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Speed matters: Managing innovation in the energy sector by building shared understanding in the face of multiple clockspeeds

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Abstract

Innovating for the green transition is increasingly important and energy producers and distributors play a central role, as they integrate rapidly emerging, new and more sustainable technologies into the much slower-changing energy system. However, there has been surprisingly little research on how differing temporal perspectives (or clockspeeds) impact innovation, particularly in traditionally slow sectors, such as the energy sector. This is linked to key questions in how to improve shared understanding in contexts with multiple clockspeeds. Thus, we—for the first time—examine how shared understanding of differing clockspeeds can be developed in innovation teams in the energy sector. We conducted a quasi-experiment using a timeline-based intervention with 38 practitioners. Our results show that teams with the timeline developed greater actual shared understanding, but did not necessarily perceive this improvement compared with teams using generic innovation support. Further, despite working with a timeline intervention, rather than traditional creativity tools, we found no negative impact on the creative performance of the teams. Therefore, we substantially add to the extant literature by highlighting the potentially important role of timelines

in supporting the development of shared understanding in creative-innovation contexts with diverse clocks speeds, even though such interventions are not typical of creative-innovation tasks.

Managerial relevance statement

Managers can use timelines as tools to create shared understanding among employees in situations with multiple clocks speeds without compromising other aspects of creative performance. This is important as multiple clocks speeds can impact innovation related firm performance and strategic success. Managers should pay attention to potential divergence between actual and perceived understanding and provide additional support to align these. This can be achieved by including a timeline as a normal part of the creative-innovation process.

Keywords: *Innovation, Shared understanding, Clockspeed, Energy, Creativity*

I Introduction

Innovation toward the green transition is an increasingly important issue, critical to addressing numerous societal challenges [1], [2]. Here, energy producers and distributors play a central role [3], [4], as they integrate rapidly emerging, new and more sustainable operating technologies into the slower changing energy system. However, there has been surprisingly little research on how differing temporal perspectives impact innovation, particularly in traditionally slow sectors, such as the energy sector [5].

Temporal lenses provide an essential means of understanding and coordinating behaviour, interaction, activity, and events embedded in a dynamic context [6]. The field of innovation

management research often neglects the critical role of time, despite recent literature emphasising time-active involvement [7]. Recent studies have shed light on how time is negotiated and shaped within institutional processes and among various actors [8]. In this context, some authors propose that innovation should be viewed as a process rather than merely an outcome if researchers are to understand the micro-foundations of innovation [9]. Consequently, an ongoing scholarly debate surrounds the role of time structuring in fostering creativity and innovation [10].

Time structures comprise formalised and observable aspects such as timing, timelines, plans, duration, and speed. While time structures are often considered actual or objective, recent literature underscores the presence of less visible and subjective temporal patterns that affect the organisation [11]. Specifically, clockspeed [12] provides a critical means of understanding and coordinating innovation at multiple speeds. Fine [13] introduced rate of change or *clockspeed*, here defined as “the usual aggregate rate of the product, process, and organisation change of the firms within an industry” [12]. Differing clockspeeds can lead to contradictory temporal orientations [14].

Guimaraes [15] found that industry clockspeed moderates specific characteristics of a company’s innovation process and holds equal importance in low- and high-clockspeed industries in relation to the successful implementation of business innovation. Other studies have indicated that innovation practices differ across clockspeeds [16]. Further, strategic flexibility is vital in fast-clockspeed industries, while slow-clockspeed industries, such as the energy sector, benefit from effective strategic schemas, and thus, shared assumptions and knowledge of companies drive their actions and practices and create the conditions of industry clockspeed [17]. Neglecting clockspeed has been linked to eventual market failure [18]. Therefore, how to improve shared understanding in contexts with multiple clockspeeds is a key question.

The above question is nowhere more pressing than in the context of the energy sector. Here, the main clockspeed is lower than in comparable industries, such as telecommunications [12], and is generally understudied [19]. However, the pace of the green transition (as well as developments such as the war in Ukraine) is increasingly demanding energy companies balance fast and slow innovation [20]. Specifically, a core challenge for energy companies is understanding innovation activities occurring at multiple speeds in various parts of the organisation (e.g., sales, development, maintenance, and production) [9]. For example, information technology typically has a fast pace of innovation, while electrical grid infrastructure has a very slow pace of innovation [12]. This highlights the importance of shared understanding of clockspeeds across the organisation. Given this research and contextual need, we examined how shared understanding of differing clockspeeds can be developed in innovation teams in the energy sector context.

To address this aim, we developed hypotheses and conducted an experiment in industry to assess the impact of an intervention targeting shared understanding of clockspeed during an innovation task. We drew on a sample of nineteen two-person teams of professionals, each comprised of employees working in related departments but with differing clockspeeds. Studying the impact of multiple clockspeeds among individuals and units is essential, as it enhances team's understanding and navigation of the micro-foundations of innovation and moves beyond the use of average clockspeeds [15]. This approach further explores how individuals and teams perceive and interact with time, which ultimately shapes their innovation behaviours and outcomes [21]. We examined outcomes in terms of shared understanding, perception of shared understanding, and task performance. We found that the intervention increased shared understanding (but not the perception of shared understanding) and task performance. These results contribute to the

clockspeed and innovation literature. Further, our work addresses calls to better understand temporal issues impacting organisational innovation behaviour in a dynamic world [30] as well as for more work on what managers and others do or can do to intervene in time-related phenomena [6]. Thus, our work provides key insights into managing organisational dynamics.

II Theoretical background and hypotheses

A. Shared understanding and innovation

The literature suggests that innovation is a three-stage process comprising the generation of ideas (ideation), their development, and their implementation [9]. Ideation deals with the development of new processes, products, procedures, or strategies that are novel and can be of value [22] and are often considered to form a foundation for success [23]. While ideation typically builds on shared understanding of vision or goal [24], such as realising innovation in an energy company, a team needs to develop ideas that work across both the short term and long term. This means that shared understanding of how to merge multiple clockspeeds becomes essential for effective ideation—and ultimately innovation.

Shared understanding and related concepts (e.g., shared mental models, team mental models, team cognition, and sense-making) are used and defined differently in various research streams [25]. However, shared understanding can be broadly understood as individual and collective ownership of a perspective accepted by a team to get everyone “on the same page” [26]. This can be further distinguished in terms of perceived and actual shared understanding [26]. Here, *perceived* shared understanding deals with the extent to which members believe they agree with each other [27], while *actual* shared understanding deals with the specific alignment between their mental models

(e.g., [28]). Shared understanding is thus an emergent state shaped by interactions among team members and is an area of sustained importance for research and industry [25]. Activities that foster shared understanding include exchanges shaped by human beliefs [29], and they occur predominantly as interactions in a team [30]. Examples of sharing activities are meetings and training [31]. Thus, shared understanding helps to account for the implicit coordination frequently observed in effective teams [32].

However, despite the inherent temporal component in coordination, there has been little explicit incorporation of time in studies dealing with shared understanding [33]. While prior research has demonstrated that shared understanding of temporal issues exerts a strong, positive influence on team performance [33] and coordination [30], this research has primarily focused on time-based characteristics, including time urgency (feeling chronically hurried), time perspective (bias towards the past, present, or future), polychronicity (preference to engage in more than one task concurrently), and pacing style (pattern of effort distribution over time in working towards deadlines), rather than clockspeed [34]. Consequently, little is known about what leads to shared understanding in situations with several clockspeeds, and practitioners need guidance on how to intentionally evoke shared understanding in this context [35].

B. Clockspeed

Clockspeed aims to capture the dynamics of processes, in order to guide choices of operations and innovation management [13, p. 223]. Clockspeed, as the rate of change, has different operationalisations in products, processes, and organisations, which are often characterised within an industry as slow, medium, or fast [12]. Further, recent literature has extended clockspeed theory

to both the sector and the ecosystem [36]. For example, fast industries such as computers, movies, and toys have an organisational clockspeed of 2–15 years and a product clockspeed of six months to three years, while slow industries such as energy companies have an organisational clockspeed of 50–100 years and a product clockspeed of 10–20 years [12].

Clockspeed has been theorised at both the organisational level and product and process levels [13]. However, organisations intermittently exhibit fast and slow clockspeed characteristics [20], which can result in conflicting temporal orientations, challenging long-term organisational survival [37]. Existing studies typically discuss clockspeed as an average measure for a product, process, organisation, or even a whole industry sector [16], [20]. However, more nuanced variations in clockspeeds have been little studied. For instance, a surface ship combines stable hulls, short-lived electronics, and frequently updated software. Focusing on these nuances rather than relying on average clockspeed to fully understand and navigate the complexities involved is essential. Clockspeed is best studied within the context of innovation projects among individuals because, at this level, the dynamics and interactions of multiple clockspeeds are most apparent and influential [38].

