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Improving hybrid brainstorming outcomes with computer-supported scaffolds: Prompts and cognitive group awareness

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ABSTRACT

Guided by the dual pathways to creativity model (DPCM), this study explores how two computer-supported scaffolds—prompts and cognitive group awareness—can enhance the quality of ideas generated in hybrid brainstorming sessions that combine individual and group brainstorming. While prior research has employed these scaffolds to improve group work focusing on convergent thinking in CSCL settings, their application to stimulate divergent thinking in brainstorming sessions remains unexplored. To address this gap, 94 higher education students were randomly assigned into triads and tasked with generating business ideas addressing sustainability issues under three different conditions. In control condition, students generated ideas in a hybrid brainstorming session following an individual-group-individual sequence without any additional support. In experimental 1 condition (prompts), students followed the same sequence but received prompts during the first individual phase, encouraging the use of SCAMPER principles to enhance cognitive persistence. In experimental 2 condition (prompts + cognitive group awareness), students received the same prompts during the individual phases and additional support during the group phase, aimed at enhancing cognitive group awareness through the sharing of individually generated ideas to increase cognitive flexibility. To evaluate the impact of providing prompts, the outcomes of the first individual phase across all three conditions were compared, revealing that students in both experimental conditions generated ideas with significantly higher originality compared to those in control condition. To assess the influence of fostering cognitive group awareness, the outcomes of experimental 1 and 2 conditions were compared. Students in experimental 2 condition showed superior idea quality in both the group and final individual phases, as evidenced by higher originality, outperforming experimental 1 condition. Furthermore, the findings revealed that flexibility mediated the relationship between cognitive group awareness and idea originality, while also suggesting that originality can emerge through alternative pathways beyond those proposed by the DPCM.

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1. Introduction

Hybrid brainstorming involves individuals alternating between brainstorming in group and individual settings, which is regarded as one of the most effective methods for organizing brainstorming sessions (Paulus et al., 2018). This is because such an arrangement would allow both unconstrained ideation in individual brainstorming and the stimulation of additional ideas by exposure to the ideas of others (Korde & Paulus, 2017). Empirical evidence suggests that hybrid brainstorming, regardless of the sequence of individual and group phases, yields superior outcomes compared to either individual or group brainstorming alone, especially in generating a greater quantity of ideas (Korde, 2014; Korde & Paulus, 2017; Paulus et al., 2015).

However, the ultimate goal of a brainstorming session extends beyond generating a large number of ideas, but to generate high-quality ones (Briggs & Reinig, 2010). Despite the increase in quantity observed in hybrid settings, research has shown no significant differences in the quality of ideas generated in hybrid brainstorming sessions compared to those produced in individual or group settings, as measured by their degree of originality (Korde, 2014; Korde & Paulus, 2017; Paulus et al., 2015). A possible reason for these findings might be that improving quality requires additional support that can effectively assist individuals to break free from conventional thinking (Rietzschel, 2018) and guide them toward generating higher-quality ideas (Althuizen & Reichel, 2016). The dual pathway to creativity model (DPCM; Nijstad et al., 2010) offers a theoretical foundation for such support in the form of scaffolds, highlighting the significance of cognitive persistence—deeply engaging with specific idea categories—and cognitive flexibility—exploring diverse and novel idea categories. According to Nijstad et al., 2010, carefully designed scaffolds are needed to effectively facilitate these essential cognitive processes, ultimately leading to higher-quality outcomes.

Researchers have long explored the use of digital technology to provide scaffolds aimed at enhancing brainstorming, leading to the development of electronic brainstorming (EBS) since the early 1990s (Dennis & Williams, 2003). EBS was primarily conceptualized as a means to increase the quantity of ideas generated during brainstorming sessions (Maaravi et al., 2021), drawing on Osborn's (1963) premise that "*quantity breeds quality*" (p. 131). To achieve this, the focus was on maximizing process gains, such as social facilitation, while mitigating common process losses associated with traditional face-to-face brainstorming, including social loafing, evaluation apprehension and production blocking (Dennis & Williams, 2003).

In line with its primary objective, early implementations of EBS incorporated several features aimed at improving brainstorming outcomes (see Maaravi et al., 2021, for an overview). These features included real-time performance feedback graphs to enhance social comparison (Shepherd et al., 1995), anonymous collaboration to reduce evaluation apprehension (Barki & Pinsonneault, 2001), and the simultaneous submission of ideas to minimize production blocking (Gallupe et al., 1994). As technology advanced, these mechanisms evolved to address specific process gains and reduce process losses more effectively. For example, integrating game elements into group brainstorming has been shown to introduce competitive dynamics that enhance social comparison, motivating participants to engage more actively (Guegan et al., 2021). Similarly, the use of virtual avatars embedded with social identity cues has reinforced group membership (Guegan et al., 2017), thereby reducing social loafing and promoting more active participation in group work (van Dick et al., 2009). Additionally, chatbots functioning as brainstorming partners have been shown to reduce evaluation apprehension by providing a non-judgmental environment (Wieland et al., 2022).

Although technological interventions in EBS have made valuable contributions, their effectiveness in enhancing brainstorming outcomes remains contested. Inconsistent findings regarding the number of ideas generated have led some researchers to characterize EBS's productivity as an "illusion" (Pinsonneault et al., 1999), suggesting that it is particularly effective for facilitating brainstorming in large group settings (Dennis & Williams, 2003). Furthermore, even when EBS successfully increases the number of ideas, this does not always translate into improved quality. Research indicates that increasing the number of ideas does not necessarily result in higher quality (Baruah & Paulus, 2008; Rietzschel et al., 2014), highlighting the intricate relationship between quantity and quality in brainstorming (Reinig & Briggs, 2008). Therefore, there is a critical need to harness technology to offer more targeted support that fosters the development of high-quality ideas in brainstorming sessions (Dennis et al., 2019), with an emphasis on the critical cognitive processes involved (Minas et al., 2018).

To address the aforementioned need, the present research draws upon a substantial body of research within the field of Computer-Supported Collaborative Learning (CSCL) and investigates the impact of two computer-supported scaffolds—*prompts* and *cognitive group awareness*—on the creative process, specifically in terms of engaging the cognitive pathways outlined by the DPCM. Prompts are designed to break down a task into specific activities at certain times, often by posing questions or providing sentence starters meant to guide participants' focus and structure their contributions (Weinberger et al., 2005). In contrast, cognitive group awareness tools focus on enhancing collaboration by providing participants with access to "information about group members' knowledge, the information they possess, or the opinions they hold, all of which can be used to coordinate activities in the content space of collaboration" (Janssen & Bodemer, 2013, p. 42).

These computer-supported scaffolds have proven effective in facilitating cognitive and metacognitive processes essential for tasks requiring collaborative effort (Schnaubert & Vogel, 2022). Numerous studies have demonstrated the efficacy of prompts in enhancing interdisciplinary collaborative problem-solving (Noroozi, Biemans, et al., 2013), enhancing peer feedback (Latifi et al., 2023), and fostering argumentative knowledge co-construction (Noroozi, Weinberger, et al., 2013, Noroozi et al., 2016). Similarly, research has shown the potential of cognitive group awareness tools in enriching collaborative learning by provoking cognitive conflicts and discussions (Farrokhnia et al., 2019; Li et al., 2021) and initiating transactive memory system processes (Schreiber & Engelmann, 2010).

Nevertheless, the application of prompts and cognitive group awareness tools has primarily been explored in contexts emphasizing convergent thinking—such as knowledge co-construction and problem-solving—where the goal is to build consensus and integrate diverse viewpoints into a shared understanding (Weinberger et al., 2007) or a solution (Noroozi, Biemans, et al., 2013). While these scaffolds have proven effective in facilitating such tasks, their potential to support tasks involving divergent thinking without premature judgment—such as brainstorming (Al-Samarraie & Hurmuzan, 2018)—remains largely unexplored. As a key contribution to the field, this study aims to investigate how these two scaffolds can be adapted, guided by the DPCM, to effectively facilitate the cognitive processes essential for generating high-quality ideas in brainstorming sessions. By addressing this gap, the current study also responds to ongoing calls for research that focuses not only on enhancing the quantity but also the quality of outcomes in brainstorming sessions (Maaravi et al., 2021; Rietzschel, 2018).

2. Theoretical framework

The DPCM proposed by Nijstad et al. (2010) identifies two cognitive pathways for generating high-quality ideas: persistence and flexibility. Engaging in these pathways requires individuals to be mentally stimulated and actively involved (Dreu et al., 2011). To facilitate this mental engagement, the provision of specific process constraints—or support—such as rules, task structures, and instructions, is essential (Nijstad et al., 2021). As illustrated in Fig. 1, the provided support might influence the cognitive pathways in diverse ways—strongly stimulating one pathway (bold lines), while weakly or even negatively affecting the other (dotted lines) (Nijstad et al., 2010). This complexity in their influence underscores the need for careful design and application of support mechanisms to optimally foster such cognitive engagements.

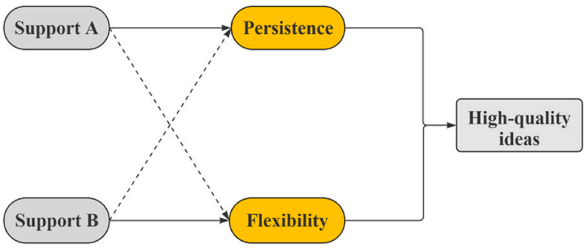

Fig. 1. The influence of support mechanisms on cognitive pathways in the DPCM-adapted from Nijstad et al. (2010)

Table 1
The Participants' demographic information.

