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Implementing the Lotus Blossom Technique to Enhance Collaboration in Software Engineering Education

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Abstract. Collaboration is a cornerstone of both professional software development and Software Engineering Education (SEE). It enables teams to align goals, formulate solutions, and address complex problems, yet it is often hindered by skill gaps, communication barriers, and lack of coordination. Design Thinking (DT) offers techniques to strengthen collaborative work by stimulating idea exchange and promoting equity in participation. Among them, the Lotus Blossom provides a structured and visual approach to idea expansion that supports both divergent and convergent thinking in an accessible way. Despite these potential benefits, its role in SEE, particularly in early stages of software development such as product discovery, remains underexplored. This study investigates how the Lotus Blossom fosters collaboration among undergraduate students in a co-creative product discovery course. Guided by the 3C Collaboration Model, we conducted a 2.5-hour activity with 21 students and assessed collaboration through a post-activity questionnaire. Results indicate that the technique helps students structure ideas, coordinate problem-solving, and establish a foundation for teamwork and shared decision-making. This study validates the Lotus Blossom, and more broadly the collaborative dimension of the DT toolbox, as an effective pedagogical approach for strengthening collaboration in SEE, while also demonstrating its potential to promote teamwork, support problem structuring, and develop soft skills essential for software engineering practice.

Keywords: Design Thinking, Lotus Blossom Technique, Collaboration, Software Engineer, Education, Active Learning

1 Introduction

Collaboration in software development teams is essential for creating a structured environment that supports the progress and success of projects at different scales [Lanubile, 2006; Chen *et al.*, 2023]. By aligning goals, jointly formulating solutions, and addressing complex problems through team interaction, developers are able to improve both the process and the quality of the final product [Cheng *et al.*, 2003].

Recognized as a cornerstone of effective learning and problem-solving, collaboration fosters a dynamic interplay of communication, coordination, and cooperation, which together create the conditions for collective knowledge construction [Fuks *et al.*, 2004]. Collaboration is commonly conceptualized as a sociotechnical process grounded in the interplay between communication, coordination, and cooperation, as defined by the 3C model [Fuks *et al.*, 2008]. Communication refers to the exchange of information among participants, coordination involves managing activities, resources, and task interdependencies, and cooperation concerns the joint execution of work within a shared workspace. These dimensions are inherently interdependent and continuously interact, characterizing collaboration as a dynamic and iterative process rather than a set of isolated activities.

Moreover, collaboration can also be understood as a learning-oriented phenomenon shaped by group composition and individual characteristics [Tardelli *et al.*, 2020]. In educational settings, including SEE, collaborative practices promote cognitive, social, and affective development through the sharing of perspectives, joint problem solving, and the generation of innovative ideas, while also fostering shared responsibility among students. However, effective collaboration does not emerge spontaneously, requiring structured task design, clear role definition, and appropriate group formation. In this sense, individual factors such as personality traits directly influence interaction patterns, participation, and decision-making processes, reinforcing that collaboration results from the interplay between structural mechanisms and human factors. Despite its benefits, collaboration in practice is often challenged by skill gaps, communication barriers, and a lack of synergy in work approaches [Jiménez *et al.*, 2009].

In this context, techniques from the Design Thinking toolkit offer a structured way to foster collaboration and support positive outcomes in software development [Parizi *et al.*, 2022]. Gonsales *et al.* [2017] emphasize that DT techniques can foster group work by stimulating idea exchange, encouraging collaboration, and nurturing a cooperative spirit, factors that help sustain process cohesion and lead to effective outcomes. Beyond their immediate contribution to project results, these practices also foster the development of essential soft skills such as teamwork, communication, and creative problem-solving, which are increasingly recognized as critical for both academic and professional success in software engineering contexts [Abich *et al.*, 2024].

Among the techniques associated with DT, the Lotus Blossom stands out due to its visual and systematic approach to idea expansion. By placing a central concept at the core and iteratively unfolding related ideas in surrounding “petals,” the method promotes both divergent and convergent thinking in a highly structured yet accessible way. This structure not only stimulates creativity but also supports coordination among participants, as each contribution becomes explicitly represented in the shared diagram. Accordingly, the Lotus Blossom technique stands out for its structured visual format, clarity in idea generation, and accessibility for first-time users [Gavrilă and Tulbure, 2018]. Unlike more complex techniques such as customer journey mapping or stakeholder analysis, Lotus Blossom enables students to engage in focused, collaborative ideation within a short session. Despite these advantages, its use in Software Engineering Education remains underexplored, especially in early stages of software development such as product discovery [Pânisoară, 2015; Abich *et al.*, 2024].

To address this gap, this study investigates how the Lotus Blossom technique supports collaboration among undergraduate students engaged in a co-creative product discovery course grounded in DT principles. To analyze the collaborative dynamics enabled by the technique, we adopted the 3C Collaboration Model [Fuks *et al.*, 2004, 2008], which conceptualizes collaboration in three dimensions: (i) Cooperation, reflected in students' willingness to share ideas and assist peers during problem-solving; (ii) Communication, examined through the quality of information exchange and group dialogue; and (iii) Coordination, assessed by how students organized tasks, assigned roles, and managed their workflow throughout the activity.

To investigate these collaborative dimensions in practice, we conducted a 2.5-hour session with 21 undergraduate students, guiding them in applying the Lotus Blossom technique while observing their interactions during the activity.

We assessed collaboration through a post-activity questionnaire aligned with the 3C model, focusing on three aspects: (i) group dynamics and participation, (ii) process structuring and execution, and (iii) the clarity of problem definitions and the innovativeness of solutions. This study aims to answer the following Research Question (RQ):

Research Question

How does the Lotus Blossom technique support collaboration among students in problem-solving activities within software development contexts?

The results suggest that the Lotus Blossom technique (i) encourages students to structure and refine ideas collaboratively, (ii) supports coordination in problem-solving, and (iii) contributes to teamwork and shared decision-making.

This study contributes by investigating the use of the Lotus Blossom technique and, more broadly, the collaborative dimension of the DT toolbox, as a promising pedagogical approach for fostering collaboration in educational settings, an area still underexplored in the SEE literature. It further suggests that the technique can (i) promote teamwork among students, (ii) support collaborative problem structuring, thereby strengthening both ideation and the transition to prototyping, and (iii) support the development of soft skills, reinforcing essential collaborative competencies for software development and beyond.

The remainder of this paper is organized as follows: Section 2 introduces the Lotus Blossom technique and the 3C Collaboration Model. Section 3 describes the study's methodology. Section 4 presents the results, while Section 5 discusses their implications. Section 6 summarizes the lessons learned from the study, highlighting practical insights for researchers and educators. Section 7 presents directions for the development of a more comprehensive framework for fostering collaboration in Software Engineering education. Section 8 discusses the threats to validity. Finally, Section 9 concludes the article and outlines future research directions.

2 Background

2.1 Collaboration in Software Engineering Education

Collaboration is widely recognized as a key competence in Software Engineering Education, as software development is inherently socio-technical and requires shared decision-making [Oelfin and Morelli, 2023], communication, and coordination. While the literature shows that collaboration supports both progress and quality in projects, its implementation in educational contexts often lacks theoretical depth and systematic attention to social and community-level learning outcomes [Lanubile, 2006; Chen *et al.*, 2023; Jiménez *et al.*, 2009].

Emerging approaches are expanding the opportunities for collaboration in SEE. Exploring collaboration is particularly relevant in software development teams, where human factors should be placed at the center of the process. Recent evidence from a tertiary study in Software Engineering by Dutra *et al.* [2021] shows that factors such as communication, collaboration, knowledge, and motivation are among the most influential elements affecting team performance, productivity, and software quality. The study identifies a broad set of human factors and their impacts across individual, team, project, and organizational levels, reinforcing that software development is inherently a human-centered activity. Despite their importance, these factors are often undervalued compared to technical aspects, which may lead to suboptimal team dynamics and project risks. Therefore, understanding and fostering human factors is essential to improve collaboration and team climate, enhance motivation, support agile practices, and ultimately contribute to higher-quality software products.

More recently, AI-based educational tools can, for example, personalize learning trajectories and simulate authentic software engineering challenges, provided that curricula remain aligned with industry practices through closer academia–industry partnerships [Jiang and Pang, 2023; Tenbergen and Krusche, 2024]. Empirical studies on human–AI collaboration suggest that teamwork improves when roles are clearly defined and communication protocols are established, although challenges such as steep learning curves and the risk of overreliance on AI continue to be reported [Garcia *et al.*, 2024; Tenbergen and Krusche, 2024].

Beyond technological mediation, pedagogical strategies have also proven effective in supporting collaboration. In particular, DT combined with Project-Based Learning (PBL) has demonstrated potential to structure interdisciplinary work, enable iterative problem-solving, and foster student motivation and creativity [Jiang and Pang, 2023]. Complementary evidence indicates that gamification can reinforce these strategies by increasing engagement and promoting teamwork through challenges and immediate feedback. Nonetheless, gamification appears more effective when employed as a supplement rather than as a substitute for established instructional methods [Di Nardo *et al.*, 2024].

In this context, collaboration in SEE becomes more effective when structured pedagogical approaches (e.g., DT–PBL or gamified tasks incorporating collaborative techniques) are aligned with socio-technical scaffolds such as communication protocols, role clarity, and authentic learning environments. Such integration not only stimulates participation and innovation but also addresses the need to evaluate collaborative outcomes at both group and community levels, as emphasized in CSCL frameworks [Fuks *et al.*, 2004].