Differences in clockspeeds and temporal orientations within an organisation can present significant challenges in achieving shared understanding. These challenges manifest as the misalignment of goals, difficulties in coordinating activities, and conflicts arising from misaligned priorities and perspectives [8]. Previous studies have consistently brought attention to the tensions that arise in temporalities within and between innovation projects, posing significant challenges to progress [9]. Consequently, organisations can operate with multiple clockspeeds, even though some authors claim that each organisation has an overall synchronised clockspeed [13, p. 238]. Consultants such

as KPMG refer to this clockspeed dilemma as the organisation managing multiple innovation paces simultaneously [39]. A clockspeed dilemma thus does not imply that either a fast or a slow clockspeed is desirable. Rather it implies that multiple clockspeeds should be understood and harmonised for the organisation to function effectively.

Most of the literature focuses on temporal synchronisation as a preference for efficiency [40]. However, in the team literature, synchronisation is related to smooth team and organisational functioning through increased coordination and control [41], with temporal conflict leading to inefficiencies and poor performance [42]. Given this link to performance, it is surprising that little literature examines how to foster shared understanding across multiple clockspeeds in teams.

The literature suggests that the homogeneity/heterogeneity of time perspectives in a team may affect the degree to which firms can leverage “old” knowledge with a short-term perspective and learn through experimentation and discovery with a long-term perspective [43]. Prior work indicates a strong link between individual time perspectives and decision-making, goal commitment, and goal attainment [44]. Moreover, differences in the level of heterogeneity in time perspectives, such as those for clockspeed, lead to difficulties in knowledge-transfer activities and undermine team effectiveness. Teams may miss windows of market opportunity, duplicate knowledge creation efforts, or create incremental advances when novel or breakthrough innovations are needed [43]. Not only are knowledge-transfer activities affected, but numerous authors suggest that a team with multiple time perspectives is likely to create disagreements, misunderstandings, and conflict, particularly during interaction-intense idea-generation activities [45]. However, mixed results in the knowledge management literature suggest that heterogeneous or diverse teams, including those with multiple time perspectives, are generally better than homogeneous teams at developing new

knowledge and innovation [46]. Therefore, there is a need to understand how to mitigate the negative effects of multiple time perspectives while retaining the positive benefits of innovation.

C. Hypothesis development and contextualisation

The literature suggests that awareness is the path to achieving shared understanding in teams [43]. Planning has especially been highlighted as a key aspect of innovation, for example, in product development, when an organisation wants to take control of the environment and set its own pace rather than follow external events [47]. A positive relationship has been shown between awareness in planning for a project's success and the final outcome, where early planning decisions can have a significantly impact [48]. Planning—for example, via timelines—embodies objective and mono-temporal assumptions about time and serves as a medium for negotiating and managing time among distinct organisational and occupational subgroups [49]. However, some authors even argue that conventional time management approaches fall short in comprehending team processes based on a linear clock-time perspective [9]. Notably, the innovation process, from ideation to implementation, is characterised by temporal complexity involving multiple rhythms, speeds, and experiences [38]. Thus, planning, for example, done through scheduling and time management, is routinely reported as a significant source of teamwork-related problems [45].

Timelines, which are adaptable and resilient temporal boundary objects, visually represent time by encapsulating key narrative elements, such as a beginning, middle, and end [49]. Timelines enable enhanced information processing, discovery, and comprehension among project team members [50]. Further, a timeline can help overcome the difficulty of reasoning about idea implementation or hypothesised effects [51] and can help shape awareness of temporalities in general [42]. Using

timelines helps mitigate biases that may arise from initial impressions, and thus improve the accuracy of judgements about a current situation [52]. They are also tools for exploring complex histories [53] and are omnipresent in time data visualisations, which highlights their widespread use [53]. Consequently, interventions such as timelines should lead to improved shared understanding—in teams comprised of members with diverse clocks speeds—and increase members' explicit awareness of this aspect of their interaction. Thus, our first two hypotheses are as follows:

Hypothesis 1: Teams exposed to “clockspeed-focused innovation support (based on a timeline)” will display greater actual shared understanding compared to teams with generic innovation support.

Hypothesis 2: Teams exposed to “clockspeed-focused innovation support (based on a timeline)” will display greater perceived shared understanding compared to teams with generic innovation support.

However, since a timeline is not commonly used in ideations sessions [54] and prior work has found that time awareness can have a complex correlation with creativity and performance [42], it is important that we qualitatively contextualise these hypotheses. Specifically, we aimed for a multifaceted examination of ideation and other relevant outcomes to ensure that the performance of the intervention teams was not negatively impacted by the use of a timeline tool, which is not a typical creativity intervention. We refrain from directly proposing a hypothesis for innovation performance, as it distinguishes between creativity and innovation in our study's scope. Our understanding of innovation covers the entire process, from idea inception to implementation. While time significantly influences transformative changes, we avoid conclusive claims about the entire innovation process due to the challenge of measuring long-term outcomes with short-term

metrics primarily linked to creativity. Instead, our focus is on exploring specific aspects contributing to understanding innovation dynamics in its initial phase like content and the number of new ideas [9], [25], [55], as well as vision, temporal, and interaction aspects of the implementation of the final output [56].

V Methodology

To test our hypotheses, we conducted an exploratory quasi-experimental study with non-equivalent teams (control versus intervention) and a one-tailed analysis [57]. A quasi-experimental design is appropriate for our research since random assignment and controlled manipulation is not practically or ethically feasible in our case [58]. The experimental ideation session was confidential and limited to departments with significantly different clockspeeds in a particular energy sector organisation.

A. Experimental procedure

Collaboration in innovation teams is common in organisations [59], and structured ideation sessions are a common subject of an experimental study in this context [59]. Therefore, to maximise comparability with the literature while also ensuring ecological validity in an energy sector organisation, our experiment was built on a structured ideation task with framing familiar to all study participants. To ensure internal validity related to our focus on shared understanding, we designed the experiment to minimise potential confounding variables. By developing a structured experimental process with clear and explicit rules and instructions in small teams, we ensured that all teams engaged with the task similarly (other than with the experimental intervention) and avoided irrelevant work or other confounding distractions, following best practices and previous examples [60].

The overall procedure comprised a preparation exchange with each participant (pre-experiment), the experiment itself based on two meetings (experiment), and an expert panel session (post-experiment). Throughout, the first author functioned as the experimental facilitator. Despite the potential bias introduced by hypothesis awareness [61], this was necessary for gaining the participants' and the organisation's support for the study. Potential bias was minimised using a standard script for all interactions between the experimental facilitator and participants (this included both email and face-to-face). The overall procedure is summarised in Figure 1.

<Please include Figure 1 about here>

B. Ideation task

To ensure ecological validity, the first author worked with four senior managers of the focal organisation to define a contextually relevant ideation problem for the teams. Further, internal validity was addressed by linking this to a theoretical understanding of ideation. We built on the fundamental steps associated with "Clarify the Problem" of the Osborn-Parnes Creative Problem Solving method [62], because this provided a constant structure for facilitating creative solutions. This involves identifying the issue, collecting information, and formulating the problem statement [62] all carried out with respect to the widely used "How might we" approach [63]. The steps resulted in a final problem statement: "How might we increase revenue by 50% or reduce the cost, resources, risks, and/or CO₂ by 50% by 2025?". The tasks of the experiment itself were structured as summarised in TABLE 1.

<Please include Table 1 about here>

A booklet was used during the experiment (Steps 1 and 3 in TABLE 1) to ensure uniformity and written documentation for the findings. All exercises had written instructions and a timeframe, and participants reported all conclusions in the booklet. The total time for the ideation tasks was similar to other studies [64]. Easy-to-use, known idea-generation techniques were used throughout to stimulate creativity while minimising any issues with methodological familiarity [65].

C. Intervention and control conditions

The intervention involved teams collaboratively drawing a timeline responding to prompting instructions for implementing the concepts (TABLE 1). Timelines are simple and intuitive to most people and are used in strategy implementation and project planning to understand performance [51]. They define a project's clockspeed [66] and are used for more than ideation sessions of teams [42]. Since time can be organised [38] (i.e., events and other data can be ordered and sequenced), a timeline is helpful for fostering comparison and shared understanding (e.g., [30]) as well as supporting team performance [45]. Further, temporal planning has been found to positively influence an organisation's growth and profitability [67, p. 218]. Thus, timelines support the development of shared understanding [68] and are well-suited to answering our hypothesis.