		Frequency	Percentage
Gender	Female	41	43.7 %
	Male	53	56.3 %
Educational level	Bachelor	12	12.8 %
	Master	82	87.2 %
Program	Food Technology	46	48.9 %
	Biotechnology	17	18.1 %
	Environmental science	11	11.7 %
	Nutrition and Health	7	7.4 %
	Forest and Nature Conservation	5	5.3 %
	Consumer studies	5	5.3 %
	Molecular Life Sciences	1	1.1 %
	Organic agriculture	1	1.1 %
	Plant Sciences	1	1.1 %
		Mean	**Std. Error**
Age	All	24.1	2.7
	Females	24.2	3.2
	Males	24.0	2.2

Next, each pathway is explained in more detail to inform the adaptation of CSCL scaffolds for enhancing persistence and flexibility in hybrid brainstorming sessions.

2.1. The DPCM: the persistence pathway

According to the Search for Ideas in Associative Memory (SIAM) model, brainstorming involves a two-step cognitive process (Nijstad & Stroebe, 2006). First, individuals retrieve knowledge concepts from long-term memory and bring them into working memory. Second, they combine these concepts to generate new ideas by forming associations or applying them in new contexts. However, individuals often retrieve concepts that are highly accessible in long-term memory (Stroebe et al., 2010) and synthesize them in conventional or less innovative ways within working memory (Rietzschel et al., 2014). Falling into this so-called "path of least resistance" often results in conventional ideas (Stroebe et al., 2010).

To overcome this tendency toward the path of least resistance and stimulate more innovative outcomes, the DPCM suggests encouraging individuals to follow what is referred to as the "persistence pathway" (Nijstad et al., 2010). This cognitive pathway involves perseverance when searching in associative memory and systematically and incrementally combining retrieved knowledge concepts (Baas et al., 2013). Following the persistent pathway manifests itself as a prolonged cognitive effort to generate a higher number of ideas within a few idea categories—also known as "within-category fluency" (Nijstad et al., 2002). This approach is effective because each idea category contains only a limited number of conventional ideas (De Dreu et al., 2008). Therefore, deep and persistent exploration within each category can elevate the likelihood of generating more quality ideas over time (Rietzschel et al., 2007).

Cognitive persistence can be influenced by external factors such as process or outcome constraints (Nijstad et al., 2021). Research has shown that strategies like increasing brainstorming time (Baruah & Paulus, 2016), narrowing problem scope (Rietzschel et al., 2007, 2014), or promoting risk-averse thinking (Levine et al., 2016) can enhance persistence and the quality of outcomes. However, these interventions are often applied "prior" brainstorming, with less attention to support "during" the task itself (Bhagwatwar et al., 2018). While effective in controlled labs, this approach may not work as well in real-world settings, where ongoing support is crucial to maintaining persistence. Furthermore, providing support during the task may be more effective, especially when delivered at the right moment to facilitate relevant cognitive processes (Molenaar & Roda, 2008), while granting learners the autonomy to choose how and when to utilize the support provided (Jang et al., 2010).

Providing support during learning activities in face-to-face settings can be difficult, but advances in computer technologies offer promising solutions. Based on the CSCL literature, computer-supported prompts have great potential to deliver real-time support and facilitate key socio-cognitive processes during collaborative tasks (Vogel et al., 2017).

2.1.1. Computer-supported prompts

Prompts in the context of CSCL are often integrated into the graphical user interface of online learning environments, typically taking the form of "sentence starters" or "question stems" (Näykki et al., 2017). These prompts are designed to provide learners with guidelines, hints, and suggestions that facilitate key cognitive and metacognitive processes not only in collaborative settings (Järvelä et al., 2016; Noroozi, Biemans, et al., 2013) but also in tasks performed individually (Tsovaltzi et al., 2014, 2015). Specifically, question prompts have been shown to help learners focus their attention and monitor their learning (Ge & Land, 2003) by encouraging deeper elaboration on the posed questions (Papadopoulos et al., 2011).

For example, Ge and Land (2003) demonstrated that using a set of 10 key question prompts for solving ill-structured problems (e.g., "*What are the technical components of the problem?*") significantly improved students' performance in addressing complex issues. Similarly, Noroozi, Biemans, et al. (2013) showed that presenting question prompts to facilitate transactive knowledge sharing, such as "*Could you please elaborate on that?*"—focusing on individual analysis of learning partners' arguments—helped learners provide higher-quality contributions, resulting in improved joint and individual problem-solving outcomes. According to Papadopoulos et al. (2011), such open-ended questions requiring short written answers are particularly effective because they encourage thoughtful responses, prompting learners to actively engage with the learning task.

Despite their demonstrated potential, scholars argue that developing effective prompts requires careful consideration of educational and psychological theories (Tchounikine, 2016), ensuring that prompts are theory-informed and thoughtfully designed to guide learners in performing specific learning tasks (Papadopoulos et al., 2011). For instance, in designing their question prompts, Noroozi, Biemans, et al. (2013) applied a coding scheme that offers an extensive categorization of transactive contributions, which are considered essential for learning. Similarly, when computer-supported prompts aim to enhance the quality of hybrid brainstorming outcomes by enhancing cognitive persistence, their design must effectively promote deeper exploration of idea categories.

2.1.2. Using "prompts" to enhance persistence in hybrid brainstorming

Effective use of prompts to enhance cognitive persistence in hybrid brainstorming requires careful attention to two critical design aspects. The *first* involves determining the optimal phase for their implementation. The persistence pathway requires systematic thinking, which involves blocking out distracting thoughts from one's working memory and maintaining full attention on the task at hand (Nijstad et al., 2010). Therefore, if a computer-supported prompt aims to facilitate cognitive persistence in hybrid brainstorming, its application might be more impactful during the individual phase of the brainstorming session. This is because, in the group phase, there is a higher likelihood of disruptions to the train of thought due to exposure to others' ideas (Korde & Paulus, 2017).

The *second* consideration relates to the content of the prompts. When using prompts to foster cognitive persistence in brainstorming sessions, the content should encourage a systematic and in-depth exploration within limited idea categories. In this context, SCAMPER principles provide a well-established framework for designing question prompts aimed at triggering deeper cognitive engagement.

SCAMPER provides process-oriented instructions by offering "concrete suggestions, or prompts, on how to act" (Weinberger, 2011, p. 194). By guiding individuals through specific cognitive operations—such as substituting, combining, adapting, modifying, putting to other uses, eliminating, or rearranging elements (Eberle, 1972)—SCAMPER can facilitate deeper activation of associative networks and the manipulation of concepts (or existing ideas) in working memory (see Appendix 1 for examples of SCAMPER principles).

To date, few studies have employed SCAMPER principles to enhance brainstorming, yielding mixed results. Some research indicates that combining SCAMPER with group brainstorming generates more original ideas than group brainstorming alone (Moreno et al., 2016; Rahimi & Shute, 2021). However, other studies suggest that group brainstorming alone may produce more original ideas than when combined with SCAMPER (Chulvi et al., 2012, 2013). This variation in effectiveness may stem from challenges in maintaining cognitive persistence in group settings, where SCAMPER's potential is hindered by frequent disruptions from others' ideas. In contrast, individual settings allow uninterrupted focus, enabling SCAMPER to more effectively promote the cognitive persistence required for generating higher-quality ideas.

Additionally, merely providing a description of SCAMPER principles does not ensure proper implementation. For instance, Rahimi and Shute (2021) embedded SCAMPER principles into a computer game using pop-up menus to better engage students. These menus presented question prompts on the screen, such as one encouraging substitution: "*Pick one object you included in this level and ask yourself, "What else can be used instead of [that item] to make the level more creative?*". Similarly, Yeo and Quek (2014) demonstrated that delivering SCAMPER principles through prompts in a computer-based environment—posing questions like "*What parts can be removed or taken away without altering its function?*" (the eliminate principle)—resulted in more original ideas than merely providing SCAMPER descriptions. They attributed this improvement to the enhanced attention to detail facilitated by the scaffolding technique.

In light of these considerations, the current study hypothesizes that providing question prompts to encourage the use of SCAMPER principles during individual brainstorming will enhance the quality of generated idea (**H1**) and increase their persistence (**H2**). Furthermore, the enhancement in idea quality is hypothesized to be mediated by persistence (**H3**), as suggested by the DPCM.

2.2. The DPCM: the flexibility pathway

Achieving high-quality outcomes in creative tasks can also be attributed to "cognitive flexibility" (Baas et al., 2013). This flexibility is characterized by an exploration of broad cognitive categories (Nijstad & Stroebe, 2006), which may lead to the formation of novel and remote associations in memory (De Dreu et al., 2008). Building on this perspective, Nijstad et al. (2010) proposed another pathway in their DPCM that can result in quality ideas, known as the "flexibility pathway". The activation of such a pathway in brainstorming sessions is manifested by the generation of ideas across a large number of idea categories (Nijstad et al., 2021). In their meta-analysis, Nijstad et al. (2010) demonstrated that an increase in the number of idea categories, is associated with generating ideas of higher average originality, a key quality criterion.

However, despite the benefits of cognitive flexibility, individuals often find it challenging to break free from their readily "accessible" ideas (Paulus & Brown, 2007), limiting themselves to only a few familiar idea categories (van Hooijdonk et al., 2022). This tendency creates a significant barrier to creative idea generation, known as the "fixation effect". From a psychological perspective, mental fixation is the inability to break free from preoccupying ideas that capture the mind's attention (Linsey et al., 2010). This may result in the generation of mostly identical ideas, which all fall within limited idea categories (George & Wiley, 2019). To address this issue, scholars recommend implementing external scaffolds to help individuals overcome mental fixation (van Hooijdonk et al., 2022), thereby stimulating them to think outside the box through increasing flexibility (Peterson & Pattie, 2022).