2.2 3C Collaboration Model

The 3C model provides a theoretical framework for understanding and improving teamwork by examining the dynamic interplay of communication, coordination, and cooperation [Fuks *et al.*, 2004, 2008]. Rather than treating collaboration as a single construct, the model conceptualizes it as a set composed of interdependent dimensions that continuously influence one another (see Figure 1). This perspective emphasizes that effective collaboration emerges not only from individual contributions but also from the structured interaction among participants, mediated by shared goals, artifacts, and communication channels. In this sense, the 3C model supports the analysis and design of collaborative activities by making explicit the mechanisms through which group work is organized, executed, and sustained over time.

The dimensions of the 3C model are defined as follows: (i) **Communication** refers to the exchange of information, feedback, and ideas among participants. It enables the construction of shared understanding, supports negotiation processes, and helps align team members around common goals [Berlo, 1987; Sousa, 2004; Canha, 2021]. Effective communication is essential for reducing ambiguity, avoiding misunderstandings, and fostering transparency within collaborative environments; (ii) **Cooperation** concerns the joint execution of tasks within a shared workspace. It involves the integration of diverse skills and knowledge to achieve collective objectives, promoting mutual support, trust, and group learning [Freitas *et al.*, 2022; Miranda and da Rosa Mangini, 2020; Peduzzi *et al.*, 2020]. Cooperation represents the productive dimension of collaboration, where tangible outcomes are generated through coordinated efforts; (iii) **Coordination** links communication and cooperation by managing task interdependencies, organizing activities, and allocating resources. It includes defining roles, sequencing tasks, and ensuring that individual contributions are properly synchronized [Miranda and da Rosa Mangini, 2020; Peduzzi *et al.*, 2020; Antunes, 2021]. Coordination transforms communicative exchanges into structured actions, enabling teams to operate efficiently and achieve their goals.

These dimensions are inherently interdependent and evolve through iterative cycles of interaction, in which communication informs coordination decisions, coordination structures cooperative work, and cooperation generates new information that feeds back into communication. In the context of software development teams, this interplay is particularly critical, as activities such as requirements elicitation, design, coding, and testing depend heavily on continuous information exchange, alignment of interdependent tasks, and collective problem-solving. Strengthening communication, coordination, and cooperation has been shown to directly impact key human factors such as motivation, knowledge sharing, team climate, and productivity, ultimately influencing software quality and project success.

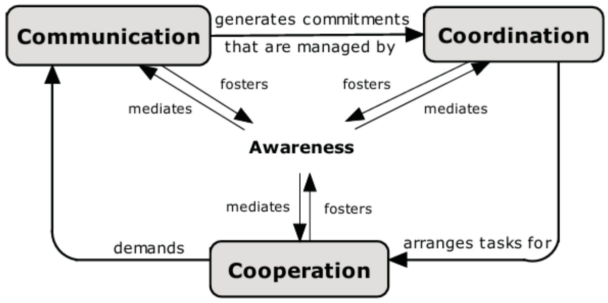

Figure 1. The 3C Collaboration Model [Fuks *et al.*, 2004].

2.3 Lotus Blossom

The Lotus Blossom technique can be seen as a user-centered method that structures creative thinking and supports systematic, collaborative ideation. As part of the Design Thinking toolkit, it complements other techniques such as brainstorming and empathy mapping [Hanesová *et al.*, 2014; Parizi *et al.*, 2022].

Figure 2 illustrates the structure of the Lotus Blossom. The central idea (I) is placed at the center and is surrounded by eight secondary ideas (A–H). Each of these expands into numbered spaces (1–8) that represent causes, solutions, or refinements of the original concept. The name derives from this layout, which resembles the petals of a lotus flower [Pérez and Rubio, 2020]. Each secondary idea then becomes the center of a new "flower", allowing for a continuous and in-depth exploration of the topic [Pânisoară, 2015].

The technique involves a sheet rotation process, where participants iteratively contribute by identifying causes, solutions, or developments related to a central problem. This cyclical brainstorming continues until a satisfactory solution is reached or a set number of ideas is generated [Pérez and Rubio, 2020].

Although designed for group collaboration, the Lotus Blossom can also be applied individually, offering flexibility and ease of use. When applied in groups, it stimulates creativity, reveals innovative connections, and supports a structured and productive environment, making it well-suited for complex problem-solving and group projects [Gavrilă and Tulbure, 2018; Shen *et al.*, 2016]. However, while the technique encourages collaboration, evaluating its effectiveness in educational settings requires a broader analytical perspective. The 3C Collaboration Model offers this broader view, enabling a

Figure 2. Lotus Blossom Technique

deeper assessment of group dynamics beyond just idea generation.

Our study explores the use of the Lotus Blossom technique in an undergraduate Software Engineering course. It examines how this approach supports collaboration during product discovery activities. Based on the 3C Model, we analyze how the technique promotes team interaction and problem-solving. The next section presents the methodology used to conduct the study and evaluate its collaborative impact.

3 Method

This section describes the application of the Lotus Blossom technique in a product discovery activity. Our goal was to assess how it fosters collaboration among students.

To guide the investigation, we defined the following Main Research Question (MRQ):

Research Question

How does the Lotus Blossom technique support collaboration among students in problem-solving activities within software development contexts?

From the MRQ, we derived three Sub-Questions (SQs) to explore specific aspects of collaboration, as outlined in the 3C Collaboration Model [Fuks *et al.*, 2004]. These SQs were formulated by mapping the theoretical dimensions of the model to the expected collaborative behaviors observed during the activity. They include:

Sub-Question SQ1

How does the Lotus Blossom technique facilitate group collaborative dynamics to ensure that all members actively contribute and integrate their ideas during the brainstorming process?

Sub-Question SQ2

How does the Lotus Blossom technique help the group structure and conduct the collaborative process, maintaining focus, meeting deadlines, and progressing through the proposed stages?

Sub-Question SQ3

How does the Lotus Blossom technique enhance collaborative dynamics to generate results that clearly define the problem and inspire practical and innovative solutions?

These sub-questions guided the analysis of the technique's impact on collaborative behavior. SQ1 focused on group dynamics and participation, SQ2 examined the structure and flow of collaboration, and SQ3 assessed the quality of the outcomes produced during the collaborative process.

We conducted the study with undergraduate students enrolled in a project-based software development course. All participants signed an Informed Consent Form before the activity, following ethical research guidelines and confirming their awareness of data confidentiality, rights, and voluntary participation. Most students had prior knowledge of Design Thinking and experience with collaborative techniques and tools, as these topics were part of the course curriculum. To ensure methodological rigor, the research design and instruments were reviewed by one of the authors, a Software Engineering researcher with experience in empirical studies and collaborative learning environments.

We implemented the Lotus Blossom technique during a 2.5-hour session, corresponding to the regular class duration on the day of the activity. To support ideation, we used white sheets, colorful post-its, and pens, allowing for both individual and group contributions. We collected feedback by using a Google Forms questionnaire[1], designed to capture participants' perceptions of the activity.

3.1 Design and Execution

Figure 3 provides an overview of the activity, which was structured into five sequential steps guiding students in the application of the Lotus Blossom technique. The steps were: (I) Setup, (II) Definition, (III) Rotation, (IV) Phrasing, and (V) Brainstorming.

We designed each step to progressively foster collaboration, moving from the initial introduction of the method to the collective generation and refinement of ideas through structured group interaction.

I) Setup

We began by introducing the Lotus Blossom technique and explaining its role within the DT approach, the central methodology of the course. This 10-minute introduction outlined the technique's purpose, structure, and how it supports collaborative problem-solving.

To encourage interaction, we arranged the classroom using round tables, supporting face-to-face collaboration. We organized the students into five groups based on project topics defined at the beginning of the Integrative Project course, where they self-selected into groups according to affinity. Three groups focused on agriculture-related issues, while the remaining two worked on education-related challenges, each at a separate table. This configuration ensured that students shared a common problem context while still bringing diverse

[1] `https://doi.org/10.5281/zenodo.15271304`

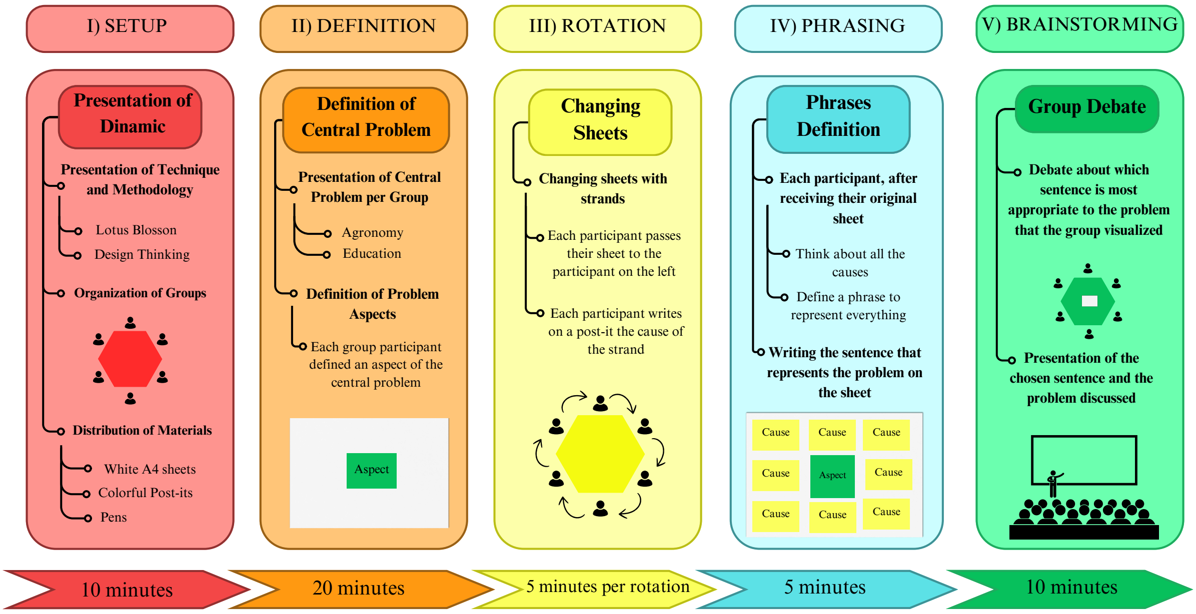

Figure 3. Methodology Diagram

perspectives to the discussion, fostering cooperation within groups.