An evaluation of the final output was constructed based on the elements in the "How might we" question and confirmed relevant by the managers. This comprised individual evaluations by the team participants as well as members of the expert panel as outlined in the qualitative contextualisation part of TABLE 3. The only difference between the intervention and control conditions in the experiment was Step 3e, shown in TABLE 1. In the control condition, teams were asked how to improve the implementation of concepts and were advised to consider general issues regarding, for

example, process structure and skills [69], to minimise the potential difference from the intervention teams [61]. In the intervention condition, we specifically asked the teams to focus on the time aspect in improving the implementation of concepts and advised them to make a timeline. Both conditions received equal attention from the facilitator, completed similarly demanding tasks, and received credible support to minimise bias while drawing out salient issues around shared understanding in the face of differing clocks speeds.

D. Sample and team formation

All participants were drawn from one energy sector organisation based in Scandinavia. As a starting point, we interviewed four managers about their best estimate of the usual solution innovation clock speed from idea to prototype in their departments using the Bluedorn Temporal Depth Index (a non-linear timescale, where 1 is one day, and 15 is more than 25 years) [67, pp. 265–272]. This scale revealed that the maintenance department had an innovation clock speed of 5–10 years, and the sales department had an innovation clock speed of 1–3 years. These departments both conduct innovation work and have experienced several organisational adjustments to avoid conflicts. Therefore, they were ideal candidates for examining innovation in teams with multiple clock speeds and a lack of current shared understanding. Further, the 5-to-10-year difference in clock speeds between the departments and the number of potentially relevant, non-management staff (51 people in the maintenance department and 25 people in the sales department) made them a suitable sample for team formation.

Two-person teams were randomly formed by combining one person from each department. Two-person teams are common in similar studies since they reduce confounding teamwork and

coordination issues [60] while still allowing us to examine shared understanding effects associated with multiple clocks. Further, the managers of the departments allowed us to create a representative expert panel (with one manager each from the maintenance, sales, and development departments) since they are responsible for go/no-go decisions regarding concept suggestions.

This process resulted in 19 two-person teams and an expert panel of three managers. Two of the managers are men. One was 46 years old, and the other was 51. The former has six years of experience as the manager of the maintenance department, and the latter has 12 years of experience in the R&D department. The other manager on the expert panel is a 48-year-old woman with 25 years of experience in the company and is currently the manager of the sales department.

This sample helped deliver reliable and meaningful results and followed best practices for sampling design [70]. The characteristics of the employee sample are described in TABLE 2.

<Please include Table 2 about here>

E. Measurement and Data Analysis

For Hypothesis 1, the actual shared understanding was evaluated based on data from concept mapping. To map concepts, participants create an interpretable map visualising a list of key concepts connected with labelled arrows [71]. For reasons of confidentiality, participant drawings and specific outcomes from the ideation tasks cannot be reproduced here. However, the mapped concepts encompassed various aspects, including implementing new organisational processes, emphasising sustainability, using digitalisation for maintenance practices, and exploring the combination of existing components, as shown in the example in Figure 2.

<Please include Figure 2 about here>

All concepts from the maps produced before and after the experimental control/intervention (Step 1c and Step 3g, TABLE 1) were transcribed, anonymised, and structured to analyse the shared understanding based on the similarity between the concepts listed by the two participants in each team in the before (the first meeting) and after (the end of the second meeting) maps [72]. Here, we followed best practices for content analysis [73, pp. 359–360]. Specifically, the wording of the mapped concepts was required to be the same to code them as analogous, however, we also allowed for understanding of the context in which the word was written. For example, “task” and “task in maintenance” were coded as the same concept if the concept map concerned maintenance. Similarly, “lower cost” and “cost” were coded as the same since the term was defined in the “How might we” challenge and hence “cost” was contextually linked lower in the task. If we had difficulties reading or understanding a concept map, we contacted the participants for clarification.

Two independent researchers verified the data. This resulted in two measures: i) A change in the number of shared concepts between the before and after maps for each team (here, a high degree of shared concepts indicates increasing shared understanding); and ii) A change in the number of listed concepts between the before and after maps for each team (here, a reduction in listed concepts indicates increasing shared understanding) [74]. Both measures were normalised with respect to the total number of concepts listed by the participants to account for variance in writing speed and wording.

For Hypothesis 2, the perceived shared understanding was measured using a Likert scale at the end of the second meeting to measure the difference between the control and intervention teams [75]. Likert scales provide a convenient way to measure unobservable constructs and are easy for

respondents to complete [76]. We adapted a set of previously established questions on shared temporalities using Van Rensburg's seven-point Likert scale (with 1 = "strongly disagree" to 7 = "strongly agree") to "The temporal aspect, implementation and coordination of the final output"[56]. Similarly, we adapted seven-point Likert scales on "shared understanding of the vision of the final output" and "shared understanding of the final output" from Cash et al. [25]. All the questions were randomly ordered, and one question for each topic was constructed as a negation to avoid acquiescence bias (a tendency to agree with statements, to some extent, irrespective of their content) [77].

Finally, to contextualise the hypotheses and ensure that performance was not negatively impacted by the timeline, intervention participants evaluated the final concept following a typical business case structure in several stages [55]. First, they evaluated a description of the main reasoning for the concept with potential advantages and disadvantages. Second, based on the literature regarding the Consolidated Framework for Implementation Research, they evaluated issues that made sense for the organisation's management [78]. The final concept was self-estimated for deployment and impact. Novelty, cost, feasibility, and resources were deployment issues. The impact evaluation was based on reduced costs, risks, resources, CO₂, and potential for increased revenue as described in the "How might we" question. We used a fully labelled four-point scale to avoid the capture biases in central tendency [79] and a fully labelled format to gain greater reliability [80]. Scales with more than four points were not found operational in the pre-testing of the study design. The final concept descriptions and individual evaluations were then transcribed, anonymised, and randomly ordered as a basis for assessment by the expert panel (Step 5, TABLE 1) [72].

In addition to the participant reflection outlined above, the data for the final concepts were also evaluated by an expert panel formed of three managers active in the organisation with different focus areas of expertise: maintenance, sales, and research and development (R&D). Each manager evaluated the final concepts on a four-point agreement scale for a realistic cost to deploy the concept. This examined whether the participants' evaluation of their final concept's novelty and potential cost aligned with the managers' judgement and hence whether the participants understood their output well. Finally, non-parametric Mann-Whitney U tests were used for all hypotheses due to the nature of the data and its non-normal distribution [81]. All measures are summarised in TABLE 3.

<Please include Table 3 about here>

F. Robustness

To ensure hypothesis blindness, neither the management nor the participants were informed about the experimental manipulation or hypotheses. Participants were only focused on solving the "How might we" question as an emergent issue for the company. Informal follow-ups the following month with all participants also ensured that they were not hypothesis-aware and had not identified the significance of the control or intervention conditions.

The effects of education, gender, and age were checked using Mann-Whitney U tests and revealed no statistically significant differences between teams in the control and experimental conditions. Further, we compared participants' evaluations of a usual solution innovation clockspeed from idea to prototype (the usual product clockspeed) and again found no statistically significant differences between teams in the control and experimental conditions ($p > .05$). Here, we used Bluedorn's scale

with numbers [67, pp. 265–272]. A Mann-Whitney U test on the time perception revealed no statistically significant differences (control mean = 34.2 months, control standard deviation = 29.3 months, intervention mean = 31.0 months, intervention standard deviation = 29.9 months). When analysing participants from the sales (S) and maintenance (M) departments separately, we found a non-significant difference (S mean = 24 months, S standard deviation = 21.7 months, M mean = 49.5 months, M standard deviation = 68.5 months).

Next, we evaluated potential differences in shared understanding in the “How might we” question as a prerequisite of the experiment. Here we used previously established questions by Cash et al.’s [25] seven-point scale for a “general shared understanding of the problem”, as shown in TABLE 4, with one revised question included. These revealed no statistically significant differences ($p > .05$), indicating no confounding differences in how teams understood the question.

<Please include Table 4 about here>

Finally, through follow-up communication with the expert panel, comments were provided on each final concept. No substantial differences were described in the novelty of the final concepts between the control and intervention teams. This provides a first piece of contextual evidence suggesting that the timeline intervention did not negatively impact overall innovation performance.

Overall, these follow-ups and tests provide qualitative and quantitative support for the robustness of our data and its suitability for hypothesis testing.

IV. Results

We present our results regarding Hypotheses 1 and 2 (quantitative testing) and the innovation outcome (qualitative contextualisation). Overall, our results strongly support Hypothesis 1. We

calculated the differences in shared key concepts in absolute listed numbers and normalised percentages, as shown in TABLE 5. The results were significant across all measures ($p < .01$). The number of actual shared concepts increased while the total number of listed concepts decreased when using a timeline (in contrast there was essential no change in either measure in the control teams). We thus confirm Hypothesis 1.