One promising approach involves introducing stimuli that activate less accessible knowledge stored in long-term memory, encouraging broader exploration of an individual's knowledge base (Althuizen & Reichel, 2016). Interventions such as immersing individuals in incongruent virtual environments (van Hooijdonk et al., 2022) or using random stimuli like everyday objects or newspaper images (Ritter & Mostert, 2018) have shown some effectiveness. However, these methods come with limitations. First, given the critical role of stimulus relatedness in influencing idea generation (Klein et al., 2020; Wang & Nickerson, 2019) and activating relevant cognitive processes (Althuizen & Reichel, 2016), such approaches may yield inconsistent results in different contexts, as stimuli considered remote in one situation may be seen as unrelated in another. Research indicates that unrelated stimuli often lead to superficial or less meaningful preliminary ideas that are eventually discarded due to low relevance (Wang & Nickerson, 2019). Second, these studies rely on manual stimulus collection, which is time-consuming and prone to biases, limiting the scalability and generalizability of findings across diverse brainstorming contexts.

A more scalable alternative is the use of cognitive group awareness tools, commonly employed in CSCL environments. These computer-supported scaffolds facilitate the sharing of remotely related yet contextually relevant knowledge among group members, enhancing cognitive flexibility without depending on pre-prepared stimuli.

2.2.1. Computer-supported cognitive group awareness

Group awareness is defined as the "consciousness and information of various aspects of the group and its members" (Gross et al., 2005, p. 327). This concept is emphasized in research as significant for effective group work (Rojas et al., 2022; Tsovaltzi et al., 2014, 2015), particularly in newly formed groups (Schreiber & Engelmann, 2010). A key aspect of group awareness is "cognitive awareness" (Bodemer & Dehler, 2011), which pertains to how well group members are aware of their collaborators' knowledge (Janssen & Bodemer, 2013). One way to foster this awareness is by providing *context-related knowledge*—information that "contextualizes the collaboration rather than presenting content information to be learned" (Engelmann et al., 2009), such as sharing scores from a multiple-choice pretest that reflects participants' knowledge and expertise (Sangin et al., 2011). While this type of information is vital for coordinating tasks, it often fails to provide detailed insights into the specific knowledge or contributions of individual group members (Janssen & Bodemer, 2013).

In contrast, promoting *content-related awareness* provides a more detailed approach by offering explicit information about each member's knowledge, opinions, and contributions. Such support fosters a more specific—rather than global—awareness of knowledge gaps (Loibl & Rummel, 2014), which can encourage the revision of "partial, naïve, or erroneous schemas" (Lee et al., 2024, p. 174), ultimately enhancing individual learning outcomes (Farrokhnia et al., 2019). Additionally, perceived differences between group members—whether in knowledge, assumptions, or opinions—can stimulate collaborative elaboration processes, such as engaging in in-depth discussions of controversial perspectives (Bodemer, 2011), often resulting in improved collaborative outcomes (Janssen & Bodemer, 2013).

Several tools have been proposed to enhance cognitive awareness among group members, leveraging the potential of computer technologies (see Buder, 2011, for an overview). One widely adopted method for promoting content-related knowledge awareness involves sharing information representations of collaborators during group activities, such as individually generated concept maps (Farrokhnia et al., 2019), opinions on various propositions (Gijlers & de Jong, 2009), or arguments on controversial topics (Tsovaltzi et al., 2015). A common feature across these practices is that, although these representations are individually generated, they remain highly relevant to the task context and are shared in a manner that enriches group knowledge, thereby fostering more effective collaboration.

2.2.2. Using "cognitive group awareness" to enhance flexibility in hybrid brainstorming

To enhance cognitive flexibility in hybrid brainstorming environments by fostering cognitive group awareness, it is essential to share individually generated artifacts that are contextually relevant and contribute to the group's collective understanding of the problem. Individually generated ideas seem to be particularly valuable for this purpose, as they reflect each member's unique knowledge and perspective. When these ideas are effectively disseminated among the group, they enrich the variety and depth of each individual's knowledge about the problem (Ma et al., 2011). Moreover, sharing ideas during group brainstorming helps unlock cognitive pathways that might otherwise remain inaccessible when working individually (Paulus & Brown, 2007). This phenomenon, known as "category accessibility", refers to the ability to access certain categories of ideas that individuals might not reach on their own due to insufficient associative cues (Brown & Paulus, 1996). In a group setting, the introduction of ideas by one member provides the necessary associative cues for others, enabling them to explore a wider range of associative pathways and semantic categories during brainstorming (Nijstad & Stroebe, 2006). This process can result in each group member generating ideas in new categories (Paulus et al., 2001), which can then positively contribute to the group brainstorming's outcomes (Paulus et al., 2013).

Given the potential for idea sharing to improve group brainstorming outcomes, numerous studies have specifically explored the role of computer technologies in facilitating idea sharing during group brainstorming sessions and their impact on the outcomes (for an overview, see Maaravi et al., 2021). However, most of these studies have primarily focused on facilitating the sharing of ideas generated "during" group brainstorming (Maaravi et al., 2021). More specifically, participants were asked to generate new ideas and share them with other members within a relatively short time frame, potentially leading to a limited number of ideas being shared among group members. Moreover, the ways in which idea sharing influences the underlying cognitive processes that lead to creative outcomes have not received sufficient attention.

Considering the significant role that the number of shared ideas plays in enhancing brainstorming outcomes (Paulus et al., 2013), this study hypothesizes that fostering cognitive group awareness by sharing ideas generated both *before* and *during* group brainstorming sessions, compared to sharing only ideas generated during the sessions, will lead to a higher quality of collaboratively generated ideas (**H4**) and an increase in the number of idea categories (i.e., flexibility) (**H5**). Furthermore, it is proposed that this enhancement in idea quality will be mediated by flexibility **(H6)**.

Additionally, since cognitive stimulation resulting from enhanced cognitive group awareness during the group phase can carry over to the subsequent individual phase in hybrid settings, as suggested by Korde and Paulus (2017), this study posits that under the condition where ideas generated both before and during group brainstorming are shared, there will be a higher number of idea categories in the subsequent individual brainstorming session (**H7**). Consequently, this is expected to improve the quality of ideas generated (**H8**), with the enhancement in idea quality being mediated by flexibility (**H9**).

3. Method

3.1. Participants and design

The experiment was conducted as a one-time workshop for students enrolled in two optional university courses designed to enhance skills relevant to future careers. Participation in the study was voluntary, resulting in a sample of 94 students. A sensitivity power analysis performed using G*Power indicated that this sample size provides statistical power above 0.8 for detecting ANCOVA effect sizes in the medium to large range at a significance level of $\alpha = .05$. This level of power is considered sufficient for interventions in brainstorming contexts, as prior research frequently reports large effect sizes for interventions aimed at fostering creative collaboration (Dennis et al., 2013), particularly in hybrid settings (Korde & Paulus, 2017; Ritter & Mostert, 2018).

As shown in Table 1, the sample consisted of 43.7% females ($n = 41$) and 56.3% males ($n = 53$). A significant majority were master's students (87.2%, $n = 82$). The participants were primarily enrolled in academic programs that showcase the university's primary focus on agriculture and food sciences. The most populated programs were Food Technology (48.9%, $n = 46$), Biotechnology (18.1%, $n = 17$), and Environmental Science (11.7%, $n = 11$). The average age of students was 24.1 years, with a standard deviation of 2.7 years. Female students had a slightly higher average age of 24.2 years ($SD = 3.2$) compared to male students at 24.0 years ($SD =$