Each group included between 4 and 5 students, all working on either the Education or Agriculture topic. We provided materials including white A4 sheets, colorful post-its, and pens to support both individual and group-based ideation and note-taking.

II) Definition

We pre-selected Education and Agriculture as the study's main topics, based on their relevance to the students' local and academic context. These topics were introduced during the definition stage, where each group evaluated both options and chose one as their focus for applying the Lotus Blossom technique. This 20-minute step was designed to stimulate critical and creative thinking.

After the topic selection, we guided discussions, fostering students to reflect on key questions related to their chosen area. Each group member then identified one specific issue within the selected topic and wrote it on a post-it. These issues addressed various relevant aspects and were placed at the center of an A4 sheet, forming the starting point for the next stage of the technique.

III) Rotation

In this step, participants exchanged sheets to collaboratively explore problems and their possible causes within their assigned themes. Groups working on the same topic, Education or Agriculture, collaborated with one another during this phase.

Each participant began by writing a central problem or key issue in the center of an A4 sheet. The rotation process then followed three main steps:

(1) Each participant received a new sheet, reviewed the problem written by a peer, and identified a cause related to that problem, which they recorded on the sheet;
(2) The sheet was then passed to the next participant, who repeated the process;
(3) This cycle continued until each sheet returned to its original author.

As a result, each group collaboratively produced a set of issues and an associated mapping of causes, supporting a structured, reflective, and interactive ideation process.

IV) Phrasing

Each participant received a sheet containing post-its filled out by their group members, listing causes related to the central problem. They had 5 minutes to review and reflect on these contributions as inspiration.

Based on this analysis, each participant then formulated a structured sentence that clearly and objectively described the refined issue. This final phrasing served as the basis for the next step, providing a well-defined problem statement to guide the subsequent phase of ideation.

V) Brainstorming

Each group engaged in an in-depth discussion, analyzing different perspectives, raising hypotheses, and exploring the causes and implications of their identified problem. These discussions supported critical thinking and collaboration within the group.

Afterward, the findings were shared across groups to foster idea exchange and broaden the collective perspective. Finally, each group presented its structured problem statement, consolidating insights and contributing to a deeper, shared understanding of the overall theme.

3.2 Data Collection and Analysis

We collected data immediately after the activity to assess the application of the Lotus Blossom technique. All participants gave their voluntary consent by signing an informed consent form, which explained the study's objectives, guaranteed data confidentiality, and clarified their right to withdraw at any time. After the session, participants completed a 12-question post-activity questionnaire.

Table 1 presents the complete data collection instrument, ensuring methodological transparency and supporting replication. We structured the questionnaire into two parts: questions Q1 through Q11 are closed-ended items measured on a 5-point Likert scale (ranging from 1 - Strongly Disagree to 5 - Strongly Agree). We designed these specific questions to map directly to the three Sub-Questions (SQ1-SQ3) derived from the 3C Collaboration Model. Finally, question Q12 is an open-ended item formulated to capture qualitative suggestions and identify potential areas for process improvement.

We based our analysis on Krippendorff's content analysis method to categorize participants' responses [Krippendorff and Bock, 2009]. We organized the answers using a five-point Likert scale, ranging from Strongly Agree to Strongly Disagree [Joshi *et al.*, 2015]. We then classified the data according to the Sub-Questions (SQs) and visualized the results using graphs to support clarity and comparison. The complete dataset is available on Zenodo[2].

4 Results

This section presents the results of the application of the Lotus Blossom technique in a classroom setting. The activity supported students in collaboratively structuring problems and generating ideas within the predefined domains of education and agriculture. To provide a clear view of the findings, this section is organized into three subsections: *Participants' Profiling (Section 4.1)*, which characterizes the sample; *Lotus Blossom Results (Section 4.2)*, which presents the artifacts and quantitative indicators derived from the activity; and *Research Questions Responses (Section 4.3)*, which analyzes participants' perceptions in relation to the study.

4.1 Participants' Profiling

Table 2 profiles the 21 participants to characterize the sample and mitigate prior knowledge as a confounding variable. Early-stage undergraduates (20 second-semester students and one fourth-semester student) dominate the cohort. The fourth-semester student followed a different academic trajectory and joined the group later, attending the introductory Software Engineering courses alongside second-semester students. Participants presented a relatively homogeneous academic background (Mean grade average = 8.03, Standard Deviation = 0.96), although variation in course completion and approval rates suggests differences in academic progression.

To provide clarity on the participants' profiles, Table 2 details nine specific academic and experiential metrics. *Group* identifies the specific team (1 through 5) the student collaborated with during the Lotus Blossom activity. *Semester* indicates their current stage in the undergraduate program. *SE Courses* lists the domain-specific modules they have taken, establishing their technical baseline. To measure academic progression, *Completed Courses* (of 48 disciplines in total) and % Completed report the absolute number and the relative proportion of the degree the student has successfully finished. Furthermore, *Possible Courses* denotes the total number of disciplines attempted since enrollment, which allows the calculation of the *Approval Rate* (the ratio of successful completions to attempted courses). *Overall Average* reflects the student's cumulative academic grade across all subjects on a standard 0-to-10 scale. Finally, Experience captures relevant extracurricular backgrounds, highlighting specific industry roles, technical leadership, or academic research scholarships.

Despite their early academic stage, the students demonstrated a strong technical baseline, maintaining an 87.3% average approval rate and having already completed a foundational Software Engineering course.

Regarding collaborative problem-solving, the sample exhibited a homogeneous profile. The course syllabus explicitly emphasized Design Thinking, equipping participants with a working knowledge of agile methodologies and iterative brainstorming techniques. Only 4 students contributed practical domain experience gained from active roles in the IT industry, including software development and technical leadership, or from an undergraduate research program in collaborative systems. This baseline reduced the Lotus Blossom technique's learning curve. Consequently, participants quickly assimilated the mechanics and focused their cognitive effort entirely on the product discovery tasks.

4.2 Lotus Blossom Results

Figure 4 shows participants applying the technique to address real-world challenges. For example, one group developed a structured framework to focus on and analyze land leasing (see Figure 5). Other groups tackled topics such as economic management, the use of Personal Protective Equipment, and inefficiencies in agricultural processes. In the education domain, discussions centered around organizational and communication barriers, with groups exploring issues such as the integration of new technologies by teachers, disorganized class schedules, and lack of accessibility in schools.

Figure 6 presents an example of a Lotus Blossom artifact produced by the students, focusing on the agriculture domain. In this representation, the central theme (Agriculture) expands into multiple problem dimensions, including lack of accessibility, water waste, lack of investment, climate-related issues, soil degradation, and poor economic management. Each dimension is further decomposed into underlying causes identified collaboratively by the participants.

The diagram shows how students moved from a broad problem space to a more structured and interconnected view of the domain. The organization of ideas highlights not only isolated issues but also the relationships among structural, environmental, and social factors. For example, elements such as lack of infrastructure, inadequate management, and limited access to resources appear across different problem dimensions, reinforcing the systemic nature of the challenges.

Figure 6 also highlights the density of ideas generated during the activity, providing evidence of the technique's role in supporting collaborative analysis, problem decomposition, and the identification of relationships across the domain.