<Please include Table 5 about here>

In contrast to Hypothesis 1, our results do not support Hypothesis 2. While participants gave overall high scores on all Likert-scale questions, the findings were not significant (TABLE 6). Only the sub-statement, “My team members have a similar understanding about the timeline for completing the final output”, was significant in the hypothesised direction (control mean = 4.6, control standard deviation = 1.7, intervention mean = 5.8, intervention standard deviation $n = 1.1$, $U = 108$, $p = .018$ (one-tailed Mann-Whitney U test)) suggesting that the intervention did indeed foster a higher level of shared understanding specifically related to the timeline intervention. Further, the mean understanding of the final output was actually negative (control mean = 6, control standard deviation = .7, intervention mean = 5.3, intervention standard deviation $n = .9$, $U = 97.5$, $p = .008$ (one-tailed Mann-Whitney U test)). While these results are negative with respect to Hypothesis 2, the first does provide a measure of confirmation of engagement with the intervention and hence serves as a positive manipulation check.

<Please include Table 6 about here>

Finally, to contextualise the innovation outcomes, we performed two qualitative outcome analyses (TABLE 7). First, we analysed the participant’s self-evaluation of the estimated deployment and effect of the final concept. The findings suggest similar self-evaluations of the teams, irrespective of their

experimental allocation to control or intervention (TABLE 7). Second, the expert panel evaluated whether the performance aligned with company processes. In the expert panel evaluation, the intervention team received, on average, a lower performance evaluation across the managers than the control teams, although this difference was not significant (TABLE 7). Overall, these evaluations suggest little difference in innovation outcomes between the control and intervention teams.

<Please include Table 7 about here>

V Discussion

This paper set out to examine how shared understanding of differing clockspeeds can be developed in the energy sector context by testing a clockspeed-focused intervention during a creative-innovation task. The research was built on two main hypotheses contextualised by additional qualitative analysis. Overall, our results substantially extend current literature by highlighting the potentially important role of timelines in supporting the development of shared understanding in creative-innovation contexts where teams have different clockspeeds, even though timelines are not typical in creative-innovation tasks.

Our results showed strong support for Hypothesis 1, suggesting that teams exposed to a clockspeed-focused innovation support, based on a timeline, will display greater actual shared understanding compared to teams with generic innovation support. We found a timeline not only provides a temporal mapping (e.g., [30]) but directly impacts actors' ideas and shared understanding. From a traditional point of view, a timeline typically supports the question of "when", but we did not find shared understanding of time in the experiment. Instead, we found a timeline influences the "what" (taskwork) and "how" (teamwork), which is indeed critical for team functioning. These findings extend existing literature on the importance of temporal synchronisation structures in facilitating

the development of understanding [25], [26] and shared awareness in creative teams [43]. In the energy sector context, this result is significant because departments have substantially different clockspeeds and are simultaneously challenged to manage ambidextrous exploration and exploitation activities to meet the demands of the green transition [1], [2]. Thus, our work highlights how temporal structures, such as timelines, can form a key element in supporting the development of shared understanding in settings with diverse clockspeeds and provide an accessible but currently little-applied tool in the creative-innovation context.

In contrast to the strong support for Hypothesis 1, we found little support for Hypothesis 2, which states that teams exposed to a clockspeed-focused innovation support, based on a timeline, will display greater perceived shared understanding compared to teams with generic innovation support. Improvement in perceived shared understanding was neither confirmed in the temporal view of implementation (“how” and “when”) nor with respect to the final concepts (“what”). The perception of shared understanding is important since it can have significant implications for strategic decision-making, change, and economic and social performance [6] beyond the development of actual shared understanding (Hypothesis 1). Therefore, the lack of improvement in perceived shared understanding suggests that additional managerial action would be needed to use the timeline intervention effectively in context if it is to improve shared understanding and build an accurate perception of the overall team understanding.

Finally, we contextualised these hypotheses via a qualitative evaluation of the intervention’s impact via participant reflection and an expert panel. Importantly, we found that although a timeline is neither a creativity tool nor typically used in creative-innovation tasks (either generally or within the focal organisation), this did not negatively impact the teams’ creative performance. This is a critical

finding because it suggests that timeline interventions can be effectively implemented in creative-innovation tasks with diverse clocksPEEDS to significantly impact shared understanding without negatively impacting other aspects of creative performance.

This study makes two significant theoretical contributions. First, this study examined the influence of diverse clocksPEEDS among individuals and departments, which is crucial for better comprehending and navigating the complexities in the energy sector [42]. This approach moves beyond relying solely on average clocksPEEDS [13]. While prior research has demonstrated the positive influence of shared understanding on team performance and coordination, little attention has been given to the impact of multiple time perspectives in teams [33]. This study extends prior research by recognising the importance of shared temporal understanding in team performance and output relevance [27].

Second, this study emphasises that shared understanding goes beyond formalised temporal structures and highlights the influence of less visible, subjective shared temporal understandings, which significantly shape individuals' and teams' behaviours [14]. Our findings thus align with studies that challenge the notion that the structure of time is solely objective [38], [45]. This interaction between actual understanding, perceptions, and formalised temporal elements highlights the complex nature of time coordination in organisations. By recognising this interplay, we gain a more comprehensive understanding of how time functions within organisational contexts.

A Managerial Implications

This work has two main managerial implications. First, it suggests that managers can use a timeline as an effective tool to create shared understanding in creative-innovation contexts with multiple

clockspeeds without compromising other aspects of creative performance. This implication is important, as multiple clockspeeds have been found to impact firm performance and strategic success in innovation efforts (e.g., [13], [15]), and timelines or other temporal supports are not typically used during creative tasks.

Second, while timelines can help foster shared understanding, managers should pay particular attention to potential divergence between actual shared understanding and perceptions of this in the team (see the contrasting results from the concept map- and Likert-based evaluations). Additional managerial support may be needed to help align these two forms of understanding and to broaden the shared understanding across the wider organisation. This could be achieved by including a timeline request from the managers as a normal part of the creative-innovation process and through active reflection on, for example, concept maps used to concretise actual shared understanding in a team. This is important given that managers and staff typically make decisions based on their perception of the situation [85]; thus, aligning actual and perceived shared understanding is key.

B Limitations and Further Work

These implications should be considered in light of two main limitations. First, the focus on shared understanding in situations with diverse clockspeeds limits the complexity of the conditions and responses but was necessary to reduce the independent variables and is typical in experimental design [61]. The conceptual scope of the work can be expanded to further examine the direct and indirect impacts on innovation outcomes or other relevant aspects related to clockspeed in the broader ambidextrous context. For example, follow-up experiments or case studies on the effects

of shared understanding over time during innovation contexts could illuminate how this impacts the wider innovation process and organisational context.

Second, the experiment was limited to the energy sector. This sector was selected due to its important role in the green transition. Moreover, in most countries the energy sector is of considerable size, making this study valid and important. However, experimenting with other sectors, particularly those facing multiple clockspeed challenges, could reveal interesting nuances in understanding the relationship between timeline-type tools, shared understanding, and innovation outcomes in diverse clockspeed contexts. Furthermore, the non-random assignment characteristic of quasi-experiments introduces the potential for bias and limits the degree to which confounding factors can be mitigated. However, the nature of the population and task meant full randomisation was not possible [58], and therefore, we adopted an approach where bias and other confounding factors were mitigated via careful consideration of how participants were allocated to each team and condition. Thus, the quasi-experimental design was valid in this case. Future experiments could aim to overcome this limitation by examining a broader population or developing a different experimental task.

More generally, future studies should investigate the nuanced clockspeeds within the innovation process beyond organisation or industry averages. For instance, when considering the widespread use of timelines in project planning, it is essential to explore when, how, and under what circumstances timelines effectively foster shared understanding to support innovation. Further, we focused on examining how we might impact shared understanding in the face of diverse clockspeeds, yet many questions remain with respect to how shared understanding emerges across different clockspeeds and temporal orientations within organizations. This points to the need for

follow-up, qualitative studies to further unpacking how shared understanding, clockspeed, and innovation interact to drive project success. Given our findings this examination is an important next step.

Behavioural effects, related to aspects such as individual team members' backgrounds, might similarly affect team members' focus on clockspeed, their ability to understand contrasting clockspeeds, and clockspeeds' effects on the innovation process. Understanding how multiple temporal structures influence shared understanding will enable organisations to implement more effective project management strategies, improve team dynamics, and ultimately drive successful innovations.

Overall, despite certain limitations, our work provides robust and nuanced insight into how shared understanding of differing clockspeeds can be developed in the context of the energy sector. However, we also highlight the need for further work exploring the relationship between actual and perceived improvement regarding shared understanding and its impact on wider innovation outcomes over time.

