Collaborative catalysts: a framework for creative interdisciplinary design workshop

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doi.org/10.21606/iasdr.2023.550

Design education is interdisciplinary in its nature, yet how to facilitate productive and authentic design processes that encourage creative collaboration within a heterogenous group needs further investigation as well as empirical evidence. This study first reviews existing frameworks and the educational factors that affect its creativity and productivity, then constructs a framework for organizing an interdisciplinary workshop aimed at leveraging collective creativity through the theme of multimodal book design for children. Qualitative empirical data was collected and analysed in accordance with the framework. Finally, we present principles and elements for consideration when conducting an interdisciplinary approach to design experience that fosters creative collaboration by using a combination of inductive and deductive approaches.

**Keywords:** interdisciplinary design; creative collaboration; educational elements; workshop

1 Introduction

Collaboration across disciplinary boundaries has become necessary for addressing the increasingly complex real-world problems that designers encounter on a daily basis. Since the introduction of co-design, the power of creative collaborations has shifted from the designer to every participant from a variety of backgrounds within the group. Thus, providing accessible entry points for designers and relevant stakeholders throughout the design process becomes the pivotal point for creative design processes and innovative practices within design education.

Despite the existing evidence strongly suggests that interdisciplinary design processes as the means and ends for kindling and supporting creative collaborations (Edmondson & Harvey, 2018; Parjanan & Hyppia, 2019), how to organize an interdisciplinary design process in order to maximize creativity among a diverse group of participants remains a relatively new and complex field. The creative collaboration that involves participants of diverse backgrounds demands a solid supporting system,
including organizers, mentors, stakeholders, team members, and other non-tangible resources; a considerate arrangement of space and how members encounter, interact, and collaborate within the space (Sa, 2007); as well as a well-paced workshop plan with the flexibility to adjust and individualize based on the needs of each participant (i.e., Patel et al., 2018).

This paper presents three research questions for the organisation of innovative interdisciplinary workshops in design education:

1. How do interdisciplinary design approaches influence creative collaboration?
2. How do educational (spatial, temporal, and social) elements empower creative interdisciplinary collaboration?
3. How to implement an interdisciplinary design framework for creative collaboration?

2 Related work

2.1 Interdisciplinary design for creative collaboration

With the development of technology and the rise of knowledge-based societies, it is increasingly important to acquire interdisciplinary knowledge and the ability to work across disciplines (Kang, 2008). In traditional design education, it is recognized that designers' ability to solve complex problems in an interconnected world is limited by their disciplinary knowledge (Mok, 2009; Norman, 2010; Norman & Klemmer, 2014). Professionals from different disciplinary backgrounds are collaborating increasingly to combine design methods and scientific knowledge to solve complex problems (Zhang et al., 2022).

Many researchers have started exploring interdisciplinary design due to its potential benefits in design education. When defining interdisciplinary in design education, Repko (2012) believes that it is not simply combining two or more disciplines, but rather integrating the teaching of disciplinary skills and knowledge into students’ learning experiences. Self et al. (2019) discussed the potential driving factors and barriers to interdisciplinary education in design from the perspective of student learning. In addition, research on innovation labs and design studios has shown that creativity is an important aspect of interdisciplinary collaborative work. Interdisciplinarity has become a widely applied approach to enhance creativity, learning, team performance, and innovation (Edmondson & Harvey, 2018; Kim, 2018; Runco, 2017; Tan, 2017).

As interdisciplinarity is seen as a creative process that operates within and beyond disciplinary boundaries (Darbellay, 2022), more and more researchers are focusing on how to promote students' collaborative creativity in interdisciplinary design processes. Moirano et al. (2020) conducted a systematic literature review on creative interdisciplinary collaboration, exploring the relationship between interdisciplinarity and collaborative innovation and identifying important factors that need to be considered in interdisciplinary collaboration to promote creativity. Wong et al. (2021) discuss a qualitative case study of collaborative creativity among education professionals who co-designed teaching activities related to environmental education. Moreover, to better assess collaborative innovation in interdisciplinary design, Mavri et al. (2020) focused on the validation and reliability of the Creative Collaboration Evaluation Scale (ASCC), which measures creative collaboration in a blended learning environment. Exploratory factor analysis showed that it has three factors (21 items), measuring "synergistic social collaboration," "distributed creativity," and "time regulation and
achievement," with good internal consistency. This provides a basis for measuring creative collaboration in our research, and we focus on exploring how interdisciplinary design can enhance students' collaborative and creative abilities.