Each participant generated, on average, between 8 and 10 ideas per subtopic, indicating a consistent level of idea production aligned with the objectives of the Lotus Blossom technique. This volume reflects a substantial group-level

[2]`https://doi.org/10.5281/zenodo.15271304`

Table 1. Evaluation Questions for Group Dynamics and Answer Types

#	Questions	Answer Type*
SQ1:	**How does the Lotus Blossom technique facilitate group collaborative dynamics to ensure that all members actively contribute and integrate their ideas during the brainstorming process?**	
Q1	Did the Lotus Blossom technique help all group members express their ideas clearly and objectively?	5-point Likert
Q2	Did the technique encourage open discussion and respect for all ideas and suggestions?	5-point Likert
Q3	Did all participants actively contribute their ideas throughout the brainstorming process?	5-point Likert
Q4	Did the technique facilitate the integration of each member's contributions into the group's discussions?	5-point Likert
Q5	Did participants remain engaged and committed to the group's success while using the technique?	5-point Likert
SQ2:	**How does the Lotus Blossom technique help the group structure and conduct the collaborative process, maintaining focus, meeting deadlines, and progressing through the proposed stages?**	
Q6	Did the group follow the structured process of the Lotus Blossom technique and meet deadlines?	5-point Likert
Q7	Was the rotation of sheets well-organized and effectively managed?	5-point Likert
Q8	Did the technique help the group maintain focus throughout the brainstorming stages?	5-point Likert
SQ3:	**How does the Lotus Blossom technique enhance collaborative dynamics to generate results that clearly define the problem and inspire practical and innovative solutions?**	
Q9	Did the Lotus Blossom technique help the group formulate a final statement that clearly represents the problem?	5-point Likert
Q10	Did the final statement, structured through the technique, inspire practical and innovative solutions?	5-point Likert
Q11	Did the technique encourage the group to explore and consider different causes of the problem?	5-point Likert
Q12:	**What suggestions would you give about the activity?**	**Open-ended**

** Note: The 5-point Likert scale ranges from 1 (Strongly Disagree) to 5 (Strongly Agree).*

Table 2. Participant Data and Academic Performance

Group	Semester	SE Courses	Completed Courses (of 48)	% Completed	Possible Courses	Approval Rate	Overall Average	Experience
1	2	SE Fundamentals	11	22.92%	12	91.67%	7.68	None
1	2	SE Fundamentals	8	16.67%	12	66.67%	7.72	None
1	2	SE Fundamentals	6	12.50%	12	50.00%	5.34	None
1	2	SE Fundamentals	7	14.58%	7	100.00%	8.4	Research scholar (collab. systems)
2	2	SE Fundamentals	9	18.75%	12	75.00%	8.19	None
2	2	SE Fundamentals	12	25.00%	12	100.00%	8.47	Software dev. scholar
2	2	SE Fundamentals	12	25.00%	12	100.00%	8.68	None
2	2	SE Fundamentals	5	10.42%	12	41.67%	4.74	None
3	2	SE Fundamentals	11	22.92%	12	91.67%	8.07	IT professional (multinational)
3	2	SE Fundamentals	12	25.00%	12	100.00%	8.75	None
3	2	SE Fundamentals	12	25.00%	12	100.00%	8.44	None
3	2	SE Fundamentals	11	22.92%	12	91.67%	7.86	None
4	2	SE Fundamentals	12	25.00%	12	100.00%	8.73	None
4	4	SE Fundamentals	12	25.00%	12	100.00%	8.14	IT manager (multinational)
4	2	SE Fundamentals	12	25.00%	12	100.00%	8.35	None
4	2	SE Fundamentals	11	22.92%	12	91.67%	8.39	None
5	2	SE Fundamentals	10	20.83%	12	83.33%	8.04	None
5	2	SE Fundamentals	11	22.92%	12	91.67%	7.97	None
5	2	SE Fundamentals	12	25.00%	12	100.00%	8.23	None
5	2	SE Fundamentals	12	25.00%	12	100.00%	8.32	None
5	2	SE Fundamentals	7	14.58%	12	58.33%	7.74	None
Mean	–	–	10.29	21.44%	11.67	88.89%	8.03	–
Standard Deviation	–	–	2.29	4.78%	1.36	16.22%	0.96	–

contribution and a broad exploration of the problem space.

Regarding execution time, each stage was originally planned to last 5 minutes; however, in practice, the rounds lasted on average between 6 and 8 minutes. This increase was associated with the number of participants and the need for synchronization among groups during interactions.

We used visual records of the activity (e.g., post-it boards) to consolidate the final set of ideas, providing an aggregated view of both the volume and diversity of contributions, which also reveals a trade-off between time and depth: increased collaborative interaction enhanced the diversity and richness of the generated ideas, but reduced time efficiency.

4.3 Research Questions Responses

Following the activity, we collected data to assess students' perceptions of the technique. The results are based on responses to the questionnaire presented in Table 1. Figure 7 shows a summary of the responses. Based on this data, we organized the analysis according to the 3 sub-questions derived from the research question (SQ1 to SQ3).

Sub-Question SQ1

How does the Lotus Blossom technique facilitate group collaborative dynamics to ensure that all members actively contribute and integrate their ideas during the brainstorming process?

SQ1 explores how the Lotus Blossom technique supports group dynamics by fostering active participation and the integration of ideas. The results indicate a strongly positive perception among participants. Across the five questions related to SQ1 (Table 1, Q1–Q5), responses were predominantly in the "Agree" and "Strongly Agree" categories, suggesting that students perceived the technique as supporting clear communication, active engagement, and mutual respect during the brainstorming process.

Figure 7 shows that participants reported feeling encouraged to express their ideas clearly and objectively (Q1: *8 Agree, 13 Strongly Agree*) and to engage in open and respectful discussions (Q2: *9 Agree, 12 Strongly Agree*). A high level of active contribution was also reported (Q3: *9 Agree,*

Figure 4. Application in the classroom

Figure 5. Examples of Problems Structured with the Lotus Blossom Technique (data in Portuguese)

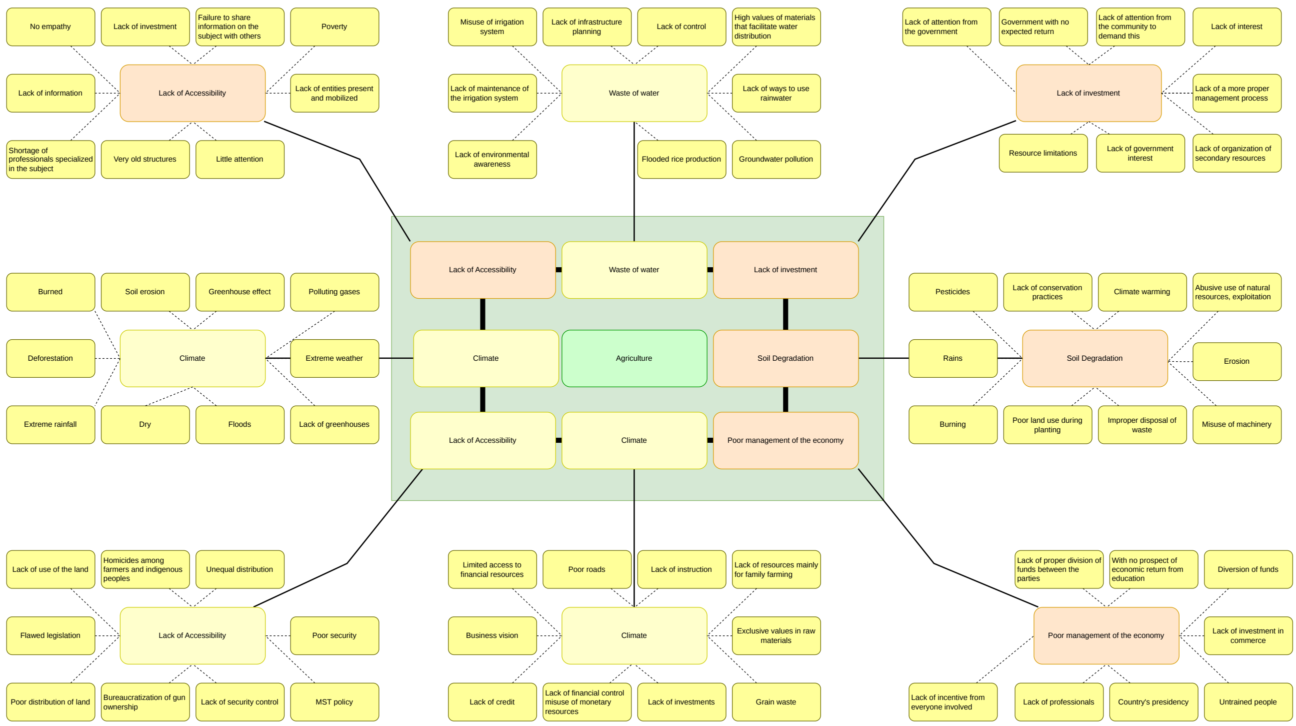

Figure 6. Examples of Problems Structured with the Lotus Blossom Technique

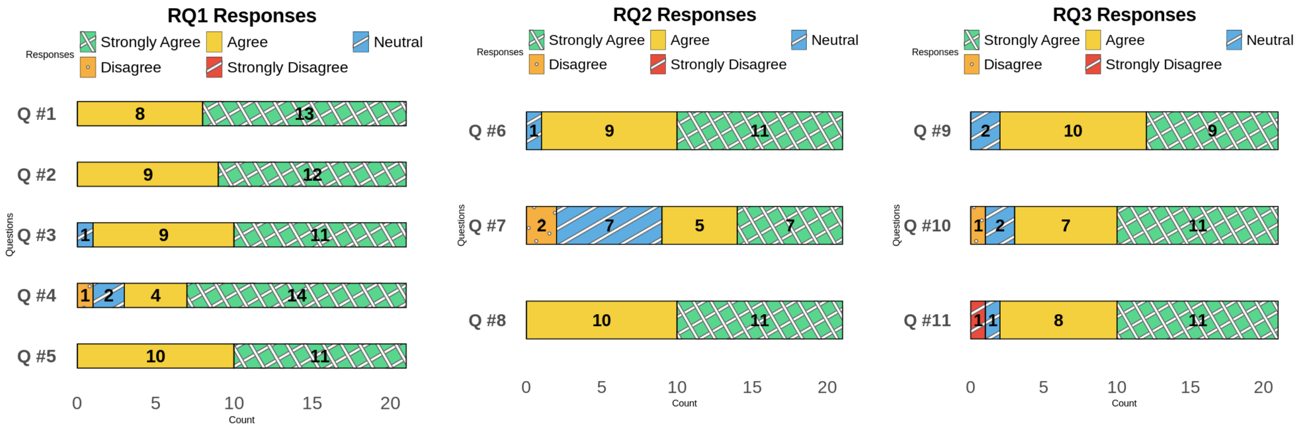

Figure 7. Results Obtained for RQs

11 Strongly Agree). Regarding the integration of individual contributions, most students viewed this positively (Q4: *4 Agree, 14 Strongly Agree*), although 2 were Neutral and 1 Disagreed, indicating some variation in experience. Finally, all participants demonstrated a strong sense of commitment to the group's success (Q5: *10 Agree, 11 Strongly Agree*), highlighting the collaborative value of the technique.