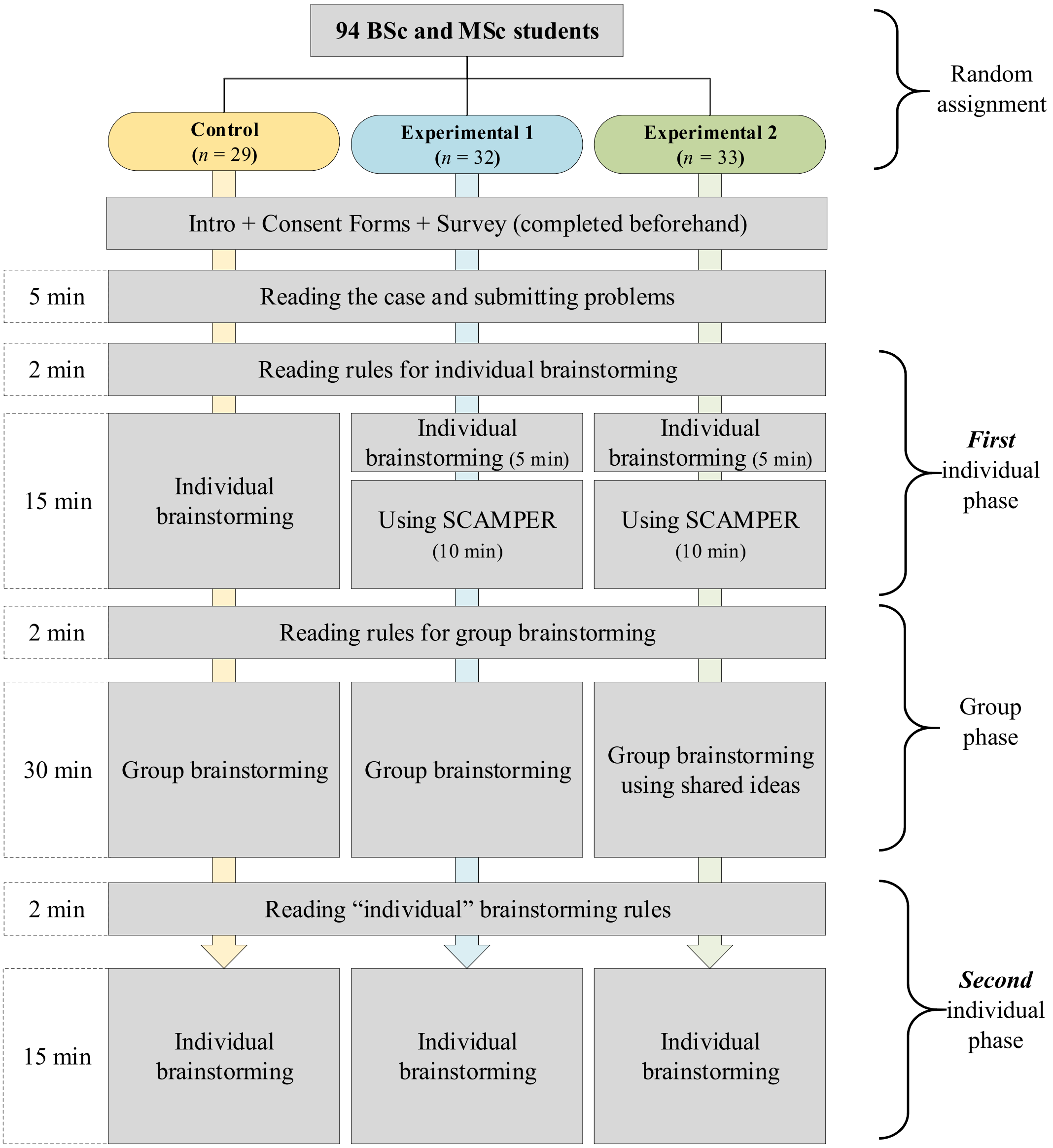

Fig. 2. The procedure followed per condition.

2.2).

Students were randomly assigned to 31 triads, which were then randomly assigned to one of three conditions: control ($n = 29$), experimental 1 ($n = 32$), and experimental 2 ($n = 33$). To maintain anonymity, each student received a unique username and password to access an online platform developed for the study. Informed consent was obtained before the study. Participants were told their results would be used for research and they could request data exclusion. In addition, ethical approval was obtained from the university's social sciences ethics committee.

The procedure used a hybrid brainstorming approach with individual-group-individual (IGI) phases, known to effectively generate many ideas (Korde, 2014; Korde & Paulus, 2017). In all conditions, students first generated ideas individually, then brainstormed in a group, and finally generated ideas individually again (see Fig. 2). At the beginning of the experiment, the lead author explained the online platform. Upon logging in, students reviewed an introduction, provided consent, and completed a demographic survey covering education, field of study, gender, and attitudes toward entrepreneurship. They were then directed to the idea generation task, activated simultaneously for all participants with a system prompt.

In all conditions, the first step involved familiarizing participants with the problem case for idea generation. Sustainable development was chosen as it is a broad, authentic topic familiar to many (Baggen et al., 2017) and aligns with the university's goal to raise awareness of sustainable development goals. Participants had *5 min* to read the problem case and reflect on sustainability issues around them (see Appendix 2). Participants in all conditions were also required to read the same brainstorming rules for 2 min before both the individual and group phases, adopted from Paulus et al. (2006) (see Appendix 3).

Control condition: Participants followed all steps without special intervention. In the first individual phase, they were asked to submit as many business ideas as possible, which were not shared with peers, even during the group phase. In the group phase, they collaborated for 30 min, with submitted ideas immediately visible to all group members. Afterwards, they had 15 min to brainstorm individually on the same case.

Experimental 1 condition. Participants followed the same steps as control condition, with a key difference in the first individual phase. This phase was divided into two parts: first, 5 min to freely brainstorm and submit ideas; second, the platform displayed their submitted ideas only to themselves, along with question prompts encouraging them to use SCAMPER principles to further develop and expand their ideas individually for an additional *10 min*.

Experimental 2 condition. All steps were identical to those in Experiment 1, except during the group phase. In this phase, the system facilitated cognitive group awareness by sharing all individually generated ideas among group members. Participants were instructed to review others' ideas for 5 min and discuss ways to expand on the ones they found interesting.

3.2. Material

3.2.1. The ideation hub

The Ideation Hub is an online platform designed specifically for this study to guide participants through a structured brainstorming process and implement the proposed scaffolds. It provides task instructions for both individual and group phases, enforces time limits, and presents the necessary rules before and during each phase. The platform also offers tailored support for each condition. For example, participants in experimental 1 and 2 conditions could view their previously generated ideas and were encouraged to apply SCAMPER principles using built-in question prompts. After viewing the prompt, participants had also access to a description of the selected principle along with an example of how to implement it (see Fig. 3).

The platform could display or hide ideas generated during the first individual phase, depending on the condition (see Fig. 4). This allowed exploration of how fostering cognitive group awareness through sharing individually generated ideas impacts group brainstorming outcomes. Research findings have demonstrated that such a feature enhances individuals' engagement with shared ideas, thereby better improve their group awareness (see Ferreira et al., 2011). During the group phase, all group members could submit

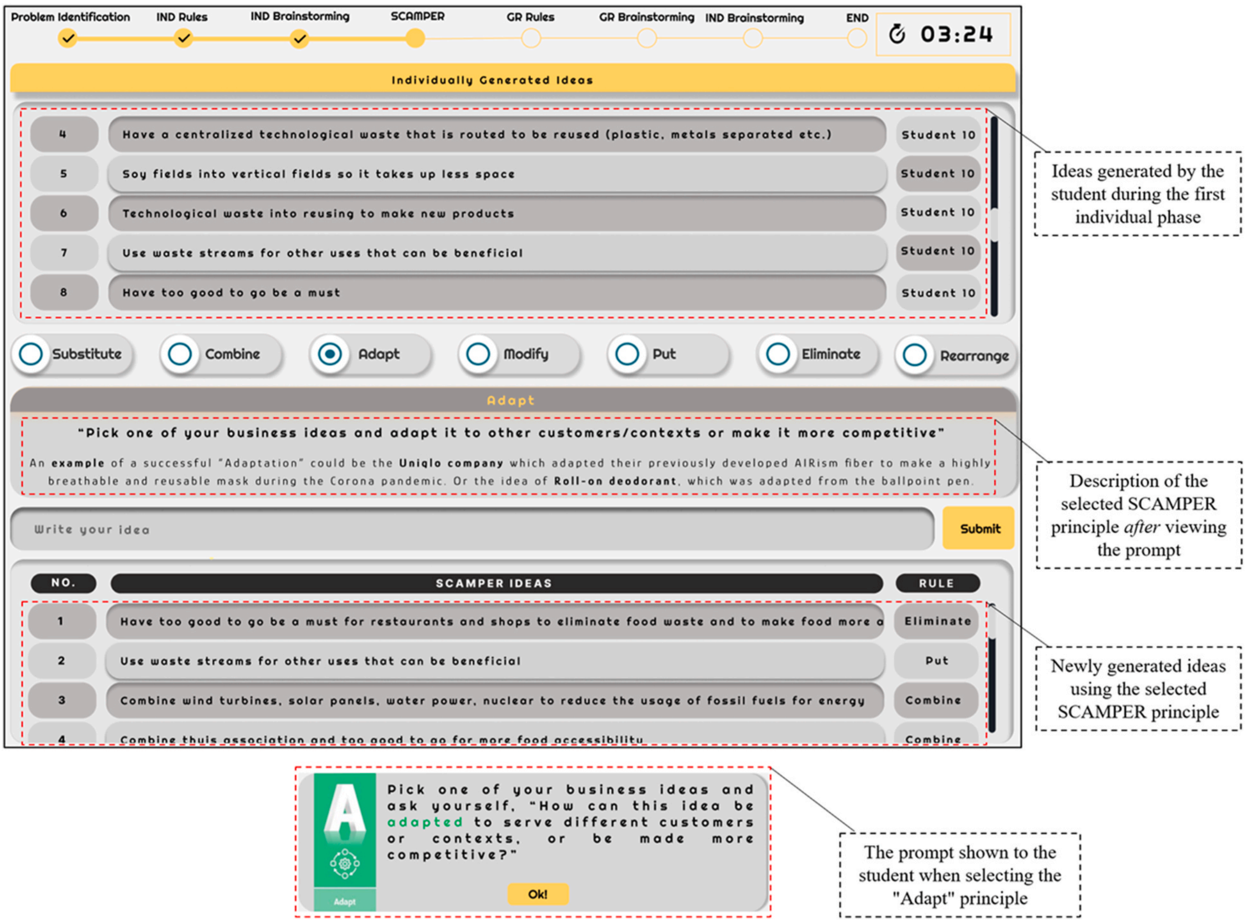

Fig. 3. A snapshot of the platform when the SCAMPER prompts were presented.