### 2.2 Educational elements for creative interdisciplinary collaboration

The field of education has been analysing what elements can influence creative interdisciplinary collaborations for years. Three prominent trends of most relevance emerge from a large body of literature on creative interdisciplinary collaboration: the spatial, temporal, and social dimensions.

Regarding the spatial dimension, scholars have found critical linkages between educational or workspaces and creative outputs. Haner points out that according to the trends in workspace design, joyful, open, and stress-free spaces can enhance creative thinking, creative outputs, and productivity (Haner, 2005). In the existing literature on design education, scholars have found that the setup and organization of physical spaces can contribute to the likelihood of interdisciplinary collaboration, especially in settings like laboratories and university campuses. Scholars have concluded that spaces provide ample opportunities for interaction, proximity, flexibility, and frequent communication can spark the highest level of creativity for groups with diverse backgrounds (Kaygan & Aydinoglu, 2017; Lehrer, 2012). Kabo et al. discovered that shared objects and spaces, as well as the possibility to rearrange the learning/working space, can all contribute to levels of creative interdisciplinary collaboration. For instance, the setup water fountain, coffee machine, lounge, and stairs can become potential spaces for encounters and interdisciplinary free discussions (Kabo et al., 2014, 2015; Björklund et al., 2011). Regarding the temporal dimension, instructional pacing and time management have been the pivotal point in maximizing learning outcomes. For instance, long or short wait time between instruction and student response and the time spacing between the teacher's feedback and the next antecedent instructional stimulus can significantly impact students' engagement and performance (Tincani & De Mers, 2016). Chivukula and Gray introduced the concept of the "Rhythm of Engagement" to reflect on the orchestration of participants' interactions with activities throughout the workshop time (Chivukula & Gray, 2022). Yet organizational pacing and workshop rhythm management for interdisciplinary collaboration to maximize participants' creativity remains a gap to be filled in the field. Regarding the social dimension, Cohen and Lotan have introduced strategies for collaboration among heterogenous groups: namely, the importance of designing group-worthy tasks and specifying roles and its accordant responsibilities (Cohen & Lotan, 2014). Meanwhile, scholars found the importance of group negotiation involving mediating between the novelty aspect of creative collaboration and appropriateness within the shared constraining frames, which is especially applicable to interdisciplinary collaborations during creative design processes (Wong et al., 2021).

### 2.3 Interdisciplinary design process for creative collaboration

Interdisciplinary collaboration has become a key approach to fostering innovative solutions and addressing complex challenges. In recent years, numerous studies have explored interdisciplinary design processes to enhance creative collaboration. In educational settings, it is crucial to consider the professional backgrounds of students from different disciplines. Cotantino et al. (2016) advocated integrating art courses, evaluation sessions, and creative thinking education into the design process and conducted pilot studies to promote interdisciplinary collaboration among art and engineering students. To promote a more holistic understanding, education should be designed to help students grasp the fundamentals of non-professional fields. This comprehensive approach to education
empowers students to embrace the benefits of interdisciplinary collaboration, enabling them to collectively tackle complex challenges and unlock innovative solutions.

On the other hand, creative interdisciplinary design works need to be evaluated and modified to effectively solve problems and promote creativity. De Beer, C. (2018) explored a creative poetic performance that used the little-c definition of creativity and analysed the threads that constituted and contributed to their performance to see how aspects of self-manifested within this creative process. Jong Boonpracha (2022) emphasizes the value of evaluating design in the course to spark students’ insights during product design and to evaluate their creativity in four aspects (fluency, flexibility, creativity, and elaboration). Researchers are actively seeking to investigate the extent to which genuine interdisciplinary collaboration can effectively bolster creative collaboration. However, these studies have not delved deeply into how to achieve interdisciplinary collaborative innovation at different stages of the design process.