Table 3 reports individual responses for each participant across five dimensions: idea expression (Q1), openness and respect in discussion (Q2), active participation (Q3), integration of contributions (Q4), and engagement with group outcomes (Q5), along with summary statistics.

The results indicate a strong positive perception of collaboration. The average scores ranged from 4.48 to 4.62 across the five questions. In particular, Q1 (Mean = 4.62, SD = 0.50) and Q2 (Mean = 4.57, SD = 0.51) suggest that the technique supported clear idea expression and facilitated open and respectful discussions. Similarly, Q5 (Mean = 4.52, SD = 0.51) indicates that participants remained engaged and committed throughout the activity.

Although slightly lower, Q3 (Mean = 4.48, SD = 0.60) and Q4 (Mean = 4.50, SD = 0.89) suggest that while most participants actively contributed and were able to integrate ideas, some variability existed in these aspects. This is further reflected in the presence of neutral and occasional disagree responses, particularly in Q4, indicating that integrating contributions may require additional facilitation or time management. Taken together, these findings suggest that the Lotus Blossom technique facilitates communication, participation, and engagement, key elements of the collaboration dimension associated with group dynamics.

Table 3. Results for SQ1: Perception of collaborative dynamics supported by the Lotus Blossom technique, including individual responses and aggregated statistics (Likert scale: 1–5).

SQ1: How does the Lotus Blossom technique facilitate group collaborative dynamics to ensure that all members actively contribute and integrate their ideas during the brainstorming process?										
Participant	**Q1 Did the Lotus Blossom technique help all group members express their ideas clearly and objectively**		**Q2 Did the technique encourage open discussion and respect for all ideas and suggestions?**		**Q3 Did all participants actively contribute their ideas throughout the brainstorming process?**		**Q4 Did the technique facilitate the integration of each member's contributions into the group's discussions?**		**Q5 Did participants remain engaged and committed to the group's success while using the technique?**	
P1	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5
P2	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5
P3	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5
P4	Strongly agree	5	Strongly agree	5	Agree	4	Strongly agree	5	Agree	4
P5	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5
P6	Agree	4	Strongly agree	5	Neutral	3	Strongly agree	5	Agree	4
P7	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5
P8	Strongly agree	5	Agree	4	Strongly agree	5	Strongly agree	5	Agree	4
P9	Agree	4	Agree	4	Agree	4	Agree	4	Agree	4
P10	Agree	4	Strongly agree	5	Strongly agree	5	Neutral	3	Agree	4
P11	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5
P12	Agree	4	Agree	4	Agree	4	Neutral	3	Agree	4
P13	Strongly agree	5	Agree	4	Strongly agree	5	Strongly agree	5	Strongly agree	5
P14	Agree	4	Agree	4	Agree	4	Agree	4	Agree	4
P15	Strongly agree	5	Strongly agree	5	Agree	4	Strongly agree	5	Strongly agree	5
P16	Strongly agree	5	Agree	4	Agree	4	Disagree	2	Strongly agree	5
P17	Agree	4	Agree	4	Agree	4	Agree	4	Agree	4
P18	Agree	4	Agree	4	Agree	4	Agree	4	Agree	4
P19	Agree	4	Agree	4	Agree	4	Strongly agree	5	Agree	4
P20	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5
P21	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5	Strongly agree	5
Total S. Agree	13		12		11		14		11	
Total Agree	8		9		9		4		10	
Total Neutral	0		0		1		2		0	
Total Disagree	0		0		0		1		0	
Average	**4.62**		**4.57**		**4.48**		**4.50**		**4.52**	
Std Dev	**0.50**		**0.51**		**0.60**		**0.89**		**0.51**	

Sub-Question SQ2

How does the Lotus Blossom technique help the group structure and conduct the collaborative process, maintaining focus, meeting deadlines, and progressing through the proposed stages?

SQ2 examines how the Lotus Blossom technique supports the structuring and execution of the collaborative process, including adherence to stages, time management, and maintenance of focus.

Figure 7 indicates that participants perceived the technique as facilitating an organized and goal-oriented workflow. Participants reported understanding and following the stages and timeline of the activity (Q6: *9 Agree, 11 Strongly Agree, 1 Neutral*). However, perceptions about the organization of the sheet rotation process were more mixed (Q7: *5 Agree, 7 Strongly Agree, 7 Neutral, 2 Disagree*), indicating that some participants faced challenges during this step. Despite that, all students confirmed that they remained focused throughout the activity (Q8: *10 Agree, 11 Strongly Agree*), highlighting the technique's role in maintaining engagement and process continuity.

Table 4 summarizes individual responses across three dimensions: process adherence and deadlines (Q6), organization of the rotation mechanism (Q7), and maintenance of focus throughout the activity (Q8), along with aggregated statistics. The results suggest that the technique supported process structuring and helped participants maintain focus. Q6 (Mean = 4.48, SD = 0.60) shows that most groups were able to follow the steps of the technique and meet the expected deadlines. Similarly, Q8 (Mean = 4.52, SD = 0.51) suggests that the Lotus Blossom helped participants maintain focus throughout the brainstorming stages, indicating its role in guiding the progression of collaborative activities.

In contrast, Q7 (Mean = 3.91, SD = 0.94) presents a lower average and higher variability, indicating that the rotation of sheets was a more challenging aspect of the process. The presence of neutral and disagree responses suggests that some groups experienced difficulties in coordinating this step, which may have affected the fluidity of interaction and time management. This variability highlights the importance of facilitation and clearer procedural guidance during this phase. Taken together, these findings suggest that while the Lotus Blossom technique provides a strong structure for organizing collaborative work and maintaining focus, specific operational aspects such as the rotation mechanism may require refinement to improve coordination and overall process efficiency.

Sub-Question SQ3

How does the Lotus Blossom technique enhance collaborative dynamics to generate results that clearly define the problem and inspire practical and innovative solutions?

SQ3 explores how the Lotus Blossom enhances collaborative dynamics to produce outcomes that clearly define the problem and inspire practical and innovative solutions. Overall, the responses suggest that the technique supported both structured problem formulation and creative exploration, which are essential in product discovery.

Figure 7 shows that participants reported that the final statement accurately reflected the problem discussed (Q9: *10 Agree, 9 Strongly Agree, 2 Neutral*). They also perceived the statement as capable of inspiring practical and innovative solutions (Q10: *7 Agree, 11 Strongly Agree, 3 Neutral*). In addition, participants indicated that the technique encouraged

Table 4. Results for SQ2: Evaluation of group process and structure using the Lotus Blossom technique, including individual responses and aggregated statistics (Likert scale: 1–5).

SQ2: How does the Lotus Blossom technique help the group structure and conduct the collaborative process, maintaining focus, meeting deadlines, and progressing through the proposed stages?						
Participant	**Q6 Did the group follow the structured process of the Lotus Blossom technique and meet deadlines?**		**Q7 Was the rotation of sheets well-organized and effectively managed?**		**Q8 Did the technique help the group maintain focus throughout the brainstorming stages?**	
P1	Strongly agree	5	Strongly agree	5	Strongly agree	5
P2	Strongly agree	5	Strongly agree	5	Strongly agree	5
P3	Strongly agree	5	Strongly agree	5	Strongly agree	5
P4	Strongly agree	5	Neutral	3	Strongly agree	5
P5	Agree	4	Disagree	2	Agree	4
P6	Agree	4	Agree	4	Agree	4
P7	Strongly agree	5	Strongly agree	5	Strongly agree	5
P8	Strongly agree	5	Agree	4	Strongly agree	5
P9	Agree	4	Agree	4	Agree	4
P10	Strongly agree	5	Strongly agree	5	Strongly agree	5
P11	Agree	4	Neutral	3	Agree	4
P12	Agree	4	Neutral	3	Agree	4
P13	Strongly agree	5	Neutral	3	Strongly agree	5
P14	Agree	4	Neutral	3	Agree	4
P15	Strongly agree	5	Neutral	3	Agree	4
P16	Agree	4	Disagree	2	Strongly agree	5
P17	Agree	4	Agree	4	Agree	4
P18	Agree	4	Agree	4	Agree	4
P19	Neutral	3	Neutral	3	Strongly agree	5
P20	Strongly agree	5	Strongly agree	5	Strongly agree	5
P21	Strongly agree	5	Strongly agree	5	Agree	4
Total S. Agree	11		7		11	
Total Agree	9		5		10	
Total Neutral	1		7		0	
Total Disagree	0		2		0	
Average	**4.48**		**3.91**		**4.52**	
Std Dev	**0.60**		**0.94**		**0.51**	

the exploration of multiple causes related to the central issue (Q11: *8 Agree, 11 Strongly Agree, 1 Disagree, 3 Neutral*), reinforcing its role in supporting deeper analysis. Despite some neutral and divergent responses, the results suggest that the technique supported both analytical depth and creative thinking in a collaborative context.