V Conclusions

Surprisingly little research has been conducted on how differing temporal perspectives impact innovation, particularly in sectors with a traditionally slow pace, such as the energy sector. Thus, knowing how to improve shared understanding in a context with multiple clockspeeds is a key question. In this research, we examined how shared understanding of differing clockspeeds can be developed in innovation teams in the energy sector. We tested hypotheses via a quasi-experiment that took place within the energy industry to assess the impact of an intervention targeting the

shared understanding of clockspeed during an innovation task. We found that a timeline intervention increased shared understanding (but not the perception of it) without negatively impacting creative task performance. Therefore, we substantially add to the extant literature by highlighting the potentially important role of timelines in supporting the development of shared understanding in creative-innovation contexts with diverse clockspeeds, even though such interventions are not typical of creative-innovation tasks.

References

- [1] IEA et al., "Pandemic, War, and Global Energy Transitions," *Energies (Basel)*, vol. 15, no. 17, pp. 1–23, 2022, doi: 10.3390/en15176114.
- [2] "World Energy Outlook 2022 – Analysis - IEA," 2022.
- [3] M. E. Kreye and Z. Perunovic, "You don't forget where you come from: linking formation and operations in publicly funded innovation networks," *Production Planning and Control*, vol. 31, no. 10, pp. 816–828, 2020, doi: 10.1080/09537287.2019.1693066.
- [4] F. Frei, S. R. Sinsel, A. Hanafy, J. Hoppmann, and M. Richter, "Leaders or laggards? The evolution of electric utilities' business portfolios during the energy transition," *Energy Policy*, vol. 120, pp. 655–665, Sep. 2018, doi: 10.1016/j.enpol.2018.04.043.
- [5] B. K. Sovacool, "How long will it take? Conceptualising the temporal dynamics of energy transitions," *Energy Res Soc Sci*, vol. 13, pp. 202–215, Mar. 2016, doi: 10.1016/j.erss.2015.12.020.
- [6] P. Bansal, J. Reinecke, R. Shuddaby, and A. Langley (Eds.), "Special Issue of Strategic Organization 'Temporal Work: The Strategic Organization of Time,'" *Strateg Organ*, vol. 17, no. 1, pp. 145–149, Feb. 2019, doi: 10.1177/1476127018824166.
- [7] P. Ellwood and S. Horner, "In search of lost time: the temporal construction of innovation management," *R&D Management*, vol. 50, no. 3, pp. 364–379, Jun. 2020, doi: 10.1111/radm.12405.
- [8] W. J. Orlikowski and J. Yates, "It's about time: temporal structuring in organisations," *Organization Science*, vol. 13, no. 6, pp. 684–700, 2002.
- [9] R. Garud, P. Tuertscher, and A. H. Van de Ven, "Perspectives on Innovation Processes," *Acad Manag Ann*, vol. 7, no. 1, pp. 775–819, Jun. 2013, doi: 10.1080/19416520.2013.791066.
- [10] M. D. Mumford, K. E. Bedell-Avers, and S. T. Hunter, "Planning for innovation: A multi-level perspective," *Research in Multi-Level Issues*, vol. 7, pp. 107–154, 2007, doi: 10.1016/S1475-9144(07)00005-7/FULL/XML.
- [11] N. Slawinski and P. Bansal, "The Paradoxes of Time in Organizations," *The Oxford Handbook of Organizational Paradox*, vol. 1, no. January 2019, pp. 1–25, Sep. 2017, doi: 10.1093/OXFORDHB/9780198754428.013.19.

- [12] O. Dedehayir and S. J. Mäkinen, "Measuring industry clockspeed in the systemic industry context," *Technovation*, vol. 31, no. 12, pp. 627–637, Dec. 2011, doi: 10.1016/j.technovation.2011.07.008.
- [13] C. Fine, "Clockspeed: Winning Industry Control in the Age of Temporary Advantage," New York, 1998.
- [14] M. Schultz and T. Hernes, "Temporal interplay between strategy and identity: Punctuated, subsumed, and sustained modes," *Strateg Organ*, vol. 18, no. 1, pp. 106–135, Feb. 2020, doi: 10.1177/1476127019843834.
- [15] T. Guimaraes, "Industry clockspeed's impact on business innovation success factors," *European Journal of Innovation Management*, vol. 14, no. 3, pp. 322–344, Aug. 2011, doi: 10.1108/14601061111148825.
- [16] L. Kavin and R. Narasimhan, "An investigation of innovation processes: the role of clock speed," *Supply Chain Forum: An International Journal*, vol. 18, no. 3, pp. 189–200, Jul. 2017, doi: 10.1080/16258312.2017.1345276.
- [17] S. Nadkarni and V. K. Narayanan, "Strategic schemas, strategic flexibility, and firm performance: The moderating role of industry clockspeed," *Strategic Management Journal*, vol. 28, no. 3, pp. 243–270, Mar. 2007, doi: 10.1002/smj.576.
- [18] J. Reinecke, R. Suddaby, A. Langley, and H. Tsoukas, "Time, temporality, and history in process organisation studies: An introduction," in *Time, Temporality, and History in Process Organization Studies*, Oxford University Press, 2021, pp. 1–14. doi: 10.1093/oso/9780198870715.003.0001.
- [19] T. Jamsb, M. Llorca, L. Meeus, and T. Schittekatte, "Energy Network Innovation for Green Transition: Economic Issues and Regulatory Options," *Danish utility regulator's anthology project series on better regulation in the energy sector*, vol. 1, no. 1, Mar. 2021, doi: 10.51138/umnp7884.
- [20] H. Mendelson and R. R. Pillai, "Industry Clockspeed: Measurement and Operational Implications," *Manufacturing & Service Operations Management*, vol. 1, no. 1, pp. 1–20, Jan. 1999, doi: 10.1287/msom.1.1.1.
- [21] C. Saunders, C. Van Slyke, and D. R. Vogel, "My time or yours? Managing time visions in global virtual teams," *Academy of Management Executive*, vol. 18, no. 1. Academy of Management, pp. 19–31, 2004. doi: 10.5465/AME.2004.12691177.
- [22] M. A. West, "Sparkling fountains or stagnant ponds: An integrative model of creativity and innovation implementation in work groups," *Applied Psychology*, vol. 51, no. 3. John Wiley & Sons, Ltd, pp. 355–387, Jul. 01, 2002. doi: 10.1111/1464-0597.00951.
- [23] F. Chu, A. Kolodny, S. Maital, and D. Perlmutter, "The innovation paradox: Reconciling creativity & discipline how winning organisations combine inspiration with perspiration," in *IEEE International Engineering Management Conference*, 2004, pp. 949–953. doi: 10.1109/iemc.2004.1408831.
- [24] P. B. Paulus, R. M. Korde, J. J. Dickson, A. Carmeli, and R. Cohen-Meitar, "Asynchronous Brainstorming in an Industrial Setting," *Human Factors*, vol. 57, no. 6. SAGE Publications Inc., pp. 1076–1094, Sep. 04, 2015. doi: 10.1177/0018720815570374.
- [25] P. Cash, E. A. Dekoninck, and S. Ahmed-Kristensen, "Supporting the development of shared understanding in distributed design teams," *Journal of Engineering Design*, vol. 28, no. 3, pp. 147–170, 2017, doi: 10.1080/09544828.2016.1274719.
- [26] C. Aubé, V. Rousseau, S. Tremblay, "Perceived shared understanding in teams: The motivational effect of being 'on the same page,'" *British Journal of Psychology*, vol. 106, no. 3, pp. 468–486, Aug. 2015, doi: 10.1111/bjop.12099.