In addition to the aforementioned studies, Ikjoon Chang & Suhong Hwang (2017) investigated the dynamics of interdisciplinary teams in the context of project-based learning. Their research explored how student reporting and expert comments from teachers in the preliminary homework, teamwork, and project creation stages of the workshop. It also introduced the educational design mechanism of company cooperation, obtained feedback from students, and gave relevant suggestions, achieving the improvement of participants' willingness to participate actively. While these studies have explored various stages for interdisciplinary design, they have not effectively integrated the different stages of the design process with interdisciplinary collaborative innovation. There remains a gap in providing practical references for interdisciplinary collaborative innovation by incorporating the various stages of design practice.

3 Organizational framework

The organizational framework of the workshop is an essential element that provides structure and guidance for participants in their design activities. The framework consists of two main stages: the preparation stage and the design practice stage.

During the preparation stage, the workshop organizers facilitate an opening ceremony to introduce the mentors and designers from different disciplines. This stage is critical in helping participants to get to know each other and establish rapport. The workshop organizers then provide role cards for each group of designers, including material managers, discussion guides, viewpoint loggers, product evaluators, and educational researchers. These role cards serve as a guide for the participants, and they are assigned based on the educational and work background of each designer. Afterward, the designers are guided to define the design issues and generate initial solutions and ideas. Meanwhile, the mentors are grouped based on their individual research background and direction, as well as the relevant disciplinary support required by each group.

The design practice stage is where the actual design work takes place. This stage is divided into several phases, including defining design problems, exploring research, prototyping, and presenting reports and testing. The mentors provide expert support in the relevant professional field through lectures and group guidance. During the mid-term reporting stage, stakeholders involved in design issues are introduced for collaborative design, while mentors provide corresponding design guidance. This stage
is crucial in ensuring that the design process remains aligned with the stakeholders' needs and goals. During the prototype design and iteration phase, the workshop organizers, mentors, stakeholders, and designers work together to iterate. This iterative process facilitates continuous interdisciplinary integration among relevant designers, allowing them to explore new and innovative solutions to the design issues. Finally, the workshop presentation and closing ceremony stages provide a platform for the designers to present their work and receive feedback from the mentors, stakeholders, and other participants.

In summary, the organizational framework of the workshop provides a structure that enables designers to collaborate across different disciplines and generate innovative design solutions. The pre-preparation stage facilitates the development of a shared understanding of the design issues and establishes the necessary roles and responsibilities for each participant. The design practice stage offers a flexible and iterative design process that allows designers to continuously integrate feedback and generate new ideas. Overall, the workshop's organizational framework serves as a foundation for effective collaboration and design excellence.

Figure 1: The organizational framework of the interdisciplinary creative design workshop

4 Method

4.1 Participants
We recruited 19 participants (18 female, 1 male) aged 20 to 40 (M = 23.2, SD = 3.4) for this workshop. All participants were recruited from local universities, including 7 undergraduates, 10 postgraduates, and 2 faculties. A pre-study questionnaire was released to participants inquiring about their field of study, as shown in Table 1. They had diverse educational backgrounds, including child and adolescent psychology, education, art, visual Communication design, digital media art, and industrial design. Before the workshop started, the author introduced the workshop process and safety precautions, and all participants signed an informed consent form and were randomly divided into four groups. Regarding the more complex backgrounds of participants, including their race, socio-economic status,
cultures, genders, etc., even though we took all of these factors into consideration, the theme of multimodal book design for children attracted mostly female participants from diverse educational backgrounds. We attempted to establish equitable and democratic discussions for each individual group member through assigned roles, discussion scaffoldings, and arranged activities. It would be more ideal for the organizers to apply the concept of interdisciplinary collaboration in more authentically diverse contexts.