Table 5 reports participants' perceptions across three dimensions: problem definition (Q9), inspiration for solutions (Q10), and exploration of problem causes (Q11), along with aggregated statistics.

The results indicate a positive perception of the technique's contribution to problem framing and solution generation. All three questions achieved identical average scores (Mean = 4.33), suggesting a consistent evaluation of the technique across these dimensions. Q9 shows that most participants agreed that the technique helped formulate clear and representative problem statements, while Q10 indicates that these structured outcomes were effective in inspiring practical and innovative solutions.

However, the standard deviation values (Q9 = 0.66, Q10 = 0.86, Q11 = 0.97) reveal greater variability compared to previous results, particularly in Q11. This suggests that although the technique generally supported the exploration of different problem causes, some participants experienced difficulties in fully engaging with this aspect. This is also reflected in the presence of neutral, disagree, and even strongly disagree responses, indicating that deeper analytical exploration may require additional guidance or time. Taken together, these findings suggest that the Lotus Blossom technique is effective in structuring problem definition and ideation, but its ability to promote deeper exploration of problem causes may depend on facilitation strategies and participant experience. This highlights an opportunity to refine the application of the technique to better support analytical depth during collaborative activities.

In addition to the quantitative results, we conducted a qualitative analysis of participants' open-ended responses to better understand their perceptions of the activity. Overall, students reported a positive experience, but also highlighted factors that influenced their comfort and engagement.

A recurring theme concerns time management. Participants emphasized the need for better control of the activity duration and longer periods for idea development. For example, P4 suggested *"better control of the time for rotating the sheets"*, while P5 mentioned the need for *"definition of a fixed time"*, and P8 highlighted *"better time control"*. In addition, multiple participants explicitly requested more time, such as P6 and P12 (*"more time to complete the tasks"*), P7 (*"more time to think about the problem"*), and P19 (*"more time"*). These responses indicate that limited time may have constrained deeper reflection and idea maturation, affecting participants' comfort with the activity.

Beyond operational aspects, some responses revealed perceptions related to collaboration and diversity of perspectives. For instance, P15 noted that the activity *"would be even more effective if we could include all types of opinions [...] as these people may bring essential information to find effective solutions"*. This suggests that participants recognized the value of including diverse viewpoints to enrich the ideation process and improve solution quality.

Other responses also pointed to the importance of structuring the dynamics to support participation. For example, P16 suggested *"to time the writing and sheet rotation"*, reinforcing the need for clearer facilitation mechanisms. These

Table 5. Results for SQ3: Perception of collaborative dynamics and solution generation using the Lotus Blossom technique, including individual responses and aggregated statistics (Likert scale: 1–5).

SQ3: How does the Lotus Blossom technique enhance collaborative dynamics to generate results that clearly define the problem and inspire practical and innovative solutions?						
Participant	**Q9 Did the Lotus Blossom technique help the group formulate a final statement that clearly represents the problem?**		**Q10 Did the final statement, structured through the technique, inspire practical and innovative solutions?**		**Q11 Did the technique encourage the group to explore and consider different causes of the problem?**	
P1	Strongly agree	5	Strongly agree	5	Strongly agree	5
P2	Strongly agree	5	Strongly agree	5	Strongly agree	5
P3	Neutral	3	Strongly agree	5	Strongly disagree	1
P4	Strongly agree	5	Strongly agree	5	Strongly agree	5
P5	Neutral	3	Agree	4	Agree	4
P6	Agree	4	Neutral	3	Agree	4
P7	Strongly agree	5	Strongly agree	5	Strongly agree	5
P8	Strongly agree	5	Strongly agree	5	Strongly agree	5
P9	Agree	4	Agree	4	Agree	4
P10	Agree	4	Agree	4	Strongly agree	5
P11	Strongly agree	5	Strongly agree	5	Strongly agree	5
P12	Agree	4	Agree	4	Agree	4
P13	Agree	4	Disagree	2	Agree	4
P14	Agree	4	Neutral	3	Neutral	3
P15	Strongly agree	5	Agree	4	Strongly agree	5
P16	Strongly agree	5	Strongly agree	5	Agree	4
P17	Agree	4	Strongly agree	5	Strongly agree	5
P18	Agree	4	Agree	4	Agree	4
P19	Agree	4	Agree	4	Strongly agree	5
P20	Strongly agree	5	Strongly agree	5	Strongly agree	5
P21	Agree	4	Strongly agree	5	Agree	4
Total S. Agree	9		11		11	
Total Agree	10		7		8	
Total Neutral	2		2		1	
Total Disagree	0		1		0	
Total S. Disagree	0		0		1	
Average	**4.33**		**4.33**		**4.33**	
Std Dev	**0.66**		**0.86**		**0.97**	

findings indicate that, while the structured nature of the Lotus Blossom technique supports participation, aspects such as time allocation and facilitation directly influence how comfortable and engaged participants feel.

Finally, as this study reports an initial classroom implementation, some inefficiencies in the rotation dynamics were expected. Despite these challenges, the technique showed promising results, particularly in smaller groups, where coordination was easier and interaction more balanced.

5 Discussion

5.1 Lotus Blossom Fostering Collaboration in SEE

The results indicate that the Lotus Blossom technique supported collaboration among undergraduate students engaged in product discovery activities. SQ1 showed that the technique fostered clear communication, active participation, and the integration of ideas within group dynamics. SQ2 revealed that it contributed to a structured and focused process, although some participants reported difficulties with the organization of the sheet rotation. SQ3 highlighted its capacity to guide students in clearly defining problems and inspiring practical solutions.

The application of the technique further demonstrated its potential to promote collaboration in problem identification and resolution. While participants expressed overall satisfaction with the activity, they also suggested improvements in time management, particularly during the rotation phase. Such challenges were expected given that it was their first exposure to the method. Students already familiar with DT adapted quickly, which likely facilitated their engagement and understanding, while those with less experience were still able to follow the steps and contribute meaningfully.

Working on different focus areas (education and agriculture) did not seem to affect the quantity or complexity of ideas generated. Despite the thematic differences, all groups demonstrated similar levels of creativity and collaborative engagement. Taken together, these findings suggest that the Lotus Blossom can serve as an accessible and effective pedagogical tool for enhancing collaboration, critical thinking, and soft skills in software engineering education.

This study addresses a gap in the literature by examining how a less frequently applied Design Thinking technique can be used in computing education to support collaboration. Our contribution includes (i) adapting the technique to a real classroom setting, (ii) evaluating its use through the 3C Collaboration Model, and (iii) providing a replicable protocol for educators and researchers.

From a broader Software Engineering perspective, our findings can be better understood when positioned within the Design Thinking literature. A previous systematic mapping conducted by the authors identified 85 DT techniques applied in software development, used across different working spaces such as inspiration, ideation, and implementation Parizi *et al.* [2022]. In this context, DT is often operationalized as a "toolbox" composed of multiple techniques that support problem understanding, ideation, and solution validation.

Compared to these techniques, Lotus Blossom can be seen as a more structured ideation approach, combining divergent and convergent thinking within a single artifact. While traditional ideation techniques (e.g., brainstorming) prioritize idea generation with minimal structure, Lotus Blossom introduces a systematic expansion of ideas around a central concept, which helps reduce cognitive overload and supports traceability of reasoning. In contrast to techniques focused primarily on user understanding (e.g., personas or empathy maps), Lotus Blossom emphasizes the organization and evolution of ideas, making it particularly suitable for early-stage problem structuring in software projects.

Furthermore, unlike loosely structured techniques, Lotus Blossom inherently supports coordination and equitable participation, as its rotation mechanism encourages balanced contribution among participants. This characteristic aligns with the collaborative demands of software development teams, where coordination of interdependent tasks and shared understanding are critical. Therefore, Lotus Blossom complements existing DT techniques by offering a more guided and collaborative ideation process, particularly valuable in educational and early-stage software engineering contexts.

Most participants had prior experience with collaborative techniques, which helped them engage more easily. Nevertheless, even students without previous exposure to Design Thinking were able to follow the activity and contribute meaningfully. This suggests that the technique requires minimal onboarding and is suitable for learners with varied backgrounds. Future studies could explore its use in contexts where students have no prior experience, in order to better assess its learning curve and broader applicability.

5.2 Related Work Analysis

Different collaborative learning techniques have been adopted in software engineering education, each presenting specific advantages and limitations. Among them, the Lotus Blossom technique stands out for its ease of use, low cost, and time efficiency, while also enabling structured brainstorming, supporting both divergent and convergent thinking, and fostering the development of soft skills. In this section, we present a comparative analysis of Lotus Blossom with other approaches reported in the literature (see Table 6).