- [27] C. B. Gibson and P. C. Earley, "Collective cognition in action: Accumulation, interaction, examination, and accommodation in the development and operation of group efficacy beliefs in the workplace," *Academy of Management Review*, vol. 32, no. 2, pp. 438–458, Apr. 2007, doi: 10.5465/AMR.2007.24351397.
- [28] E. A. C. Bittner and J. M. Leimeister, "Why shared understanding matters - Engineering a collaboration process for shared understanding to improve collaboration effectiveness in heterogeneous teams," in *Proceedings of the Annual Hawaii International Conference on System Sciences*, 2013, pp. 106–114. doi: 10.1109/HICSS.2013.608.
- [29] C.-M. Chiu, M.-H. Hsu, and E. T. G. Wang, "Understanding knowledge sharing in virtual communities: An integration of social capital and social cognitive theories," *Decis Support Syst*, vol. 42, no. 3, pp. 1872–1888, Dec. 2006, doi: 10.1016/j.dss.2006.04.001.
- [30] J. M. P. Gevers, S. Rispens, and J. Li, "Pacing style diversity and team collaboration: The moderating effects of temporal familiarity and action planning," *Group Dynamics*, vol. 20, no. 2, pp. 78–92, 2016, doi: 10.1037/gdn0000049.
- [31] C. Stockstrom and C. Herstatt, "Planning and uncertainty in new product development," *R and D Management*, vol. 38, no. 5, pp. 480–490, 2008, doi: 10.1111/j.1467-9310.2008.00532.x.
- [32] A. Dong, M. S. Kleinsmann, and F. Deken, "Investigating design cognition in the construction and enactment of team mental models," *Des Stud*, vol. 34, no. 1, pp. 1–33, Jan. 2013, doi: 10.1016/j.destud.2012.05.003.
- [33] E. Krull, P. Smith, and K. Husted, "Knowledge Sharing in Roadmapping: Toward a Multilevel Explanation," *IEEE Trans Eng Manag*, vol. 69, no. 1, pp. 67–80, Feb. 2022, doi: 10.1109/TEM.2021.3052974.
- [34] S. Mohammed and K. K. Alipour, "It's Time for Temporal Leadership: Individual, Dyadic, Team, and Organisational Effects," *Ind Organ Psychol*, vol. 7, no. 2, pp. 178–182, Jun. 2014, doi: 10.1111/iops.12128.
- [35] E. Bittner and J. Leimeister, "Creating shared understanding in heterogeneous work groups: Why it matters and how to achieve it," *Journal of Management Information Systems*, vol. 31, no. 1, pp. 111–144, Jul. 2014, doi: 10.2753/MIS0742-1222310106.
- [36] S. J. Mäkinen and O. Dedehayir, "Business ecosystems' evolution-an ecosystem clockspeed perspective," *Advances in Strategic Management*, vol. 30, pp. 99–125, 2013, doi: 10.1108/S0742-3322(2013)0000030007.
- [37] J. Gerdal, I. Stjerne, and J. Oehmen, "ACTING IN TIME: TEMPORAL WORK ENACTING TENSIONS AT THE INTERFACE BETWEEN TEMPORARY AND PERMANENT ORGANISATIONS," in *Research in the Sociology of Organizations*, Emerald Group Holdings Ltd., 2020, pp. 81–103. doi: 10.1108/S0733-558X20200000067010.
- [38] F. Simon and A. Tellier, "Balancing contradictory temporality during the unfold of innovation streams," *International Journal of Project Management*, vol. 34, no. 6, pp. 983–996, Aug. 2016, doi: 10.1016/j.ijproman.2016.05.004.
- [39] G. Silberg, "The clockspeed dilemma," 2015.
- [40] D. Sandra, J. Segers, and R. Giacalone, "How organisations can benefit from entrainment: a systematic literature review," *Journal of Organizational Change Management*. Emerald Publishing, 2022. doi: 10.1108/JOCM-01-2022-0023.
- [41] N. Granqvist and R. Gustafsson, "Temporal institutional work," *Academy of Management Journal*, vol. 59, no. 3, pp. 1009–1035, Jun. 2016, doi: 10.5465/amj.2013.0416.

- [42] S. Mohammed and D. Schillinger, "Translating Time-Based Research into Team Interventions: An Actionable, Evidence-Based Approach," *J Clin Transl Sci*, vol. 6, no. 1, p. e2, 2021, doi: 10.1017/cts.2021.874.
- [43] M. J. Waller, A. E. Franklin, and D. B. Parcher, "Time perspective balance and team adaptation in dynamic task contexts," *J Organ Behav*, vol. 41, no. 3, pp. 263–275, 2020, doi: 10.1002/job.2431.
- [44] I. Soucy Chartier, P. Gaudreau, and M. C. Fecteau, "From dispositional affect to academic goal attainment: The mediating role of coping," *Anxiety Stress Coping*, vol. 24, no. 1, pp. 43–58, Jan. 2011, doi: 10.1080/10615801003725360.
- [45] S. Mohammed and S. Nadkarni, "Temporal diversity and team performance: The moderating role of team temporal leadership," *Academy of Management Journal*, vol. 54, no. 3, pp. 489–508, Jun. 2011, doi: 10.5465/AMJ.2011.61967991.
- [46] P. B. Paulus, K. I. van der Zee, and J. B. Kenworthy, "Diversity and Group Creativity," in *The Oxford Handbook of Group Creativity and Innovation*, Oxford University Press, 2019, pp. 32–49. doi: 10.1093/oxfordhb/9780190648077.013.3.
- [47] M. A. Le Dain, V. Merminod, and M. Yager, "Collaborative practices in new product development projects involving suppliers," *Production Planning and Control*, vol. 31, no. 4, pp. 308–321, 2020, doi: 10.1080/09537287.2019.1632500.
- [48] P. Serrador, "The importance of the planning phase to project success," Paper presented at PMI Global Congress, no. October 2012, pp. 1–8, 2012, Accessed: Jul. 14, 2023. [Online]. Available: <https://www.pmi.org/learning/library/importance-planning-phase-project-success-6021>
- [49] E. K. Yakura, "Charting Time: Timelines as Temporal Boundary Objects," *Academy of Management Journal*, vol. 45, no. 5, pp. 956–970, Oct. 2002, doi: 10.5465/3069324.
- [50] I. Nawrot and A. Doucet, "Timeline localisation," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, Springer Verlag, 2014, pp. 611–622. doi: 10.1007/978-3-319-07233-3_56.
- [51] E. N. Johnson, P. M. J. Reckers, and G. D. Bartlett, "Influences of timeline and perceived strategy effectiveness on balanced scorecard performance evaluation judgments," *Journal of Management Accounting Research*, vol. 26, no. 1, pp. 165–184, Apr. 2014, doi: 10.2308/jmar-50639.
- [52] D. L. Alonso, A. Rose, C. Plaisant, and K. L. Norman, "Viewing personal history records: A comparison of tabular format and graphical presentation using lifelines," *Behaviour and Information Technology*, vol. 17, no. 5, pp. 249–262, Jan. 1998, doi: 10.1080/014492998119328.
- [53] M. Brehmer, B. Lee, B. Bach, N. H. Riche, and T. Munzner, "Timelines Revisited: A Design Space and Considerations for Expressive Storytelling," *IEEE Trans Vis Comput Graph*, vol. 23, no. 9, pp. 2151–2164, Sep. 2017, doi: 10.1109/TVCG.2016.2614803.
- [54] R. Sosa, "Accretion theory of ideation: evaluation regimes for ideation stages," *Design Science*, vol. 5, 2019, doi: 10.1017/dsj.2019.22.
- [55] B. J. Van Putten, "Business case framework," in *Supporting Reuse in Business Case Development*, Springer Fachmedien, 2013, pp. 57–80. doi: 10.1007/978-3-658-01171-0_5.
- [56] J. J. van Rensburg, C. M. Santos, S. B. de Jong, and S. Uitdewilligen, "The Five-Factor Perceived Shared Mental Model Scale: A Consolidation of Items Across the Contemporary Literature," *Front Psychol*, vol. 12, p. 6189, Jan. 2022, doi: 10.3389/fpsyg.2021.784200.