Table 1. The demographic analysis of the workshop’s participants

<table>
<thead>
<tr>
<th>Group</th>
<th>Participants</th>
<th>Age</th>
<th>Gender</th>
<th>Occupation</th>
<th>Field of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>P1</td>
<td>26</td>
<td>F</td>
<td>undergraduate</td>
<td>Child and adolescent psychology</td>
</tr>
<tr>
<td>G1</td>
<td>P2</td>
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<td>F</td>
<td>undergraduate</td>
<td>production design</td>
</tr>
<tr>
<td>G1</td>
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<td>F</td>
<td>undergraduate</td>
<td>industrial design</td>
</tr>
<tr>
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<td>F</td>
<td>postgraduate</td>
<td>industrial design</td>
</tr>
<tr>
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<td>P5</td>
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<td>F</td>
<td>postgraduate</td>
<td>Art</td>
</tr>
<tr>
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<td>faculty</td>
<td>New Media Art and Design</td>
</tr>
<tr>
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<td>20</td>
<td>F</td>
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<td>Digital Media Art</td>
</tr>
<tr>
<td>G2</td>
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<td>F</td>
<td>postgraduate</td>
<td>Electronic information technology</td>
</tr>
<tr>
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<td>P9</td>
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<td>F</td>
<td>postgraduate</td>
<td>industrial design</td>
</tr>
<tr>
<td>G3</td>
<td>P10</td>
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<td>F</td>
<td>faculty</td>
<td>Brain and Cognitive Science</td>
</tr>
<tr>
<td>G3</td>
<td>P11</td>
<td>24</td>
<td>M</td>
<td>postgraduate</td>
<td>Information art design</td>
</tr>
<tr>
<td>G3</td>
<td>P12</td>
<td>27</td>
<td>F</td>
<td>postgraduate</td>
<td>Information art design</td>
</tr>
<tr>
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<td>F</td>
<td>postgraduate</td>
<td>Curriculum and Teaching Methodology</td>
</tr>
<tr>
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<td>F</td>
<td>postgraduate</td>
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</tr>
<tr>
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<td>F</td>
<td>postgraduate</td>
<td>industrial design</td>
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<tr>
<td>G4</td>
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<td>20</td>
<td>F</td>
<td>undergraduate</td>
<td>Digital Media Art</td>
</tr>
</tbody>
</table>

4.2 Procedure

The theme of this activity is a multimodal educational book workshop, as shown in figure 2. The organizers wanted to let more stakeholders get involved in the design process to better use this workshop as a case study to validate the efficiency and conduciveness of the organizational framework the paper delivered earlier.
Figure 2: The actual interdisciplinary situation when executing the workshop

1. Kick-off. The organizers invited teachers in education, design, and science engineering to guide the work. At the same time, the organizer arranged the venue according to the needs of the workshop, which was convenient for participants to conduct user interviews, model making and periodic reports in the venue. In addition, the organizers purchased materials to facilitate the participants to prototype. The organizers assigned role cards to participants with different professional backgrounds through pre-background research, ensuring that each group of characters with different professional backgrounds, such as education, engineering, and design. Each mentor was assigned to different groups to lead their design process better.

2. Week 1, Problems Definition. The organizers introduced the workshop's theme, and mentors delivered several lectures for the participants to ensure they had abundant knowledge to design stand-up books. After brainstorming and idea convergence, four groups confirmed the design problems they wanted to solve and presented the topic selection at the end of the first week.

3. Week 2, Exploration. To make participants gain a deeper understanding of children's learning needs, the organizers invited teachers from primary school and families with school-age children to participate in co-design. The workshop participants interviewed those stakeholders about their needs, worries, and expectations. The participants could also check the instructional syllabus suggested by the professional education institute to know the need during children's growth. In the meantime, different groups started to work together when they encountered difficulties.

4. Week 3, Prototyping. The manual and MultiMaker's toolkit presented the modules' functions in the toolkit and provided four demonstration prototypes for designers to understand how to use the toolkit for rapid prototyping. Then the participants can use the material offered by the workshop to design a stand-up book to meet their original design goals. Organizers and mentors provided necessary guidance whenever the participants were in need.

5. Week 4, Test and Presentation. Organizers set up midterm reporting to obtain mentor feedback, focusing on the design's rationality, feasibility, and creativity. It lets the participant iterate the prototype quickly based on user feedback from stakeholders and mentors. After several versions of the design, all groups presented their prototypes on-site and verbally demonstrated their ideas with slides, some of which delivered video essays to the organizer, showing their design procedure. At the end of the workshop, all participants were asked to investigate their overall attitude toward the workshop and themselves. Mentors also rated each group's work based on multiple dimensions.
4.3 Data collection and analysis

To assess students' collaborative and creative abilities in this workshop, we utilized the Creative Collaboration Evaluation Scale (ASCC) for self-evaluation after the workshop (collaborative social collaboration, distributed creativity, time regulation and achievement). The ASCC comprises 21 items, rated on a 7-point Likert scale, which has been proved to be reliable and valid. Additionally, to evaluate the level of innovation in each group's final product, the instructor rated the level of innovation using a 5-point Likert scale.