To better position Lotus Blossom among collaborative and active learning approaches, we compare it with World Café [Dornelles *et al*., 2024] and Problem-Based Learning (PBL), as summarized in Table 7. While all three approaches promote collaboration and active engagement, they differ significantly in structure, duration, and expected outcomes. World Café emphasizes iterative dialogue through rotating group discussions, typically conducted over multiple sessions, enabling progressive refinement of ideas and deeper collective reflection. In contrast, PBL adopts a broader pedagogical framework centered on complex problem solving, requiring extended periods of investigation, self-directed learning, and iterative solution development.

Lotus Blossom offers a structured and time-efficient approach to ideation. Its grid-based format systematically expands ideas around a central concept, enabling the rapid generation of a large number of alternatives within a single session. This makes it particularly suitable for educational contexts with limited time, where fostering participation and idea generation is a priority. However, this efficiency introduces a trade-off: while Lotus Blossom supports a broad exploration of the problem space, approaches such as World Café and PBL tend to promote greater depth through extended discussion and reflection.

Rather than framing these approaches as competing alternatives, we position them as complementary strategies. Lotus Blossom is particularly effective in early stages of exploration and idea generation, whereas World Café better supports collective sense-making and reflection, and PBL is more suitable for deep learning and complex problem resolution. This distinction clarifies the specific contribution and applicability of Lotus Blossom within Software Engineering Education.

Computer-Supported Collaborative Learning (CSCL) [Knutas *et al*., 2019] aligns with Lotus Blossom with its emphasis on student participation and collaborative artifacts. While CSCL requires digital support and tends to focus on large-scale or distributed groups, Lotus Blossom as an analog model is small-groups oriented with advantages of quicker and less-expensive enactment at the class level.

Active Learning with Augmented Reality (AR) [Jesionkowska *et al*., 2020] fosters creativity and solving problems through iterative prototyping and experimentation. As Lotus Blossom, it makes ideas explicit through observable artifacts and collaboration. Yet, AR methods have significant technical and cognitive demands, e.g., customized hardware and software, while Lotus Blossom has low-tech and generally transferable application, with the same collaborative benefits not without such barriers.

Ulrich and Eppinger's product design methodology [T Ulrich and D Eppinger, 2024] aligns with the Lotus Blossom technique in its structured treatment of creativity, particularly through divergent–convergent idea cycles and the externalization of concepts into tangible forms. A central distinction, however, lies in the role of prototyping. The authors argue that prototypes are indispensable artifacts not only to test technical feasibility but also to communicate ideas, reduce ambiguity, and foster team alignment across engineering, design, and business domains. In contrast, Lotus Blossom remains in the ideation stage: it generates, clusters, and prioritizes ideas using low-tech visual grids but does not extend into the materialization of solutions. Prototyping requires resources, infrastructure, and longer timelines, which makes Ulrich and Eppinger's framework more demanding to implement in classroom contexts.

Abich *et al*. [2024] demonstrate how DT fosters collaboration in SEE through empathy, ideation, prototyping, and testing across an 18-week course. Similar to Lotus Blossom, the process follows a divergent–convergent cycle; however, while DT is resource-intensive, Lotus Blossom provides a faster and low-cost format for idea exploration.

Fonseca *et al*. [2024] compare USARP and ACUX, two methods for specifying usability requirements in agile contexts. Both encourage collaboration through shared artifacts and structured documentation. Unlike Lotus Blossom's simple and visual ideation, they emphasize precision and formalization of usability and UX requirements.

Table 6. Studies applying similar techniques to the Lotus Blossom

Article	Similarities	Differences
Dornelles et al. (2024) *Brewing Ideas: World Cafés in SDLC Learning*	Group rotation, visual records, and collective synthesis; divergent–convergent cycles; fosters engagement and collaboration.	Conversational and free-flowing, no fixed visual grid; focus on narratives rather than concise clustered ideas; requires multiple sessions over weeks.
Jesionkowska, Wild & Deval (2020) *Active Learning AR Workshop*	Project-based prototyping and testing; iterative idea refinement; visual artifacts; teamwork emphasis.	Requires AR technology and technical skills; produces functional products rather than idea maps; short intensive workshops instead of brainstorming sessions.
Knutas, Ikonen & Porras (2015) *CSCL in SE Education: Mapping Study*	Supports benefits of collaborative learning; highlights role of shared artifacts; framework for method comparison.	Theoretical mapping with no direct Lotus Blossom application; includes digital tools beyond in-person brainstorming; lacks specific procedural details.
Ulrich & Eppinger (2024) *Product Design and Development*	Structured ideation with divergent–convergent cycles; emphasizes prototyping as a collaborative tool; visual organization of concepts; supports systematic creativity for design.	Resource-intensive and focused on full product lifecycle; prototyping requires materials, facilities, and technical expertise; broader scope beyond ideation sessions, unlike the lightweight and low-tech Lotus Blossom.
Abich, Parizi & Marczak (2024) *Fostering Collaboration through Design Thinking: A Study among Software Engineering Students*	Emphasizes collaboration as a core learning outcome; structured process with divergent–convergent phases (empathy, ideation, prototyping, testing); development of teamwork, communication, and problem-solving skills.	Design Thinking is broader and iterative, often requiring multiple sessions and prototypes; stronger emphasis on empathy and user-centered design, while Lotus Blossom focuses on rapid, visually structured idea generation in a single session.
Fonseca, Zaina & Marques (2024) *Evaluating Methods for Eliciting and Specifying Usability Requirements with User Stories: A Controlled Experiment*	Promotes structured collaboration in agile contexts by supporting requirement elicitation and specification through user stories; participants collectively refine requirements with emphasis on usability and UX; validated through a controlled experiment with qualitative and quantitative measures.	Focuses on non-functional requirements and precise documentation (USARP and ACUX), while Lotus Blossom emphasizes creativity and divergent–convergent idea generation; outcomes differ, with usability requirements as formal artifacts in Fonseca et al., versus visual idea maps in Lotus Blossom.

Table 7. Comparison: Lotus Blossom, World Café, and PBL

Aspect	Lotus Blossom	World Café	Problem-Based Learning (PBL)
Preparation Effort	Low to Moderate	Moderate	High
Material Production	Structured templates (canvas)	Guiding questions + discussion materials	Complex problem scenarios + supporting resources
Execution Time	Short (single session)	Medium (multiple sessions or weeks)	Long (weeks or full course cycle)
Number of Ideas Generated	High (systematic expansion)	Moderate to High (discussion-driven)	Moderate (focused on problem solving)
Depth of Ideas	Moderate (structured exploration)	High (iterative reflection and dialogue)	Very High (deep investigation and solution development)
Interaction Structure	Visual and grid-based	Conversational and rotational	Problem-centered and iterative
Best Use Context	Time-constrained ideation sessions	Collaborative reflection and knowledge sharing	Deep learning and complex problem solving

In summary, whereas approaches such as World Café, CSCL, AR workshops, Ulrich and Eppinger's product design, Design Thinking, and Fonseca et al.'s methods rely on extended, technology-driven, or formal processes, Lotus Blossom stands out for being structured, time-efficient, and easy to implement. It thus complements heavier approaches by providing a lightweight entry point for collaborative ideation in computing education.

5.3 Challenges and Student Engaging

Although the technique was well received, students noted difficulties with time management, particularly during the sheet rotation phase. These challenges were understandable, given that it was their first exposure to the method. While the activity was planned for a regular 2.5-hour class, the size of the class and the complexity of the task required more time for transitions and coordination.

During the petal rotations and the presentation of the technique's development, students reported that the activity became more tiring and required greater cognitive effort. Furthermore, despite the evaluations carried out, uncertainty remains regarding the actual level of collaboration achieved, since, to the best of our knowledge, no consolidated metrics exist to accurately measure and classify collaboration.

Another relevant aspect concerns the facilitator's role. Without their mediation, the dynamics tend to become more difficult to manage, especially in activities with limited time. The facilitator therefore played a crucial role not only in guiding the execution of the technique but also in keeping students engaged.

Nevertheless, observations showed that during group discussions, some students lost focus, which highlights the need for additional strategies to sustain attention and ensure the participation of all members.

Even so, all groups completed the activity, and the quality of the output in both ideas and clarity justified the time spent. These insights suggest that future implementations should consider adjustments in facilitation and timing, especially in larger groups, to further improve the learning experience, as discussed in the Lessons Learned section (Section 6).

6 Lessons Learned

6.1 Positive Outcomes

The application of the Lotus Blossom technique engaged students and promoted balanced participation among group members. Organizing the teams enabled greater integration among students, including across different groups, which fostered communication and cooperation. The visual structure of the petals encouraged idea generation and helped participants connect their contributions to the central problem. This format also prompted everyone to express themselves concisely, ensuring active participation from each member. Consequently, even more reserved or less active students had space to contribute, promoting greater equity in participation, which is central in collaborative activities.

Furthermore, students reported a stronger sense of belonging to the process, in line with previous studies on structured ideation techniques in educational contexts. This feeling was reinforced by sharing and analyzing the opinions recorded on the petals, contributing to an environment of mutual respect and appreciation of individual contributions.

Another important point is that the technique not only fostered idea generation but also supported the development of soft skills, such as clear communication, group coordination, critical thinking, synthesis, and shared leadership. These aspects align directly with the 3C collaboration model (Communication, Coordination, and Cooperation).