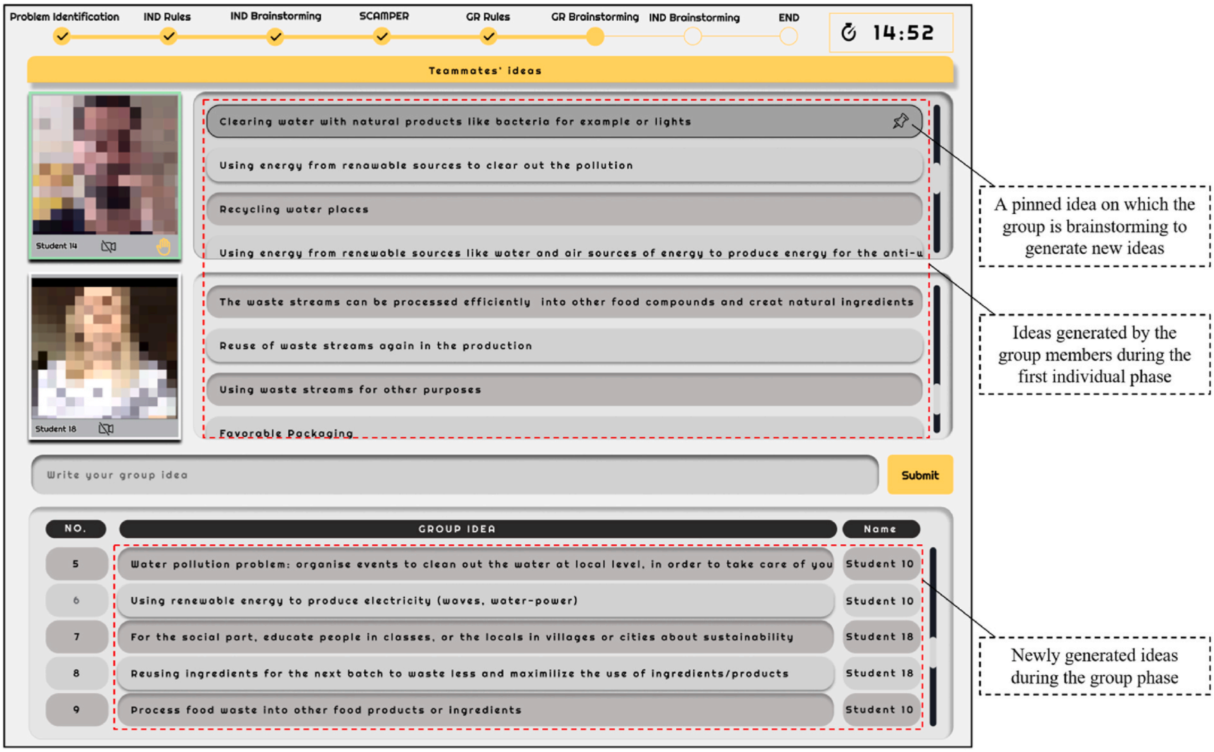

Fig. 4. A snapshot of the platform used in "experimental 2" condition, showing the individually generated ideas being shared with all team members.

ideas, which became visible to the entire group upon submission.

3.2.2. SCAMPER principles

The SCAMPER principles can be applied in various contexts. To make them more relevant to the task of generating business ideas, the first and third authors adapted the principles by refining descriptions and providing real-world examples of successful businesses that have applied them (see Appendix 1). These examples were included to help participants better understand each principle and apply them practically. For instance, a notable example of the "Combining" principle is the creation of eco-friendly hybrid cars, which merge internal combustion and electric engines for a more sustainable transportation solution.

3.3. Dependent measures

Creative task outcomes are commonly evaluated based on two dimensions: (1) the quality of generated ideas and (2) the cognitive processes underlying idea generation (Atakaya et al., 2022). *Originality* is the most common criterion for evaluating the quality of ideas (Guilford, 1950), while *fluency*, *flexibility*, and *persistence* represent cognitive processes involved in retrieving stored mental representations (Atakaya et al., 2022). This study uses criteria from both aspects to measure students' brainstorming outcomes across different phases and the cognitive processes involved, as explained below.

(1) *Originality*: Defined as "the degree to which an idea is innovative" (Rietzschel et al., 2007, p. 934), originality was measured using DeTienne and Chandler's (2004) 6-point scale, which includes: (1) no innovation or insufficient information; (2) an existing product/service offered to an underserved market; (3) a new application of an existing product/service with little or no modification; (4) a significant improvement to an existing product/service; (5) a combination of existing products/services into a new or unique offering; and (6) a new-to-the-world product/service. The originality score for individual and group phases was the average of the originality ratings of ideas generated in that phase.

(2) *Fluency*: This refers to whether an idea qualifies as an opportunity in terms of socially valued products or services within the sustainability context (1 = comprehensible, 0 = incomprehensible). For example, "Banning cars from cities to reduce air pollution" is technically feasible but not a product or service (Eller et al., 2020). Ideas like "wearing an extra sweater" or "turning down the heating" were considered incomprehensible, as they are general suggestions rather than start-up business ideas. Incomprehensible ideas were excluded from further analysis, and the number of comprehensible ideas represents fluency.

(3) *Flexibility*: This measures the extent to which participants generated ideas across different categories (Nijstad et al., 2010). In this study, idea categories were defined using seven of the United Nations' *Sustainable Development Goals* outlined in the

problem case presented to participants: (1) affordable and adequate food supply, (2) decent housing, (3) energy and climate change, (4) economic wealth, (5) education, (6) sustainable water supplies, and (7) personal health and safety. The flexibility score was determined by counting how many of these categories were covered by each participant's ideas.

(4) *Persistence:* This refers to the number of comprehensible ideas generated within a single category (Nijstad et al., 2010). Persistence for each student was calculated by dividing the number of comprehensible ideas by the flexibility score.

To ensure accurate and consistent application of the criteria, a rigorous coding process was followed. First, redundant ideas from the brainstorming session were eliminated. A codebook was then developed in collaboration with two entrepreneurship scholars to score the ideas generated during the individual phases. Each expert applied the preliminary codebook to 10% of the ideas (about 60), then discussed findings and made adjustments. This process continued until inter-rater reliability reached acceptable levels: weighted kappa of 0.73 (originality), Cohen's kappa of 0.91 (fluency), and intraclass correlation of 0.89 (flexibility). Two trained master's student assistants then evaluated the full set of ideas using the finalized codebook.

3.4. Control measures

In this study, students' educational level and attitude toward entrepreneurship were treated as covariates due to their potential influence on business idea generation. Prior research has shown that educational level impacts business idea outcomes (Baggen et al., 2017), likely due to the greater prior knowledge master's students acquire, which is crucial for identifying business ideas (Shepherd & DeTienne, 2005). Moreover, strong feelings toward entrepreneurship can affect the ability to generate business ideas, especially in sustainability contexts (Eller et al., 2020). To measure students' attitudes toward entrepreneurship, we used Liñán and Chen's (2009) survey, which includes five items like "Being an entrepreneur implies more advantages than disadvantages to me," rated on a 7-point Likert scale (1 = "strongly disagree" to 7 = "strongly agree"). Liñán and Chen (2009) reported a high reliability for the survey (Cronbach's alpha = 0.90), which was also confirmed in this study (Cronbach's alpha = 0.84).

In addition, group outcomes were treated as a covariate when comparing the second individual brainstorming outcomes to control for the influence of group performance on individual idea generation.

3.5. Unit of analysis and statistical tests

The unit of analysis, whether at the individual or group level, depended on the hypothesis being examined (see Table 2).

In line with previous studies (e.g., Korde & Paulus, 2017; Paulus et al., 2015), when the group level was the unit of analysis, all the ideas submitted within a group were combined to form the group aggregate. Multiple analyses of covariance (ANCOVA) were used to test research hypotheses for each facet of brainstorming outcomes (originality, fluency, flexibility, and persistence) as dependent variables, with condition as the independent variable and students' educational level and attitude toward entrepreneurship as covariates.

Before conducting ANCOVA, standard checks for homogeneity and normality were performed, confirming that all data sets met the assumptions ($p > .05$) using Levene and Kolmogorov–Smirnov tests. After confirming these assumptions, multiple ANCOVAs were carried out to examine significant differences between conditions for each dependent variable. Post hoc pairwise comparisons, using Bonferroni corrections, were conducted to pinpoint specific group differences (Field, 2011).

Additionally, to assess whether the interventions had indirect effects on originality through pathways like flexibility or persistence, a regression-based mediation analysis was performed, following the approach of previous studies (e.g., Althuizen & Reichel, 2016). Dummy variables were created for each intervention type, and Hayes's (2017) PROCESS macro v4.2 (Model 4) was applied using SPSS 23. Mediation is said to occur when zero falls outside the 95 percent confidence interval around the estimated indirect effect (Preacher & Hayes, 2008), which was generated in this study using a bootstrapping procedure with 5000 samples.

4. Result

4.1. Hypothesis 1 to 3

It was hypothesized that the provision of prompts during the first individual phase of the IGI sequence to encourage the use of SCAMPER principles would enhance the quality of ideas (H1) and increase persistence (H2). Overall, the results indicated significant differences among conditions in terms of the average originality of ideas ($p < .001$) and persistence ($p = .04$). However, the differences were not significant for the ideas' fluency ($p = .32$) and flexibility ($p = .80$) (see Table 3).

Therefore, further analysis was conducted to locate the significant differences using pairwise comparisons with the Bonferroni

Table 2
Overview and their unit of analysis.

Hypotheses	Unit of analysis	Data collection phase	Condition
H1-3	Individual	First individual phase	Control vs. Experimental 1 and 2
H4-6	Group	Group phase	Experimental 1 vs. 2
H7-9	Individual	Second individual phase	Experimental 1 vs. 2

Table 3
Means, adjusted means, overall ANCOVAs for H1 and H2.

Dependent V.	Condition	*n*	*M (SD)*	*Adj. M (SE)*	95% CI		*F (df1, df2)*	*p**	$\eta_p 2$
					LB	UP			
Originality	Control	29	1.96 (0.49)	1.98 (0.09)	1.81	2.16	10.56 (2, 89)	**<.001**	0.19
	Experimental 1	32	2.39 (0.45)	2.42 (0.09)	2.25	2.60			
	Experimental 2	33	2.59 (0.47)	2.54 (0.09)	2.36	2.72			
Fluency	Control	29	3.59 (2.78)	3.86 (0.53)	2.81	4.91	1.17 (2, 89)	.32	0.03
	Experimental 1	32	4.56 (2.75)	4.87 (0.51)	3.85	5.89			
	Experimental 2	33	5.33 (3.06)	4.79 (0.54)	3.72	5.86			
Flexibility	Control	29	2.17 (1.10)	2.24 (0.21)	1.83	2.65	0.22 (2, 89)	.80	0.01
	Experimental 1	32	2.09 (0.99)	2.18 (0.20)	1.78	2.57			
	Experimental 2	33	2.52 (1.18)	2.38 (0.21)	1.96	2.80			
Persistence	Control	29	1.62 (0.85)	1.67 (0.17)	1.33	2.01	3.46 (2, 89)	**.04**	0.07
	Experimental 1	32	2.14 (0.63)	2.19 (0.17)	1.86	2.51			
	Experimental 2	33	2.32 (1.16)	2.24 (0.17)	1.90	2.59			

Note. **p* < .05; The F tests are for the condition effect on the dependent variables.