We recorded the final two stages for analysis, and participants completed a follow-up survey containing questions and two open-ended questions. We conducted structured face-to-face interviews with participants, which lasted approximately 60 minutes each. Before the interviews, we reviewed the survey results and workshop records to identify interesting points and construct in-depth interview questions and topics.

During the interviews, we asked participants about their participation, such as how they collectively brainstormed and made design decisions. We also asked for their feedback on our workshop organization while encouraging them to report any difficulties or challenges. With the participants' consent, we recorded audio during the interview process and transcribed it into text for subsequent analysis. To ensure privacy, we anonymized their data in transcription and paper.

We used a mixed-method approach to analyse the collected data, which included post-study questionnaires, transcribing interviews, and reviewing workshop videos. Two researchers reviewed the on-site collected data (prototypes and videos) to understand each group's participation process and output. We then conducted a quantitative analysis of the questionnaire results to understand how participants evaluated the workshop organization, and whether their professional knowledge (programming) was related to their evaluation. Following this, we used thematic analysis to summarize the interview (Virginia Braun & Victoria Clarke. 2012. Thematic analysis. 2012). We first familiarized ourselves with the data individually, and then the two researchers coded the data separately. Finally, we discussed the codes and generated recurring themes from the analysis. These themes covered how participants collaborate throughout the workshop process and views on further applications.

5 Results

5.1 Interdisciplinary design support creative collaboration

In this workshop, we create interdisciplinary teams to design multimodal interactive books for children's learning. To gain insight into the collaborative innovation experience of participants in our interdisciplinary design workshop, we analysed data from their post-workshop surveys and interviews. The results of the post-study questionnaires are presented below: Participants rated the quality of the workshop very highly (M = 4.9, SD = 0.2). The scores of creative collaborations, including collaborative social collaboration (M = 5.79, SD = 0.79), distributed creativity (M = 5.78, SD = 0.63), time regulation and achievement (M = 6.07, SD = 0.91), are higher than the average (with 1 being strongly disagreed and 7 is strongly agreed). We also collect the scores of every group's creative production (M = 4.22, SD = 0.23, with 1 to 5). There is a significant correlation between each group's collaborative innovation ability and the level of innovation in their work (r = 0.85, p = 0.003).
To fully support participants’ design needs in the interdisciplinary section, we invited more than ten mentors with different professional backgrounds to provide immediate feedback at different workshop stages. Each group was assigned 5-6 mentors according to their backgrounds and needs, who provided support during open times to help participants with any problems they encountered. All interviewees gave positive feedback on the interdisciplinary design for creative collaboration. They felt that interdisciplinary collaboration made the design process more professional and gave a more comprehensive perspective of the current project.

For example, P6 felt that "the group members with technical and educational backgrounds made it more professional and accessible to implement prototypes and find theories from existing academic knowledge to support the design." P5 stated, "In the interdisciplinary team, I suddenly realized that disciplines are not supposed to be separated and that completing a project itself involves multiple disciplines, but perhaps because education forces them into separate categories when it comes to execution." P2, as a student from an art college, teamed up with a student from university and thought they were more grounded and rigorous in their approach to design. P19 thought that "the interdisciplinary practice process is mixed in terms of the roles and work we take on, and we can give advice to others from our areas of expertise, so it makes the work more challenging in a good way." P3 stated that such a support system created an unprecedented interdisciplinary tool and environment for them, allowing them to try any design they wanted in the workshop because they were not afraid of not being able to accomplish it and could ask mentors for help at any time. The design itself is an interdisciplinary profession, and the use of any creative design tools requires guiding designers to try interdisciplinary collaborative creation, reducing their concerns about technology and enhancing designers’ interdisciplinary effectiveness.

Overall, the interdisciplinary design workshop experience was highly praised by the participants. Everyone stated that in-depth interdisciplinary collaboration broke down disciplinary boundaries and greatly inspired collaborative creativity.

