the candidates' green personal values. For existing employees, organizations can foster green values by creating a work environment with a shared green culture, supported by green policies and practices, which can transform the personal values of employees (Tepeci, 2001).

## 5.3. Study limitations and future research directions

This study has several limitations that should be considered when interpreting the findings and designing future investigations. First, the generalizability of the findings may be limited because the data were collected from a single country, Taiwan. The external validity of our study can be enhanced by replicating the analysis with respondents from other countries, especially those from non-Asian contexts. Although existing studies have not shown evidence that respondents in Taiwan are more likely to underreport or overreport the focal measures than those in other countries, we still encourage future research to re-examine our theoretical propositions by collecting data from diverse national, cultural, and industrial contexts to address the issue of generalizability.

Second, the current outcome measure of green creativity was reported by managers four weeks after the assessment of employees' I40T perceptions. Despite using a multi-source, multi-wave research design, the findings are not entirely free from endogeneity issues and the accompanying limitations on causality (Hill et al., 2021). To further replicate and expand the current empirical analysis and inferences, future research should consider alternative research designs to mitigate causality concerns and use objective, quantifiable measures of green creativity (Hill et al., 2021). By employing different operationalizations, researchers can also develop action-oriented managerial interventions aimed at improving environmental performance.

Third, while our model incorporates green personal values as a potential boundary condition for the effects of I40T perceptions on employee proactivity and green creativity, there is a need for further theoretical exploration of contextual moderating contingencies. Our framework primarily emphasizes individual perceptions and behaviors, but its scope could be expanded by examining the potential moderating roles of organizational and social contextual factors. For instance,

organizational contexts such as green culture, corporate ESG initiatives, external demands, and environmental training programs could provide valuable alternative contingencies. These situational factors may complement individual values by influencing how I40T perceptions translate into green creativity.

Additionally, social contextual factors, including green leadership, coworker support for environmental issues, and family endorsement or participation in green activities, could also serve as significant boundary conditions. The presence or absence of these organizational and social contexts, in combination with green personal values, could either amplify or diminish the resource-like functions of I40T perceptions in fostering green creativity. It is also important to highlight that we accounted for a resource-related situational factor (i.e., work overload) in our analysis to ensure that the analysis results reflect the resource-based effect of I40T perceptions, independent of situational resource constraints.

Fourth, we employed a multi-wave, multi-source design to empirically validate the current hypotheses with rigor (Liao et al., 2016). However, concerns may arise regarding the time lag used in this research. Since there is no universally accepted time lag (Menard, 2002), we followed the recommendations of existing studies that suggest short time lags may be appropriate for exploring the impact of individuals' perceptions on subsequent behaviors (Dormann & Griffin, 2015). A common practice in organizational literature is to maintain two- to four-week intervals between each survey wave (Schulte-Braucks et al., 2019). Future research could consider alternative designs with longer time lags to replicate the current findings.

Finally, we theorized the effects of perceived usefulness and ease of use of I40Ts from the perspective of resource flow based on COR theory. Although existing studies have supported the notion that both factors contribute similarly to individuals' innovation behavior and other outcomes, perceived usefulness and ease of use may operate through different underlying mechanisms. In other words, there might be distinct pathways driving their effects on green creativity and other work outcomes. We suggest that future research explores these possibilities by identifying additional mediators beyond playful work design and leisure crafting.

## 6. Conclusion

This study addressed the practical challenges of rapid technological developments, characterized as I40Ts, and the increasing demands for environmental management, such as ESG and green issues, that contemporary organizations encounter. To tackle these challenges, we integrated the TAM and COR perspectives and advanced several bodies of organizational literature. Specifically, we demonstrated that when individuals perceive innovation as easy to use and useful, they see available resources that motivate them to shape their work tasks playfully and craft leisure activities in their private lives. This, in turn, enables them to engage in environmentally friendly creativity at work.

We explained the connection between I40Ts and green creativity by elaborating on the resource availability provided by I40T implementation, which employees can invest in proactive behaviors in both work and non-work domains. These proactive behaviors, namely playful work design and leisure crafting, promote green creativity, particularly when green personal values are high. Our analysis demonstrated how TAM and COR theories can be combined and extended to address the emerging business challenges posed by technology and social movements. Further studies are required to identify contingencies and managerial interventions that may activate the positive versus negative resource implications of new technologies in shaping employee and organizational responses and outcomes.

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## CRediT authorship contribution statement

**I-Shuo Chen:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Jin Nam Choi:** Writing – review & editing, Supervision, Conceptualization.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jbusres.2024.115103>.

## Data availability

Data will be made available on request.

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