Table 4
Pairwise comparisons.

Dependent V.	Condition (I)	Condition (J)	*MD* (I-J)	*SE*	*p*[a]	95% CI for Difference [b]	
						LB	UB
Originality	Control	Experimental 1	−0.44[a]	0.12	0.001	−0.74	−0.15
		Experimental 2	−0.55[a]	0.13	<0.001	−0.88	−0.23
	Experimental 1	Control	0.44[a]	0.12	0.001	0.15	0.74
		Experimental 2	−0.11	0.13	1.000	−0.44	0.21
Persistence	Control	Experimental 1	−0.52	0.23	0.08	−1.08	0.05
		Experimental 2	−0.58	0.26	0.08	−1.20	0.05
	Experimental 1	Control	0.52	0.23	0.08	−0.05	1.08
		Experimental 2	−0.06	0.25	1.000	−0.67	0.56

Based on estimated marginal means.
[a] The mean difference is significant at the 0.05 level.
[b] Adjustment for multiple comparisons: Bonferroni. MD = Mean Difference.

correction to control for the type I error (i.e., false positives). As shown in Table 4, the average originality of ideas generated in experimental 1 (*Adjusted M* = 2.42, *SE* = 0.09) and 2 (*Adjusted M* = 2.54, *SE* = 0.09) conditions were significantly higher ($p \leq .001$) than those in control condition (*Adjusted M* = 1.98, *SE* = 0.09). Results also showed a significant difference at the 10 percent level ($p = .08$) regarding the persistence of ideas generated in experimental 1 (*Adjusted M* = 2.19, *SE* = 0.17) and 2 (*Adjusted M* = 2.24, *SE* = 0.17) conditions compared to those in control condition (*Adjusted M* = 1.67, *SE* = 0.17). These results confirm H1 and H2, suggesting that the use of the SCAMPER prompt improved the quality and persistence of ideas generated individually.

Additionally, a mediation analysis was conducted to examine H3 and determine whether the prompts used in experimental 1 and 2 conditions exerted their effects on originality through the persistence pathway. Initial linear regression results indicated that the direct effect of the provided prompts on average originality was significant ($b = 0.53$, $SE = 0.11$, $t = 5.01$, $p < .001$, 95% CI [0.32, 0.74]). After including persistence as a mediator in the model, this direct effect decreased slightly to $b = 0.50$, $SE = 0.11$, but remained significant ($t = 4.50$, $p < .001$, 95% CI [0.28, 0.72]).

Further analysis indicated that intervention had a significant effect on persistence, $b = 0.72$, $SE = 0.20$, $t = 3.65$, $p < .001$, 95% CI [0.33, 1.11]. However, the effect of persistence on originality was not significant ($b = 0.06$, $SE = 0.06$, $t = 1.04$, $p = .30$, 95% CI [−0.05, 0.17]). In addition, results showed that the indirect effect of the provided prompts on originality, mediated by persistence, was not significant ($b = 0.04$, 95% CI [−0.02, 0.13]). This suggests that the positive effect of prompts aimed at encouraging the use of

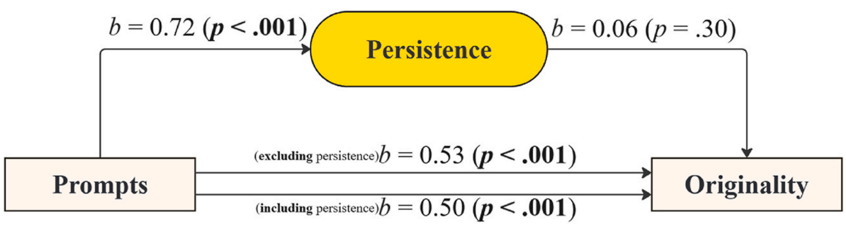

Fig. 5. Path coefficients from the mediation analysis of persistence between the provided prompts and the originality of ideas in the first individual phase.

Table 5
Means, adjusted means, overall ANCOVAs for H4 and H5.

Dependent V.	Condition	*n*	*M (SD)*	*Adj. M (SE)*	95% CI		*F (df1, df2)*	*p**	$\eta_p 2$
					LB	UP			
Originality	Experimental 1	11	2.62 (0.23)	2.61 (0.08)	2.44	2.78	6.37 (1, 19)	**.02**	0.25
	Experimental 2	11	2.91 (0.26)	2.91 (0.08)	2.75	3.08			
Fluency	Experimental 1	11	10.18 (12.76)	11.53 (3.04)	5.17	17.88	1.38 (1, 19)	.26	0.07
	Experimental 2	11	7.55 (4.74)	6.20 (3.04)	−0.15	12.56			
Flexibility	Experimental 1	11	2.91 (1.04)	3.11 (0.35)	2.38	3.84	0.09 (1, 19)	.77	0.00
	Experimental 2	11	3.45 (1.21)	3.26 (0.35)	2.53	3.99			
Persistence	Experimental 1	11	3.02 (2.36)	3.24 (0.56)	2.07	4.42	2.45 (1, 19)	.13	0.11
	Experimental 2	11	2.16 (0.83)	1.93 (0.56)	0.76	3.11			

Note. *$p < .05$; The F tests are for the condition effect on the dependent variables.

SCAMPER principles on idea originality was not mediated through the persistence pathway, leading to the rejection of H3 (see Fig. 5). Additionally, an exploratory mediation analysis examining the role of flexibility yielded no significant results, indicating that flexibility did not mediate the relationship between the provided prompts and originality during the first individual phase.

4.2. Hypothesis 4 to 6

The study also examined the impact of fostering cognitive group awareness by sharing ideas generated both before and during group brainstorming sessions on the quality of collaboratively generated ideas (H4) and their flexibility (H5), while exploring the mediating role of flexibility in enhancing idea quality (H6). The data analysis indicated that the difference between experimental 1 and 2 conditions in the group phase was significant for the average originality of ideas ($p = .02$); however, no significant differences were found for the fluency ideas ($p = .26$), their flexibility ($p = .77$) and persistence ($p = .13$) (see Table 5). The average originality of ideas generated in experimental 2 condition (*Adjusted M* = 2.91, *SE* = 0.26) was shown to be significantly higher than those in experimental 1 condition (*Adjusted M* = 2.62, *SE* = 0.23), thus confirming H4. However, fostering cognitive group awareness by sharing individually generated ideas did not increase the flexibility of ideas generated during the group phase, and therefore, its positive effect on their originality was not mediated through the flexibility pathway, leading to the rejection of H5 and H6.

4.3. Hypothesis 7 to 9

Finally, the study investigated whether fostering cognitive group awareness by sharing ideas generated both before and during group brainstorming would result in a higher number of idea categories in the subsequent individual brainstorming phase (H7) and whether this would enhance the quality of generated ideas (H8). The results revealed significant differences between experimental 1 and 2 conditions in the second individual phase for idea flexibility ($p = .04$), average originality ($p = .002$), and fluency ($p = .001$), but no significant difference for idea persistence ($p = .25$) (see Table 6). These findings confirm both H7 and H8.

Finally, a mediation analysis was conducted to test H9, examining whether the impact of fostering cognitive group awareness during the group phase of experimental 2 condition on originality of ideas generated in the second individual phase was mediated through the flexibility pathway. Initial linear regression results indicated that the direct effect of the intervention on average originality was significant ($b = 0.84$, $SE = 0.18$, $t = 4.54$, $p < .001$, 95% CI [0.47, 1.20]). After including flexibility as a mediator in the model, this direct effect decreased slightly to $b = 0.65$, $SE = 0.18$, but remained significant ($t = 3.68$, $p < .001$, 95% CI [0.30, 1.01]).

Further analysis indicated that fostering cognitive group awareness during the group phase had a significant effect on the flexibility of ideas generated in the second individual phase ($b = 0.64$, $SE = 0.26$, $t = 2.46$, $p = .02$, 95% CI [0.12, 1.16]) and also revealed that flexibility significantly predicted average originality of generated ideas ($b = 0.29$, $SE = 0.08$, $t = 3.47$, $p < .001$, 95% CI [0.12, 0.45]) (see Fig. 6). The indirect effect of the intervention on originality, mediated by flexibility, was also significant ($b = 0.18$, 95% CI [0.02, 0.40]), confirming H9. Given that both the direct effect of the intervention on originality and the indirect effect through flexibility exist and point in the same direction, this indicates that flexibility functions as a "*complementary*" mediator (Zhao et al., 2010), reinforcing

Table 6
Means, adjusted means, overall ANCOVAs for H7 and H8.