Finally, the technique demonstrates strong replicability potential. The Lotus Blossom is easy to implement, requires few resources, and can be conducted both in face-to-face settings, using posters and boards, and in collaborative digital platforms. This simplicity and flexibility expand its applicability across different courses, institutions, and knowledge areas, reinforcing its external validity and its usefulness as a pedagogical strategy aimed at promoting collaboration and collective thinking.

6.2 Improvements for Future Applications

Despite its benefits, the activity also revealed areas for improvement. The main challenge concerned time management: some phases required longer duration depending on the groups' formation. Another aspect to consider involves team size, which could be reduced to foster the effective participation of all members.

In this regard, defining an ideal number of participants can rely on the communication complexity formula, balancing idea diversity with coordination feasibility. In addition, the activity showed the need to dedicate more time to explaining the technique and the steps to follow, since insufficient guidance may create confusion and compromise the flow of the exercise. In cases involving new students who have never encountered the technique before, a facilitator is necessary to mediate discussions, improve the activity flow, and keep students focused. In the future, if possible, a collaboration assessment method using well-defined metrics should be implemented to determine the level of collaboration achieved with the technique.

7 Practical Recommendations

The Lotus Blossom offers a visual and iterative format that helps participants formulate well-defined problem statements. Figure 8 presents a suggested procedure for applying the Lotus Blossom technique in classroom or workshop settings, organized into the following steps:

I) **Prepare the required materials**, including an introductory presentation[3] on the Lotus Blossom technique, A4 sheets of paper, colored post-its, pens, timers, and a post-activity evaluation questionnaire.

II) **Organize participants** into groups of five to six members, ideally seated at round tables. Try to balance their prior experience when possible. Assign one or two instructors or facilitators to guide the activity. Their role is to explain the technique, control the time during the sheet rotations, and keep the process running smoothly.

III) Run the activity using the following sequence: introduction (10 min), group formation (5 min), definition of the theme and central problem (20–25 min), sheet rotation rounds (4–5 rounds of 6 to 8 min each, adjusted according to progress), individual formulation of problem statements (10 min), and group discussion to select the final statement (20–30 min).

We also suggest that after validating the problem statements, they can be converted into possible user stories [Noel *et al.*, 2018] using the following format:

As a [type of user], I want [action] so that [benefit].

For example:

- **Problem statement**: "Students cannot locate feedback in a timely manner."
- **User story**: "As an undergraduate student, I want to receive automatic notifications when the instructor posts feedback so that I can review my work before the next deadline."

IV) Evaluate the outcomes by collecting all problem statements and conduct the post-activity questionnaire. Analyze the open-ended responses and the closed-ended items, based on Likert scales, using descriptive statistics [Joshi *et al.*, 2015].

Practical recommendations for time management: Based on our experience, time management is a critical factor for the successful application of the Lotus Blossom technique. To mitigate this limitation in future applications, we recommend: (i) using strictly controlled time intervals with visible timers to regulate each rotation round; (ii) assigning a dedicated facilitator to monitor time and coordinate transitions between stages; (iii) reducing the number of rotation rounds when working with less experienced groups; and (iv) adopting digital collaboration tools (e.g., online whiteboards such as Miro or Mural) to streamline idea recording and rotation,

[3] See a slide model in the Zenodo repository.

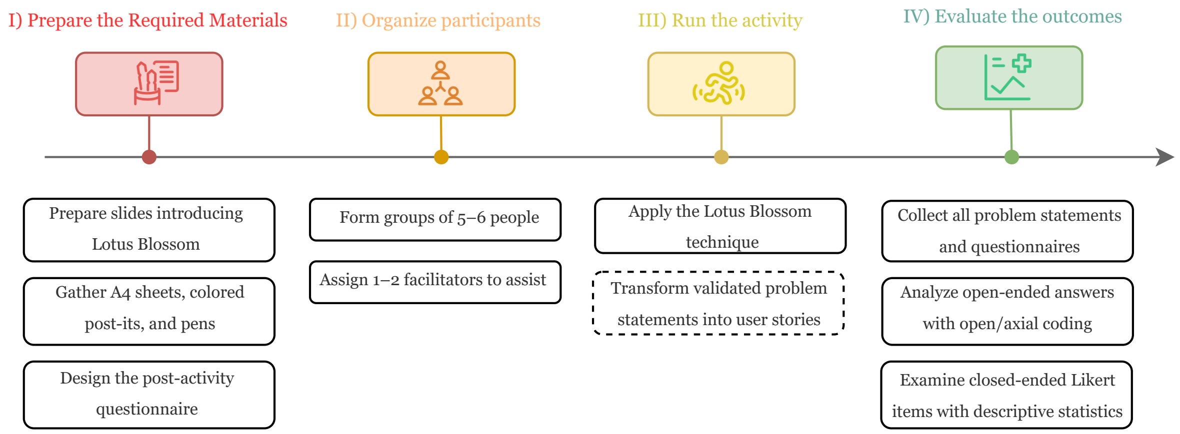

Figure 8. Lotus Blossom Application

especially in larger or remote groups. These strategies can help maintain engagement while ensuring that the activity progresses efficiently.

8 Threats to Validity

While the findings are promising, this study presents some threats to validity that must be acknowledged.

Regarding external validity, we conducted this study with a limited number of participants from a single academic context, primarily composed of undergraduate students with similar educational backgrounds. This relatively small and homogeneous sample restricts the generalizability of the results to other populations, such as students from different institutions, professional developers, or multidisciplinary teams. To address this limitation, future studies should replicate this investigation with larger and more diverse samples, strengthening the external validity of the findings.

The study also relies partially on self-reported measures, which may introduce subjective bias. To mitigate these issues, we designed the research protocol with the support of a senior Software Engineering researcher to ensure methodological rigor. We also ensured data confidentiality and voluntary participation to reduce potential response bias.

The study adopted a short-term intervention conducted in a single session. Therefore, we could not observe how the technique performs over longer periods or in more complex project settings. In addition, participants had no prior experience with the Lotus Blossom technique, which required an initial adaptation effort and affected time management. To mitigate coordination difficulties, we organized participants into smaller groups, which facilitated interaction and helped balance participation.

9 Final Considerations

This section summarizes the key insights, outcomes, limitations, and future directions of this study, which investigated the use of the Lotus Blossom technique as a tool for fostering collaboration in computing education. The study involved a 2.5-hour classroom activity in which undergraduate software development students used the technique to identify and analyze a central problem in either agriculture or education. Using post-its and A4 sheets, students collaboratively organized ideas, engaged in discussions, and refined their problem definitions, supporting a structured ideation process.

The results indicate that the Lotus Blossom technique supports student engagement, collaborative behavior, and communication clarity. Participants reported feeling encouraged to share ideas openly and contribute meaningfully, reinforcing the method's role in fostering a cooperative learning environment. The activity also stimulated creativity and innovative thinking, demonstrating its usefulness for educational problem-solving. However, feedback on time constraints highlights the need for adjustments in timing and logistics, especially for first-time users or larger groups.

This study contributes to addressing a gap in computing education by applying a structured yet underused Design Thinking technique to support collaborative practices. The technique's simplicity, low resource requirements, and ability to engage diverse student profiles make it a strong fit for academic settings. While the results suggest that Lotus Blossom may contribute to the development of collaboration-related competencies such as communication, coordination, and cooperation, these findings are based on participants' perceptions rather than direct measurements.

Future research can expand the applicability of the Lotus Blossom technique by exploring its integration with digital collaborative environments, enabling more fluid interaction, idea sharing, and traceability in both in-person and remote settings. Building on this, another promising direction is to investigate the use of the technique in distributed or hybrid teams, examining how it supports coordination, communication, and shared understanding when participants are not co-located.

In addition, comparative studies with other ideation and design approaches commonly used in Software Engineering Education can provide deeper insights into the relative strengths and limitations of the technique across different learning scenarios.

Future studies should also adopt more robust experimental designs, including controlled comparisons between groups and the use of inferential statistical analyses, to strengthen the evaluation of the technique under different conditions.For instance, the use of data triangulation strategies, such as semi-structured interviews and think-aloud protocols, can provide deeper insights into participants' cognitive processes, complementing quantitative findings and increasing the overall rigor of the analysis.

Finally, longitudinal studies would help to evaluate how repeated use of the technique influences participant engagement, idea generation patterns, and its sustained impact over time. Nevertheless, the results obtained in this study suggest that the Lotus Blossom technique is a viable and promising approach for supporting collaborative activities in Software Engineering Education.

Declarations

Authors' Contributions

Enzo Kleinpaul (EK), Lorenzo Acosta (LA) and Alexandre Pires (AP) contributed to investigation — conducting the research and performing the study — and to writing – original draft, which involves preparing and drafting the initial manuscript. Rafael Parizi (RP) contributed to data curation, writing, review and editing, focusing on critical review and content evaluation, and supervision, providing mentorship and oversight for the research activity. All authors read and approved the final manuscript. Contributions were described using the CRediT taxonomy.

Competing interests

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Availability of data and materials

The datasets of this study are available in `https://doi.org/10.5281/zenodo.15271304`.

Use of AI Tools

We used ChatGPT (Instant model 5.3) during March and April 2026 to support the revision of the manuscript, particularly for improving grammar, clarity, and overall language quality. These tools were employed solely for linguistic refinement and did not contribute to the study design, data analysis, or interpretation of results. All content was critically reviewed and validated by the authors to ensure accuracy and alignment with the intended scientific contributions.

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