- [57] A. Onwuegbuzie and K. Collins, "A Typology of Mixed Methods Sampling Designs in Social Science Research," *The Qualitative Report*, 2015, doi: 10.46743/2160-3715/2007.1638.
- [58] P. Cash, O. Isaksson, A. Maier, and J. Summers, "Sampling in design research: Eight key considerations," *Des Stud*, vol. 78, p. 101077, Jan. 2022, doi: 10.1016/j.destud.2021.101077.
- [59] P. B. Paulus, J. Baruah, and J. B. Kenworthy, "Enhancing collaborative ideation in organisations," *Front Psychol*, vol. 9, no. OCT, pp. 1–12, 2018, doi: 10.3389/fpsyg.2018.02024.
- [60] P. B. Paulus and H. C. Yang, "Idea generation in groups: A basis for creativity in organisations," *Organ Behav Hum Decis Process*, vol. 82, no. 1, pp. 76–87, 2000, doi: 10.1006/obhd.2000.2888.
- [61] P. Cash and S. Culley, "The role of experimental studies in design research," *The Routledge Companion to Design Research*, pp. 175–189, Oct. 2014, doi: 10.4324/9781315758466-17.
- [62] G. J. Puccio, R. L. Firestien, C. Coyle, and C. Masucci, "A Review of the Effectiveness of CPS Training: A Focus on Workplace Issues," *Creativity and Innovation Management*, vol. 15, no. 1, pp. 19–33, Mar. 2006, doi: 10.1111/j.1467-8691.2006.00366.x.
- [63] D. Siemon, F. Becker, and S. Robra-Bissantz, "How Might We? From Design Challenges to Business Innovation BeDien-Begleitforschung Personennahe Dienstleistungen View project," *Journal of Creativity and Business Innovation*, vol. Vol. 4, no. December, 2018, [Online]. Available: www.journalcbi.com
- [64] A. Brem, "Creativity on Demand: How to Plan and Execute Successful Innovation Workshops," *IEEE Engineering Management Review*, vol. 47, no. 1, pp. 94–98, Mar. 2019, doi: 10.1109/EMR.2019.2896557.
- [65] K. Wang, "Towards a Taxonomy of Idea Generation Techniques," *Foundations of Management*, vol. 11, no. 1, pp. 65–80, Jan. 2019, doi: 10.2478/fman-2019-0006.
- [66] A. J. Shipp and Y. Fried, *Time and work: How time impacts individuals*, vol. 1. Taylor and Francis, 2014. doi: 10.4324/9781315817019.
- [67] A. C. Bluedorn, *The human organisation of time : temporal realities and experience*. Stanford Business Books, 2002.
- [68] A. Chang, C. Hatcher, and J. Kim, "Temporal boundary objects in megaprojects: Mapping the system with the Integrated Master Schedule," *International Journal of Project Management*, vol. 31, no. 3, pp. 323–332, 2013, doi: 10.1016/j.ijproman.2012.08.007.
- [69] R. G. Cooper, S. J. Edgett, and E. J. Kleinschmidt, "Optimising the Stage-Gate Process: What Best-Practice Companies Do—I," <http://dx.doi.org/10.1080/08956308.2002.11671518>, vol. 45, no. 5, pp. 21–27, 2016, doi: 10.1080/08956308.2002.11671518.
- [70] J. N. Druckman and C. D. Kam, "Students as Experimental Participants: A Defense of the 'Narrow Data Base,'" *SSRN Electronic Journal*, Jul. 2009, doi: 10.2139/SSRN.1498843.
- [71] W. M. Trochim and D. McLinden, "Introduction to a special issue on concept mapping," *Eval Program Plann*, vol. 60, pp. 166–175, Feb. 2017, doi: 10.1016/j.evalprogplan.2016.10.006.
- [72] P. Cash and C. Snider, "Investigating design: A comparison of manifest and latent approaches," *Des Stud*, vol. 35, no. 5, pp. 441–472, 2014, doi: 10.1016/j.destud.2014.02.005.
- [73] K. A. Neuendorf, *The Content Analysis Guidebook*, 2nd ed. 2455 Teller Road, Thousand Oaks California 91320, USA: SAGE Publications, Inc, 2017. doi: 10.4135/9781071802878.

- [74] W. M. K. Trochim, "An introduction to concept mapping for planning and evaluation," *Eval Program Plann*, vol. 12, no. 1, pp. 1–16, Jan. 1989, doi: 10.1016/0149-7189(89)90016-5.
- [75] P. Badke-Schaub, K. Lauche, A. Neumann, and S. Ahmed, "Task – Team – Process: Assessment and Analysis of the Development of Shared Representations in an Engineering Team," in *Design Thinking Research Symposium*, London, UK, 2007, pp. 1–12.
- [76] A. T. Jebb, V. Ng, and L. Tay, "A Review of Key Likert Scale Development Advances: 1995–2019," *Frontiers in Psychology*, vol. 12, 2021, doi: 10.3389/fpsyg.2021.637547.
- [77] J. J. Ray, "Acquiescence and problems with forced-choice scales," *Journal of Social Psychology*, vol. 130, no. 3, pp. 397–399, 1990, doi: 10.1080/00224545.1990.9924595.
- [78] M. A. Kirk, C. Kelley, N. Yankey, S. A. Birken, B. Abadie, and L. Damschroder, "A systematic review of the use of the Consolidated Framework for Implementation Research," *Implementation Science*, vol. 11, no. 1, BioMed Central Ltd., pp. 1–13, May 17, 2016, doi: 10.1186/s13012-016-0437-z.
- [79] P. E. Rossi, Z. Gilula, and G. M. Allenby, "Overcoming scale usage heterogeneity: A bayesian hierarchical approach," *J Am Stat Assoc*, vol. 96, no. 453, pp. 20–31, Mar. 2001, doi: 10.1198/016214501750332668.
- [80] L. J. Weng, "Impact of the number of response categories and anchor labels on coefficient alpha and test-retest reliability," *Educ Psychol Meas*, vol. 64, no. 6, pp. 956–972, Dec. 2004, doi: 10.1177/0013164404268674.
- [81] T. W. MacFarland and J. M. Yates, "Mann–Whitney U Test," in *Introduction to Nonparametric Statistics for the Biological Sciences Using R*, Springer International Publishing, 2016, pp. 103–132, doi: 10.1007/978-3-319-30634-6_4.
- [82] C. A. O'Reilly and M. L. Tushman, *Lead and Disrupt*. Stanford University Press, 2021, doi: 10.1515/9781503629639.

Tables and Figures

Figure 1 Experimental procedure

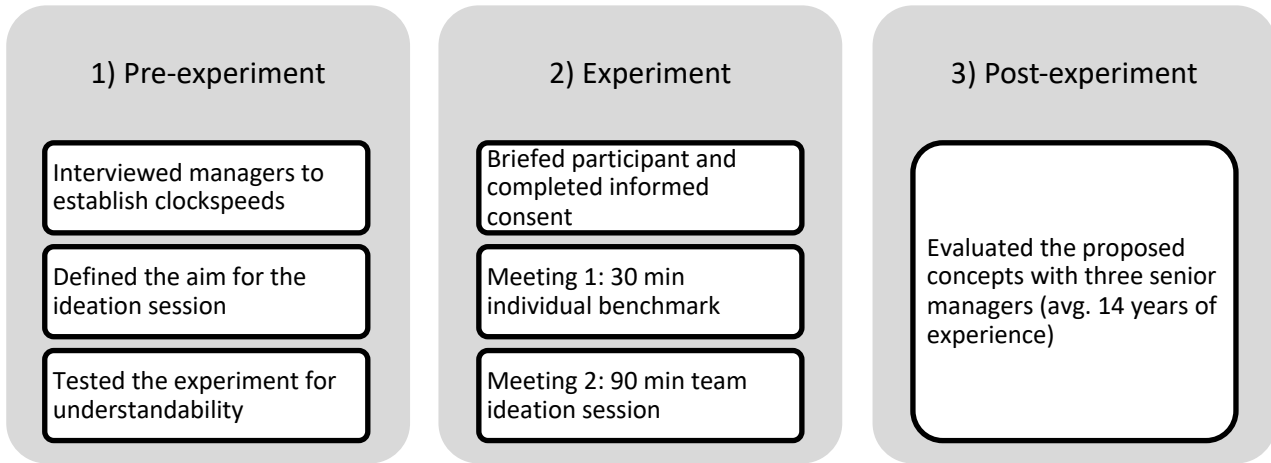


Figure 2 Example of concept mapping

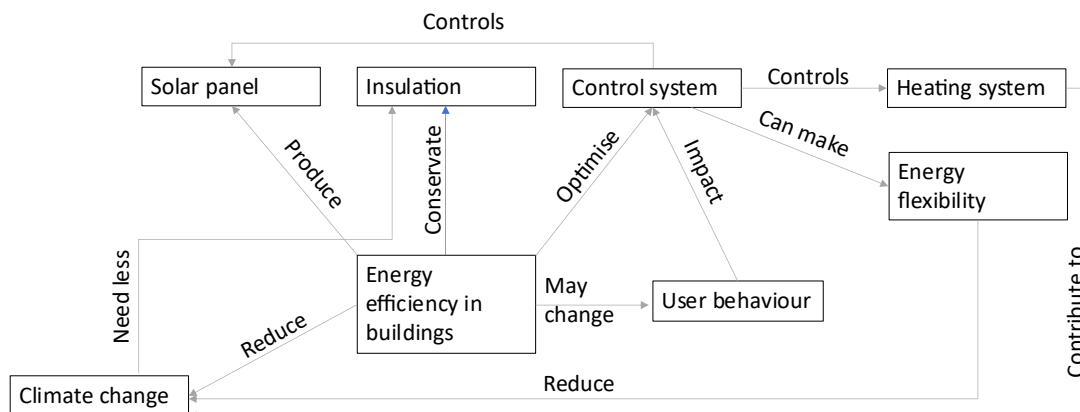


Table 1 Steps in the experiment

Step	Activity
1)	Online individual meeting (30 min) <ol style="list-style-type: none"> Briefing and informed consent Gathering demographic and work experience data Concept mapping to answer the “How might we” question (10 min)
2)	Two-week gap to ensure consistency across teams and to give participants time to reflect on the “How might we” question
3)	Physical meeting with hybrid creatives process (90 min including presentation, reading time, and debriefing) <ol style="list-style-type: none"> Briefing and informed consent. Individual work Icebreaker with a revised brainwriting in answering “How might we hinder....” Individual brainwriting (5 min) and sharing the findings with the team. Teamwork (7 min) Brainwriting new concepts. Individual work (10 min) Break (5 min) Brainwriting to jointly improve concepts with control or intervention. Teamwork (15 min) <div> <div> e i) Control Discussing how to, in general, improve and deploy ideas in practice but not limited to, e.g.: <ul style="list-style-type: none"> What do functions, structure, interface, and process look like? Which skills, competencies, or management are needed? In general: question how, what, who, why, and where, to your ideas? </div> <div> e ii) Intervention Discussing how to, in general, improve and deploy ideas in practice by leveraging their implementation over time. Considering but not limited to, e.g.: <ul style="list-style-type: none"> What does a realistic timeline and interface for the concepts look like? How do we collaborate better for innovation over time? When is the timeline appropriate to have a maximum impact? </div> </div> Brainwriting to improve the concepts. Teamwork (13 min) Concept mapping to answer the “How might we” question. Individual work (10 min) Choosing the best concept. Teamwork (5 min) Brainwriting of the best concept for implementation. Teamwork (13 min) Evaluating the final concept for impact and deployment on a four-point scale and estimating the product clockspeed. Individual work (10 min)
4)	Data handling <ol style="list-style-type: none"> Transcribing all the text from booklets Anonymisation and randomisation in preparation for expert evaluation
5)	Expert evaluation via individual online meeting (60 min) <ol style="list-style-type: none"> Reading the listed final concepts with participants’ descriptions (text from this TABLE step 3a and 3h) Evaluation of the associated participant evaluations using a four-point Likert scale for agreement. Individual work (45 min).