Dependent V.	Condition	*n*	*M (SD)*	*Adj. M (SE)*	95% CI		*F (df1, df2)*	*p**	$\eta_p 2$
					LB	UP			
Originality	Experimental 1	32	2.18 (0.91)	2.20 (0.16)	1.88	2.51	10.86 (1, 60)	**.002**	0.15
	Experimental 2	33	3.02 (0.53)	3.01 (0.15)	2.70	3.31			
Fluency	Experimental 1	32	2.94 (1.76)	2.83 (0.39)	2.04	3.61	11.17 (1, 60)	**.001**	0.16
	Experimental 2	33	4.70 (2.36)	4.80 (0.39)	4.03	5.57			
Flexibility	Experimental 1	32	1.97 (0.97)	1.98 (0.20)	1.58	2.38	4.30 (1, 60)	**.04**	0.08
	Experimental 2	33	2.61 (1.12)	2.60 (0.19)	2.21	2.99			
Persistence	Experimental 1	32	1.58 (0.81)	1.59 (0.16)	1.27	1.91	1.34 (1, 60)	.25	0.02
	Experimental 2	33	1.88 (0.79)	1.87 (0.16)	1.56	2.19			

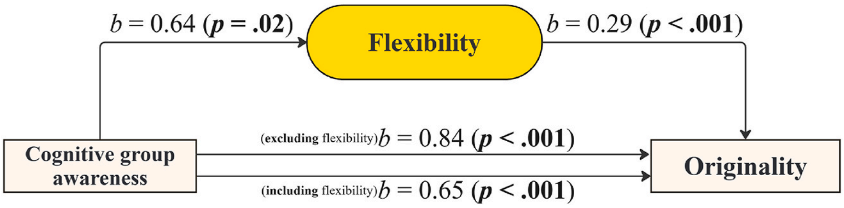

Fig. 6. Path coefficients from the mediation analysis of flexibility between cognitive group awareness facilitated during the group phase and the originality of ideas in the second individual phase.

the overall impact on originality. The exploratory mediation analysis involving persistence yielded no significant results, indicating that persistence did not mediate the relationship between fostering cognitive group awareness during the group phase and the originality of ideas generated in the second individual phase.

5. Discussion

The primary objective of this research was to assess the effect of two computer-supported scaffolds — prompts and cognitive group awareness— on the quality of ideas generated in a hybrid brainstorming session. Utilizing a between-subjects post-test design and an assessment of idea quality based on the degree of originality, it was observed that the variations in the three conditions, namely control, experimental 1, and experimental 2, stemmed from the implemented scaffolds. A detailed discussion of the effects of each support mechanism follows.

5.1. Computer-supported prompts

In this study, we delivered question prompts inspired by SCAMPER principles through an online platform during the initial individual phase of a hybrid brainstorming session following the IGI sequence. Our findings supported our hypotheses regarding the potential of these prompts to foster deeper cognitive engagement and increase the originality of outcomes. Specifically, participants supported by prompts aimed at encouraging the use of SCAMPER principles (in experimental 1 and 2 conditions) demonstrated higher levels of persistence and generated ideas with greater originality compared to those in control condition without such support. This outcome corroborates previous research (Rahimi & Shute, 2021; Yeo & Quek, 2014), reinforcing the idea that effectively delivering SCAMPER principles during individual brainstorming can enhance creative performance. The implementation of SCAMPER as built-in question prompts can increase learners' attention to the shared guidelines (Yeo & Quek, 2014) while maintaining their autonomy regarding when and how to utilize the provided instructions. This type of scaffolding enhances learners' agency by "offering" suggestions informed by theory rather than "imposing" them (Tchounikine, 2019). By preserving this sense of agency, learners' motivation and engagement are enhanced, ultimately fostering more meaningful learning experiences (Reeve & Tseng, 2011).

However, upon further analysis, it was discerned that although there was a significant increase in persistence for participants who were provided by the SCAMPER prompts, this increase does not seem to be the driving factor behind the heightened originality of ideas. Furthermore, the findings show that the positive influence of using the SCAMPER prompts on the originality of ideas generated during the first individual brainstorming phase was not mediated by any of the pathways proposed by the DPCM. Two potential reasons might account for these observations. *First*, the amount of time allocated to students to employ the SCAMPER principles could be an influential factor. As Nijstad et al. (2010) showed, the positive impact of a systematic exploration of specific idea categories on average originality is likely observed only when participants have ample time to initially generate mainly unoriginal ideas and subsequently delve into more original ones.

Second, the above observations may indicate that question prompts inspired by SCAMPER principles could affect originality through alternative pathways. This view aligns with Bollimbala et al. (2023), who posited that originality can be enhanced through several pathways, not just the two highlighted in the DPCM. For example, according to the Theory of Literal Divergent Thinking proposed by Acar and Runco (2015), one of the 11 dichotomous pathways to originality is "synthetic versus non-synthetic". The synthetic pathway, which resonates well with how SCAMPER works, emphasizes that combining objects, words, or concepts results in mental synthesis. The process of mental synthesis has been proven beneficial for creativity, leading to the generation of original outcomes (Acar & Runco, 2015).

5.2. Computer-supported cognitive group awareness

Our findings showed that fostering cognitive group awareness by sharing individually generated ideas during the group phase increased the average originality of ideas in both the group and final individual phases. Further analysis revealed that, while idea sharing did not significantly impact flexibility during group brainstorming, it significantly influenced flexibility in the final individual phase. Additionally, the improvement in the average originality of ideas in the final phase was mediated by flexibility, consistent with the DPCM. These results suggest that the mechanisms influencing originality in the group and final individual phases may differ.

Sharing ideas during group brainstorming provides opportunities for cognitive stimulation, wherein group members' ideas inspire novel thought patterns in others (Nijstad et al., 2006). This inspiration becomes even more pronounced when previously generated ideas are shared among group members, prompting them to build upon more ideas and contribute additional, often more original, ones (Paulus et al., 2013). However, depending on the nature of the ideas and their presentation, certain cognitive interferences may occur. Exposure to many ideas may distract from idea generation, especially when ideas have few connections to an individual's semantic network (Nijstad & Stroebe, 2006). Moreover, increasing shared ideas may heighten the likelihood that the group experiences extraneous load—the cognitive burden imposed by the format of information presentation (Janssen & Kirschner, 2020). This cognitive load can occur when the same concept is expressed using different wording, requiring additional cognitive resources for members to identify similarities and differences (Kolfschoten, 2011). Facing these challenges may cause group members to concentrate on a limited set of ideas, which can increase originality without a corresponding increase in flexibility (Kohn & Smith, 2011). This phenomenon may explain why participants in experimental 2 condition generated ideas with higher originality compared to condition 1, despite the lack of improvement in flexibility.

In the final individual phase, participants in both experimental conditions could likely benefit from a phenomenon commonly observed in hybrid settings, known as "group-to-individual (G-I) transfer of learning" (Laughlin & Barth, 1981). This concept refers to the enhancement of group members' knowledge and skills after participating in a similar collaborative task (Schultze et al., 2012). G-I transfer may occur because interpersonal interactions in hybrid settings can alter individual resources (Brodbeck & Greitemeyer, 2000) and expand knowledge repertoires (John-Steiner & Mahn, 1996). Studies have indicated that such transfer happens in hybrid brainstorming sessions with a G-I sequence, leading to improved individual outcomes in idea fluency and flexibility (Korde & Paulus, 2017). Our research not only reinforces these findings but also offers deeper insights into how G-I transfer affects both the quantity and quality of ideas, especially when tackling real-world problems. The results showed that participants in experimental 2 condition outperformed those in experimental 1 condition, generating more business ideas with higher flexibility and originality.

6. Conclusions and implications for practice

Responding to the growing demand for research aimed at improving brainstorming outcomes (Maaravi et al., 2021), this study investigated the impact of two key computer-supported scaffolds—prompts and cognitive group awareness—operationalized to specifically stimulate the two cognitive pathways proposed by the DPCM toward generating ideas with higher originality in hybrid brainstorming sessions. The findings revealed that these computer-supported scaffolds had an additive effect, leading to an overall improvement in the originality of ideas generated during hybrid brainstorming using the IGI sequence. Moreover, the study supported the relationship between the flexibility and originality of ideas but also presented evidence that originality might be achieved through pathways other than those suggested by the DPCM.

Our findings have significant implications for practitioners aiming to organize effective brainstorming sessions. This study builds on the well-supported premise that hybrid brainstorming is one of the most effective techniques for organizing brainstorming sessions across various disciplines (Paulus et al., 2018). However, as with all types of brainstorming, additional support mechanisms must be still provided during various phases of a hybrid brainstorming session to guide individuals toward quality outcomes. A prime example of such a mechanism is the use of question prompts inspired by SCAMPER principles. This study showed that effectively prompting participants to utilize the SCAMPER technique during the individual phase of a hybrid brainstorming session significantly enhances the originality of their ideas. One critical consideration when using such prompts is to introduce them after participants have had a brief individual brainstorming period, allowing them to generate a pool of ideas to which the technique can be applied (Moreno et al., 2016; Rahimi & Shute, 2021). Moreover, it is highly advisable to adapt the technique to the context in use, providing concrete examples of how to apply each SCAMPER principle. This approach enables participants to better understand how to utilize the SCAMPER technique in the given context (Gu et al., 2022). Finally, it is essential to allocate sufficient time for the effective deployment of the technique. The duration might vary based on the context and the nature of the problem at hand, be it an open-ended query or a complex real-life issue.

Another effective support mechanism is fostering cognitive group awareness by facilitating the sharing of individually generated ideas during group brainstorming. Consistent with prior studies (e.g., Michinov et al., 2015; Paulus et al., 2013), the current research indicated that prompting participants to read, discuss, and comprehend their peers' ideas can significantly enhance the originality of ideas generated collaboratively. This positive impact was found to be even more pronounced when participants had the chance to brainstorm individually on the same topic after the group session. This approach allows them to assimilate the insights they gained from synthesizing others' ideas, enabling them to engage in more productive brainstorming after the group work without being distracted by others.

7. Limitations and avenues for future research

The study has some limitations that open avenues for future research. First, while it offers new insights into how to design hybrid brainstorming sessions that yield higher-quality outcomes, it does not confirm that this specific design can outperform other approaches to organizing brainstorming sessions. Future empirical research is necessary to thoroughly investigate this by comparing the effects of the proposed design on the quality of outcomes, not only with an (unsupported) hybrid brainstorming session with an IGI sequence but also with sessions that employ repeated individual or group brainstorming, such as in Korde and Paulus's (2017) study.