5.2 Educational elements empower creative interdisciplinary collaboration

Even though the scope of educational elements that may influence the process of interdisciplinary collaboration remains vast and broad, our qualitative empirical evidence suggests that the temporal, spatial, and social dimensions contribute the most to groups’ creative outputs throughout the workshop.

First, during our focus group interview sessions, almost all groups reflected that the physical space has a significant impact on their own group’s creative output and inter-group collaborations and inspirations. The physical space, as shown in figure 3, of the workshop took place at an interdisciplinary research lab at a research university. Over 100 principal investigators, researchers, staff, and students from over 50 disciplines work or study in an open office space adjunct to the creative collaborative space. The workshop participants share common spaces including the leisure area, the discussion areas, and the prototyping areas with other members of the lab during the workshop period. The proximity with group members, other groups, mentors, and other resources within a shared place increased the levels of creativity and productivity (Kohane, 2012; Lehrer, 2012). During the workshop preparation period, the organizers rearranged the creative collaborative space so that it provides sufficient tools and materials needed for the production of multimodal books while it remains an open space that encourages free-flow setups for group work. P15 in Group3 has also mentioned that during
each phase of the workshop, she and her group members would often take a stroll to see other groups' progress, which often inspire them to refine their own work. The flowing nature of the creative collaborative space allowed the workshop organizers to embed activities like gallery walks, on-site interviews, and one-on-one mentor meetings into different phases based on the educational needs for creative output. Additionally, for three consecutive weekends, all participants presented their books in the presentation area, with the last presentation being a semi-public "new book release gathering." The reporting space with a presentation stage, an audience area, and a demo display area increased the sense of celebration and ceremony. The body of literature on Project Based Learning in the educational field also echoes that it is crucial to provide a sense of authenticity through a ceremonial event in order to increase students' levels of engagement and interest over time (Kokotsaki, Menzies, & Wiggins, 2016). It is noteworthy that the initial ice-breaking took place online, and some participants also remained online during the team-up period due to pandemic travel restrictions. Participants (4,6,11,15) shared that they felt immediate relief when they finally had the chance to meet up in person, while their levels of trust and reliance on each other significantly increased when they began to work closely daily in the creative collaboration space. Hence, the online period due to the pandemic functions as a natural experiment that empirically verifies the importance of utilizing a shared open space with key functional divisions is crucial for interdisciplinary creative collaborations. Workshop organizers need to arrange the space according to all participants' educational goals and creative production needs.

Figure 3: the main areas of the workshop space

The temporal dimension is another important educational element that significantly influences the learning and creating process. During the preparation phase, the organizers hypothesized that students' levels of engagement would fluctuate significantly over time. Meanwhile, each participant's engagement and motivation determine the overall quality of the ultimate product due to the interdisciplinary nature. Thus, as inspired by instructional pacing and curriculum design principals, we introduced the concept of organizational pacing and workshop rhythm for interdisciplinary creative
collaboration, specifically we pin-pointed several time nodes and key milestones for each phase of the workshop. At each temporal node, we planned our workshop activities based on the overall goals of the workshop while adjusting the specificities based on participants' needs. The specific strategies include introducing various stakeholders at different stages; instilling one-on-one sessions with mentors before and after each week's presentation; and increasing opportunities for mini-presentations each weekend. After the workshop, we reflected on the organizational pacing and workshop rhythm with all participants through focus group interviews: participants (P7, P9, P11, P17, P18, P19, P20) thought that designers needed to do more prototype testing and iteration with children at an earlier stage because there is always a discrepancy between what designers envision and what children do. For example, children's attention is easily drawn to irrelevant elements of the book, which is different from the designer's original intention for children to focus on. P17 states that "I think it may be even better if we made a pre-prototype or showed the materials to children and collected another round of feedback before the prototype. We discovered that children ignore the facts presented in the prototype and they may make up their own rules about colours and their represented meanings. The participants' reflections on timing and rhythms made it clear to us that pacing in the temporal dimension needs to be taken into account more seriously into the overall planning of the workshop. Pacing is not only the administrative managerial side of workshop organization, it also the key determinator for interdisciplinary creative collaboration.

