Chapter 41
Visualising Student Interaction and Collaborative Design Ideation for Design Sessions with School Students

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Abstract Group work is an important focus of Design and Technology (D&T) education research. In order to design effective collaborative structures facilitating divergence during design thinking sessions, we tested the effect of four group compositions on collaborative ideation. We conducted two design trials with thirty middle school students and investigated the effect of group composition on design output and communication. Under each grouping condition, the students participated either as male, female or mixed-gender groups. Along with a detailed protocol analysis of the video data, we also mapped group interactions by creating a visualisation on a linear timeline for each group. The objective of the same was to visually represent the progression of ideas and inspect collaborative ideation. These timelines helped us understand participant involvement and the nature of group interaction. A series of visual markers were created to visualise each transcript. This representation highlighted active and hesitant episodes within groups and revealed that collaboration occurred mainly in the later phase of the design thinking process. During the design process, elaboration and documentation of ideas had its effects on team collaboration.

41.1 Introduction

Group work has been recommended by design educators worldwide as it replicates actual design practice. It also enables developing new skills such as learning multiple perspectives, analysis and synthesis, advancing both verbal and non-verbal communication and peer learning. But minimal research exists suggesting effective collaborative setups to develop design problem-solving and idea generation in school students. D&T education acknowledges the difference between professional designers' design process and objectives of novice school children learning design [1]. In spite of considerable evidence to the contrary, a rigid, linear approach to designing still predominates school's design education which is highly influenced

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by design methods suitable for professionals. Design education practitioners follow certain distributed models for teaching design to children, but barely any of these models explore the dimension of organisation of student groups.

41.2 Background

Welch [2] suggests that pairing or grouping participants allows for the design process to emerge naturally as most design efforts occur when people work together. Multidisciplinary teamwork, although well-practised in the industry, is not always implemented effectively in education [3, 4]. While implementing a group activity, the facilitator usually recommends predefined guidelines and directions for group work. Group organisation or composition is an important factor while designing group activities. It has been observed that generally formation of groups for classroom learning is based on either different levels of skills, diverse background of children such as socio-economic, gender or at times a random group partnership like a lucky draw. Unlike curriculum learning, which aims at concept development, design may have a different purpose for forming groups. Design teams may be formed for framing a design problem, understanding design criteria and constraints, for idea generation, prototyping, testing design solutions or for all of the above. Therefore, it is important to investigate group composition specific to design problem-solving.

41.3 Participant Description and Experiment Design

Four grouping conditions were under investigation, and each condition comprised of three dyad groups (male, female and a mixed-gender group). Thirty students (15 boys and 15 girls in the age group 11–14 years) voluntarily participated in this study. All the participants were studying in local Marathi or English medium municipal schools. Their parents were informed and consent was taken for this study.

41.3.1 Design Trials (DTx)

The student design sessions followed the design-without-make approach [5], where students had to only conceptualise without making prototypes. There were two design trials (DT1 and DT2), and the task was a game design challenge. DT1: Design at least five new games for a young visually impaired girl. DT2: Design at least five new games for two children situated at a distance but can see each other through windows. The design task was (1) unfamiliar and challenging (2) had explicit instructions to encourage ideational fluency. Methodologically, everything was same for both the trials and same students participated in both. But, in DT2, students who participated

in DT1 were shuffled such that no student participated with the same team member and under the same condition. Both trials were conducted in a controlled setup with installed video cameras. The sessions were carried out by a trained research team. Each student group was provided a kit including the design problem, loose sheets to sketch, pencils, crayons and separate sheets for their final ideas.

41.3.2 Experiment Conditions for Group Organisation (DTxCn)

For both the design trials, students participated in pairs under four different grouping conditions. By a grouping condition, we mean the time when students form a group to collaborate and solve the design problem. For the purpose of analysis, the conditions were labelled as DTxCn, where x could be design trial 1 or 2 and n stands for condition 1, 2, 3 or 4. Following were the four conditions (C1, C2, C3 and C4):

1. C1: The teammates are given the design task at the same time, and they solve the problem together from start to finish.
2. C2: Only one member of the team is given the task, the other participant waits outside. After ten minutes, they form a team and solve the problem together. This condition is based on the benefits of elaboration and exploratory talk.
3. C3: Teammates are given the task together. They are instructed to first solve the problem individually and later form a group. This technique known as nominal grouping ensures everyone gets a chance to make an equal contribution.
4. C4: Swapping: Four students participate as pairs and are considered as one big team. The design task is given to all the pairs at the beginning. After fifteen minutes, one participant is randomly swapped with another group member to continue solving the task. This condition is inspired from a known grouping technique known as ‘Jigsaw’ [6].