Second, the experimental design in this study was specifically intended to measure the independent effects of each intervention, which demonstrated an additive effect, resulting in overall improvements of outcomes. A future study could investigate whether these interventions might also exhibit an interaction effect. For example, previous studies have shown that improved individual performance can create greater group performance through enhanced synergy within the group (Dennis et al., 2013). In the context of this study, the findings suggested that using prompts based on SCAMPER principles significantly improved the originality of ideas during the first individual phase. This enriched idea pool, when shared during the subsequent group phase to foster cognitive group awareness, could serve as higher-quality input, potentially amplifying the positive effect of cognitive group awareness on group brainstorming performance and collaborative outcomes.

Third, contrary to theoretical expectations, this study did not confirm that prompts using SCAMPER principles enhance originality through the persistence pathway. This may be due to insufficient time for students to employ the technique. According to Nijstad et al. (2010), the correlation between persistence and originality is relatively weak compared to flexibility, partly because it depends on the time participants invest in systematically exploring a few idea categories. Therefore, to clarify how such prompts influence originality and verify Acar and Runco's (2015) proposition that originality can be realized through multiple pathways beyond those proposed by the DPCM, future research should examine their effect when participants use them over a longer duration.

Fourth, enhancing cognitive group awareness by sharing individually generated ideas was shown to be effective in increasing originality, but it did not affect idea flexibility as hypothesized. The lack of effect on flexibility may be due to various cognitive interferences, such as extraneous load—a factor that warrants further investigation. While this load cannot be entirely eliminated, it can be effectively managed with additional support during collaborative tasks (Janssen & Kirschner, 2020). For instance, in the context of brainstorming, filtering shared ideas and presenting them in a more structured, informative manner could potentially reduce cognitive load (Kolfschoten et al., 2014). Furthermore, the representational measures available in some CSCL environments may support students during the process of structuring and organizing shared information (Kollöffel et al., 2011; van Amelsvoort et al., 2007). Future research could investigate how managing extraneous load influences the effectiveness of sharing individually generated ideas in group work, with the goal of further enhancing creativity outcomes.

Fifth, while the present study provided empirical evidence, obtained under controlled conditions, suggesting that fostering cognitive group awareness during the group phase can enhance the originality of outcomes in the subsequent individual phase, it remains an assumption that the G-I transfer of learning is responsible for such a positive finding. To clarify this, future empirical studies should examine changes in participants' knowledge of the given problem before and after group work—using tools like concept maps (e.g., Farrokhnia et al., 2019)—and assess whether these changes correlate with individual performance in the subsequent phase.

Sixth, for hypotheses related to the group phase, the current study treated the group as the unit of analysis for dependent variables. This decision was driven by the collaborative nature of group tasks across all conditions, emphasizing collective creativity. Therefore, although ideas were submitted by individual students, these contributions could not be considered independent. While this approach helped accurately explore the hypotheses, it made it challenging to employ more advanced analytical techniques, such as multilevel modeling (MLM), to capture the complexity of interactions between individual and group processes (Cress, 2008). MLM would enable researchers to disentangle how individual performance contributes to group-level outcomes and, conversely, how group interactions influence individual outcomes in subsequent phases. Future studies with larger sample sizes and careful attention to the hierarchical nature of tasks could leverage MLM to provide deeper insights into these dynamics and better account for the nested nature of individual and group-level interactions.

Last but not least, future research could track interactions during group work to gain a deeper understanding of how differences between conditions emerge and which elements of interaction contribute to improved outcomes in the subsequent individual phase. For example, researchers could delve further into identifying the collective synergetic qualities of successful groups that may enhance the performance of individual members after group work. A more focused examination of the quality of interactions during the group phase could be achieved by applying Curseu et al.'s (2015) concept of group synergy. The group synergy concept captures the effectiveness of the collective induction processes in groups that exceed their best member's performance. Curseu et al. (2015) reported that members of synergetic groups better develop their decision competencies through group interaction processes, and members of strong synergy groups obtain the highest cognitive benefits.

CRediT authorship contribution statement

Mohammadreza Farrokhnia: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Omid Noroozi:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Yvette Baggen:** Writing – review & editing, Supervision, Conceptualization. **Harm Biemans:** Writing – review & editing, Supervision, Conceptualization. **Armin Weinberger:** Writing – review & editing, Conceptualization.

Declaration of competing of interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript, and there is no financial interest to report.

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Appendix 1

The (adapted) SCAMPER principals.

Substitute: Pick one of your business ideas and replace/change part of the idea (components, ingredients, materials, shape, process, etc.) to make it better and more appealing to customers.
An example of a successful 'Substitution' could be the **TIPA company** substituting conventional plastic material with *Bio-Based* material to produce compostable flexible food packaging.
Combine: Pick one of your business ideas and combine it with another idea or existing product/service to extend/improve its functionality.
An example of a successful 'Combination' could be the idea of combining two different technologies (internal combustion and electric engine) to produce eco-friendly **electric hybrid** cars.
Adapt: Pick one of your business ideas and adapt it to other customers/contexts or make it more competitive.
An example of a successful 'Adaptation' could be the **Uniqlo company** which adapted their previously developed *AIRism fiber* to make a highly breathable and reusable mask during the Corona pandemic. Or the idea of **Roll-on deodorant,** which was adapted from the ballpoint pen.
Modify: Pick one of your business ideas and modify, magnify, maximize, or minimize its features (e.g., size, shape, form, color, etc.) in a way that enhances its perceived value or improves its function.
An example of successful 'Modification' could be **Soda companies** that offer you different bottle *sizes* to fit your individual or family and party needs. This way, they maximize their profit by making the same product larger or smaller, thus appealing to more customers.
Put to another use: Pick one of your business ideas and use it for another purpose.
An example of successful 'Putting to another use' could be using **VR headsets** for educational purposes such as raising awareness of environmental concerns.
Eliminate — Pick one of your business ideas and remove one of its features to attract new customers and/or improve its perceived value.
An example of a successful "Elimination" could be **Beverage companies** that offer sugar and/or preservative-free drinks, thus managing to attract a whole new sector of health-oriented consumers.
Rearrange/Reverse — Pick one of your business ideas and evolve it into something new by reordering and/or reversing its parts/processes.
An example of a successful "Rearranging" could be **Uber**, which rearranged the process by which people take a taxi, i.e., ordering instead of searching!

Appendix 2

The problem case.

Imagine that you are asked to give input for business ideas (e.g., new product, service, or process) to start a new start-up in the context of sustainable development. These business ideas can concern people, the planet, and/or profit and may lead to social, environmental, and/or economic gains. However, to have a fruitful idea generation experience, you should first identify an unmet problem and/or need. So, please take **5 min** to read the following case carefully and identify as many unmet problems and/or needs within this context.
The Case: Sustainable development
The growing attention to sustainability creates greater awareness amongst businesses. Because of this growing awareness, companies have started to act to address environmental and societal problems. These problems include the areas of people, planet and profit and concern, for instance, the following:
(1) affordable and adequate food supply
(2) decent housing
(3) energy and climate change
(4) economic wealth
(5) education
(6) sustainable water supplies
(7) personal health and safety
It has become essential for organizations to face challenges concerning sustainability (people, planet, and profit) so that it leads to gains for the organization. Gains can be social, environmental, or economic. For instance, social gains may lead to better education, environmental gains to reduce CO2 emissions, and economic gains to more economic wealth.
- Now, considering the above-mentioned case, please write as many problems/needs as you are aware of in relation to sustainability in the following box and then press Submit: You should write and submit each problem/need **separately**.

Appendix 3

Brainstorming rules - adopted from Paulus et al., 2006.

Individual phase

(1) Stay Focused on the Task. Concentrate on the problem at hand and avoid engaging in irrelevant thought processes or discussions. *a) Do not tell stories.* We are only interested in your ideas. Do not tell stories about your experiences.

b) Do not explain ideas. Do not expand on why you think something is good or bad. Simply state your idea and then continue on with the next idea.

(2) Keep the Brainstorming Going. When you have no ideas during a lapse of time, restate the problem and try to think of additional ideas.

(3) Do not Criticize. Do not criticize any of the ideas that you generate. State any idea that you think of and do not evaluate its usefulness.

(4) Return to Previous Categories. When you cannot think of other ideas, go back to categories of ideas that you have already mentioned and try to build on these previous ideas.

Collaborative phase

(1) Stay focused on the task. Concentrate on the problem at hand and avoid engaging in irrelevant thought processes or discussions. When it is necessary to interrupt a group member, say something like, "Remember that we need to stay focused on our task." **a)** *Do not tell stories*. We are only interested in your ideas. Do not allow your group members to tell stories about their experiences.

b) *Do not explain ideas*. Do not allow your group members to expand on why they think something is good or bad. Let them say an idea and then interrupt them.

(2) Keep the brainstorming going. During a lapse of time when no one is talking, someone in the group should say something like, "Let's see what other ideas we can come up with for (restate the problem)."

(3) Encourage Others to Contribute. If one person is not talking as much as everyone else, ask that person something such as "Do you have any other ideas about (restate the problem)."

(4) Do not Criticize: Do not criticize any of the ideas that are generated either by you or by your group members. All group members should state any ideas that are thought of, without evaluating the usefulness of the ideas. When a group member criticizes another person's idea, say something like "Remember that we cannot criticize each other's ideas."

(5) Return to previous categories. When the group members are not talking very much, go back to categories of ideas that have already been mentioned and try to build on these previous ideas. For example, say, "Does anyone have any more ideas related to (restate an idea already suggested)?"

Data availability

Data will be made available on request.

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