Lastly, our empirical evidence shows that the interdisciplinary creative collaboration process itself is a social conduct that empowered students, mentors, and stakeholders. Participants P5 and P6 shared that "the thoughtful questions raised by the mentors challenged our design process from different angles and we had to think of ways to compromise and negotiate a lot during the discussions;" P3 reflected that "the process gave us a sense of meaning and responsibility in the project we were working on and inspired us to continue trying". During the reflection interviews, group 1 stated, "we think any task can be accomplished in this lab. You can find any experts from any discipline here". Indeed, when group 1 encountered technical difficulty at 9 pm the night before their final presentation, they were able to find a PhD student from the lab assisting them with Arduino problems. Group 4 shared that the social and leisure atmosphere helped them to be engaged and motivated. Specifically, they believe that the provided snacks, tea, and coffee created a social space that encourages small talk across groups within the cohort. Although food-for-thought and tea-time are widely adopted practices in western cultures, it remains uncommon in East Asian education systems, so that it left an impression on the participants' social behaviours during creative collaboration.
5.3 Interdisciplinary design experience for creative collaboration

The multimodal design workshop for creative learning, guided by the framework of interdisciplinary collaborative design, integrates designers and mentors from different disciplines, as shown in figure 4. In the participatory design process of the workshop, whether it is a mentor with a professional background, an interdisciplinary organizer of the workshop, or a designer with an interdisciplinary background, they have all gained their own interdisciplinary experience in a good space and collaborative atmosphere. It is worth mentioning that the workshop explored the introduction of stakeholder nodes for participatory design. At present, the organizers of the workshop introduce relevant suggestions from primary school teachers in the stage between designing problem definitions, exploring research, and prototyping; At the same time, relevant child audiences have been introduced, and designers are requested to conduct user research based on children’s reading and behavioural preferences.

After the workshop, the organizer conducted a questionnaire survey and interviews with each designer team. The designer provided feedback on team building, mentor guidance, and creative space support. At the same time, designers feel that through the design process of the workshop,
designers from different professional backgrounds have better integrated together. Everyone has a clear liking for the role allocation plan during the team building process, as it allows designers who are not familiar with each other to quickly form teams and clarify their relevant tasks within the team. In addition, discussions in open spaces are more conducive to interdisciplinary communication and collaboration, enabling designers to quickly solve complex interdisciplinary problems.

P15 mentions the importance of open space. "I think communication between the groups was the key to success," she recalled the night before the final presentation, "We were able to have contact and learn from the next group conveniently from here, and the G1 group not only gave us very crucial advice on structure, but our group's overall momentum was also driven by them, which in general was a very positive boost." P3 felt that the open space also made it easy to ask for help: "I asked the instructor for technical support, and the instructor worked with us on the long table in the Prototyping Area to solve code-related problems, and the other groups were able to discuss together, which I thought was a great space and atmosphere", which proves the influence of spatial arrangement in educational elements.

P18 believes that the periodic debriefs significantly pushed the group’s progress and that the instructor's periodic feedback played an essential role in making decisions on topics such as: "Most of the members of our group were busy, and the checkpoints gave us a sense of urgency to move forward, which in turn facilitated the production of creative designs in a short time... Also, the mentors' advice in the midterm presentation was so helpful in confirming our design goal from the confusion of topic selection", which proves the importance of reporting and evaluation in the design process.

G1 (P1, P3, P4) expressed his love for the group vibe and believed that the good vibe made members from different majors work better together when designing, "We had a clear mutual goal and trusted each other. It made the students who coded the Arduino board, tested the three-dimensional structure, and designed the educational content do their jobs efficiently. In addition, the workshop provided a large variety of materials that allowed us to iterate on creative prototypes easily."

G2 (P8, P10) was satisfied with the group made up of people with different backgrounds, "P7 was able to give us a lot of professional guidance on the product due to his working experiences, and we were delighted with the final work we presented", which believed that the good atmosphere of the group made members of different majors cooperate better in creative design, and interdisciplinary team formation and cooperation within the team was an important factor affecting the creation of works.