Table 2 Overview of the employee sample with two experimental conditions

General information	Control Team	Intervention Team
Team size	2	2
Number of employees	20	18
Number of teams	10	9
Age (years) in Mean (M) and Standard Deviation (SD)	M 47.3 S.D. 8.2	M 48.6 S.D. 12.2
Experience in the same national company (years) in Mean (M) and Standard Deviation (SD)	M 10.1 S.D. 11.1	M 11.3 S.D. 12.7
Education (years) in Mean (M) and Standard Deviation (SD)	M 13.9 S.D. 1.6	M 13.9 S.D. 1.7
Gender	17 males and 3 females	14 males and 4 females

Table 1 Summary of measures

Hypothesis	Measures
1)	<p>Comparison of the concepts listed by participants in the before and after maps (Step 1c and Step 3g, TABLE 1) for actual shared understanding:</p> <ul style="list-style-type: none"> i) Change in the percentage of <u>shared</u> concepts between before and after maps in control versus intervention ii) Change in the percentage of <u>listed</u> concepts between before and after maps in control versus intervention participants
2)	<p>Participants self-report seven-point Likert scale (strongly disagree to strongly agree), assessing perceived shared understanding for the final concepts following [56] (a-c), and participants self-report seven-point Likert scale (strongly disagree to strongly agree) assessing perceived shared understanding for [25] (d-e).</p> <p>a) The temporal aspect of the final output:</p> <ul style="list-style-type: none"> i) My team members have a similar understanding about the specific processes for completing various tasks for implementing the final output. ii) My team completely disagrees about how to deal with implementing the final output. iii) My team members have a similar understanding about how to best implement the final output. iv) My team members have a similar understanding about the relationships between tasks when implementing the final concept. <p>b) The temporal aspect of the implementation of the final output:</p> <ul style="list-style-type: none"> i) My team members have a similar understanding about the deadlines for implementing the final output. ii) My team members do not have a similar understanding about how quickly we need to work to implement the final output. iii) My team members have a similar understanding about appropriately timing our work for implementing the final output. iv) My team members have a similar understanding about coordinating the timing of our work for implementing the final output. <p>c) The temporal aspect of coordination in the implementation of the final output:</p>

	<ul style="list-style-type: none"> i) My team members have a similar understanding about coordinating the timing of our work for implementing the final output. ii) My team members do not have a similar understanding about sharing information with each other when implementing the final output. iii) My team members have a similar understanding about how we should interact with each other when implementing the final output. iv) My team members have a similar understanding about the best methods to communicate with each other when implementing the final output. <p>d) The final output:</p> <ul style="list-style-type: none"> i) My team completely disagrees about the final output. ii) My team members have a similar understanding about the final output as a commercially competitive product or process for our organisation. iii) I fully understand the final output. iv) I fully understand the final output as a commercially competitive product or process for my organisation. <p>e) The vision for the final output:</p> <ul style="list-style-type: none"> i) I completely misconceived the understanding of the final output. ii) My team members have a similar understanding about the vision for the proposed final output. iii) My team completely disagrees about the goal for the proposed final output. iv) My team members have a similar understanding about the timeline for completing the final output.
Qualitative contextualisation	<p>The participant's evaluation of the final concept by following (a-b)</p> <p>The expert panel evaluation of the final concept by following (a-c)</p> <ul style="list-style-type: none"> a) Four-point fully labelled Likert scale for participant self-report evaluation of the final concept for deployment, based on [55]: <ul style="list-style-type: none"> i) Evaluate the novelty of the final concept to the organisation (improvement, big improvement, change, or radical innovation). ii) Evaluate the feasibility of deploying the final concept (very easy, easy, complex, or very complex). iii) Evaluate the cost of deploying the final concept (less than 13,000 euros, 13,000–134,000 euros, 134,000 euros–1 million euros, 1–10 million euros, more than 10 million euros). iv) Evaluate the resources of deploying the final concept (less than one person-month, up to one person-year, 1–10 person-years, and more than 10 person-years). b) Four-point fully labelled Likert scale for participant self-report evaluation of the final concept for effect, based on the “How might we” question and [55]: <ul style="list-style-type: none"> i) Evaluate the impact on the reduced cost of the final concept (target 50%) (less than 3%, 2%–10%, 10%–25%, more than 25%). ii) Evaluate the impact on the reduced risks of the final concept (target 50%) (less than 3%, 2%–10%, 10%–25%, more than 25%). iii) Evaluate the impact on the CO₂ reduction of the final concept (target 50%) (less than 3%, 2%–10%, 10%–25%, more than 25%). iv) Evaluate the impact on the increased revenue of the final concept (target 50%) (less than 3%, 2%–10%, 10%–25%, more than 25%). c) Four-point Likert scale from expert panel analysis of participants' evaluations from A and B together with the written description of the final concept [77], with the following question:

	Please make an X on your evaluation (1-4) of the teams' realistic assessment of the proposed concept on cost for deployment (strongly disagree, disagree, agree, and strongly agree)
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Table 4 Results of shared understanding in general to the “How might we” question

Likert (seven-point scale)	Control participants (n=20)		Intervention participants (n=18)		Difference (Mann-Whitney U test)	
	Mean	Standard Deviation	Mean	Standard Deviation	U	p
i) My understanding of the team's definition and requirements of the problem decreased since the start of the task.	4.5	2.0	4.4	2.2	174	.436
ii) I fully understand the definition and requirements of the problem.	6.1	0.8	5.9	0.9	161.5	.298
iii) My team members have a similar understanding about the definition and requirements of the problem.	6.4	0.6	6.3	0.6	168	.364

Table 2 Results for actual shared understandings

Concept map measures	Control teams (n=10)		Intervention teams (n=9)		Difference (Mann-Whitney U test)	
	Mean	Standard Deviation	Mean	Standard Deviation	U	p
i) Change in the number of shared concepts	.0	1.2	2.8	1.0	2.5	<.001
ii) Percentage change of shared concepts	-.1%	12.3	30.8%	12.6	1	<.001
iii) Change in the number of listed concepts	.7	3.5	-5.3	4.4	11.5	.004
iv) Percentage change in the number of listed concepts	.1%	13.9	-21.0%	17.6	15	.008

Table 3 Results for perceived shared understandings (using two tailed testing)

Likert (Seven-point scale)	Control teams (n=20)		Intervention teams (n=18)		Difference (Mann-Whitney U test)	
	Mean	Standard Deviation	Mean	Standard Deviation	U	p
2. a) The temporal aspect of the final output	4.3	.9	4.1	.3	154.5	.233
2. b) The temporal aspect of the implementation of the final output	5.7	1.1	5.5	.8	156	.245
2. c) The temporal aspect of coordination in the implementation of the final output	5.8	.9	5.5	.9	146	.164
2.d) The final output	6.0	.7	5.3	.9	97.5	.008
2. e) The vision of the final output	5.4	1.1	5.7	.7	156.5	.252

Table 7 Self-evaluation of the Final Concept and Expert Panel Evaluation of the Realistic Cost for Deployment of the Final Concept

Performance analysis	Likert (Four-point scale)	Control teams (n=10)		Intervention teams (n=9)	
		Mean	Standard Deviation	Mean	Standard Deviation
i) Self-evaluation from participants	Deployment	2.4	.8	2.6	.8
	Effect	2.7	.9	2.7	.9
ii) Expert panel	Maintenance manager	3.1	.7	2.4	1.0
	Sales manager	2.9	.6	2.7	.5
	R&D manager	3.7	.7	3.4	1.0