6 Discussion

6.1 Promoting interdisciplinary creative collaborative from the perspective of educational elements

In previous research on interdisciplinary design, researchers found it difficult to arrange participant schedules, and the composition of interdisciplinary teams was not strictly designed (Zhang et al., 2022). Therefore, throughout the entire interdisciplinary collaborative design process of this study, we conducted in-depth analysis and design from the perspectives of the three educational elements of time, space, and social. As shown in Fig.1, it is a design framework created through interdisciplinary collaboration.
In order to promote collaborative creation in interdisciplinary design, we established good pacing, provided open collaborative space, and designed roles for the composition of interdisciplinary teams. These methods greatly promoted interdisciplinary collaboration and creation. For example, we designed an exhibition space and collaborative creation space in the workshop, which greatly promoted collaborative creation among interdisciplinary teams. In addition, by assigning roles, we enabled responsibility to circulate within interdisciplinary teams and fully mobilized the participants' enthusiasm. However, we found that due to the differences in the objects, usage scenarios, and design progress of each design group, it was relatively limited to arrange a unified time rhythm, and this type of interdisciplinary collaborative creation requires more flexibility.

6.2 Involving interdisciplinary mentors and multiple stakeholders to form interdisciplinary support system

In our workshop, we aimed to create a support system for interdisciplinary collaboration. To achieve this, we invited a team of interdisciplinary mentors and stakeholders who were related to the theme of the practice to participate in the design process. The designers conducted interviews with teachers, parents, and children, while mentors from different fields provided professional feedback on the designs.

However, we found that the introduction of different mentors and stakeholders was not always the best throughout the process, as shown in Fig4. The engagement of organizers, designers, stakeholders, and mentors varied in different stages of the design process. Therefore, organizers and designers need to explore and flexibly adjust when introducing each role in the design process.

Additionally, through feedback from the design team, we discovered that visiting children's real spaces, such as their homes, schools, and bookstores, during interviews can help them integrate earlier. Therefore, we can conduct interviews or track in different, more diverse, and realistic fields for different user objects and design scenarios. This way, stakeholders can provide support for interdisciplinary collaboration to the greatest extent possible.

7 Conclusion and future work

This study examines how interdisciplinary design can foster collaborative creativity, proposes a framework for interdisciplinary creative collaboration, and validates and tests the framework empirically through a workshop on multimodal book design for children. This study reveals that educational elements are crucial to the interdisciplinary collaborative design process, which we analysed from the perspectives of time, space, and social factors. We found flexible time, an open and flowy spatial environment, as well as specific role allocation were all very helpful factors for their interdisciplinary cooperation. Furthermore, by pacing interdisciplinary mentoring teams and multiple stakeholders throughout the interdisciplinary design process, we found that under the framework proposed in this study, designers have a greater degree of interdisciplinary integration, providing strong support for interdisciplinary collaborative creation. Overall, this study empirically confirmed the effectiveness of the interdisciplinary collaborative creation framework through practical workshops and identified a framework that has broad significance. It is anticipated that this will serve as a useful guide and source of inspiration for future interdisciplinary design innovation in design education.
However, there are still some limitations and challenges in this interdisciplinary design study. For example, while we explored specified group member roles in the interdisciplinary design process with the aim of allowing more equitable conversations and multiple conversational access points within heterogenous groups across disciplines. Meanwhile, it is necessary to further explore the potential of using roles in a variety of activities at different design stages to ensure each participant can contribute equitably and democratically regardless of their academic and social status. Furthermore, participants suggested that, in addition to role-specific cards, they would like more hands-on design tools, design manuals, or scaffolds to support their interdisciplinary design process. Another limitation is that the theme we chose for the workshop attracted mostly university female participants to apply. Although we attempted to maintain as diverse backgrounds as possible, but the participants have very similar academic experiences and social backgrounds: they are mostly females who are extremely passionate about education and child development. Therefore, future works can focus on how to facilitate interdisciplinary design processes across different cultural and socio-economic contexts; or emphasis on how to apply the proposed framework outside of the design education field.

References
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Acknowledgement: We would like extend our profound gratitude to the Lab for Lifelong Learning and the Future Laboratory at Tsinghua University for their unwavering support throughout this research endeavor. Additionally, this work was generously supported by the Youth Program of Beijing Social Science Foundation (21YTC037).