41.4 Method of Analysis

The data for DTs was collected in the form of drawings, writings and video recordings. We used a mixed method analysis for analysing the data. Mixed method is a procedure for collecting, analysing and combining both qualitative and quantitative data at some stage of the research process within a single study [7]. The design output collected in the form of sketches was marked and analysed on the measure of divergent thinking on the following four factors—appropriateness, originality, ideational fluency and flexibility [8]. Protocol analysis, a qualitative method was used, where video recordings were transcribed and coded to analyse conversations using Dialogue Act Coding (DAC) [9]. Each utterance within a group was coded following five types of talk—argumentative, responsive, elicitative, informative and imperative talk. The findings from the design output analysis were validated using the DAC method [10].

To triangulate, we also analysed the transcripts by creating timeline visualisations to map the group ideation process. These timeline visualisations are discussed in the next section and are the main focus of this paper. Discussing a detailed protocol analysis with design output sketches is beyond the scope of this paper. For further details, correlations and analysis please refer to the authors' thesis [10].

41.5 Timeline Visualisations

The verbal interactions and idea generation in each group were mapped on a linear timeline for both DT1 and DT2. The objective of creating these timelines was to investigate progression of ideas, and most importantly to investigate whether the ideas generated were collaborative ideas or individuals' ideas. Such examination was crucial as several groups under different conditions scored high on the measure of divergent thinking and produced multiple solutions but protocol analysis and DAC revealed that group work and the nature of talk were not necessarily collaborative. To create these timeline visualisations, a set of action markers and legends (see Fig. 41.1) were designed to visualise each transcript and represent actions such as participants' discussion and turn-taking, highlighting individual versus collaborative ideas, improvised and borrowed ideas, reading the design task, drawing and documenting. The average time spent by groups for design problem-solving was ~ 60 min.

41.5.1 Design Trial 1-Condition 1 (DT1C1)

Figures 41.2, 41.3 and 41.4 show the visualisations of all the three groups (F, M and X) who participated under C1. Here, participant 1 (P1) and participant 2 (P2) worked together from the beginning till the end.

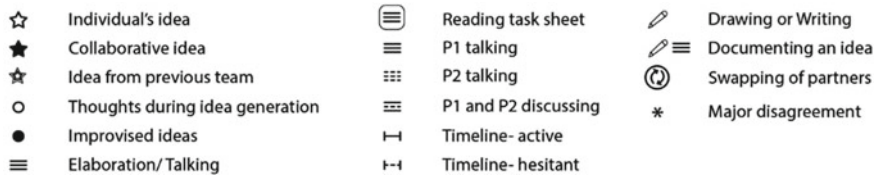

Fig. 41.1 Marker set and legends for the timeline visualisations

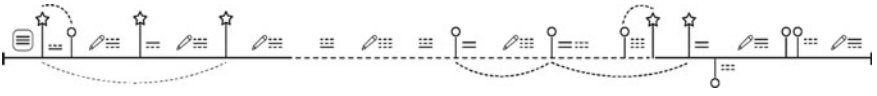

Fig. 41.2 Timeline visualisation of DT1C1F

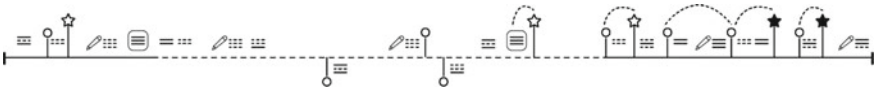

Fig. 41.3 Timeline visualisation of DT1C1M

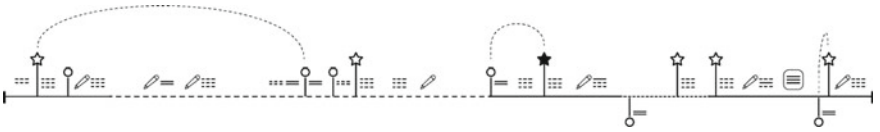

Fig. 41.4 Timeline visualisation of DT1C1X

We observed in all the three groups one members focused on generating ideas and the other spent time reading and understanding the task before idea generation. These two different approaches helped the students, especially in the later phase of design, when they were struggling to think of more solutions. As seen in the visualisations above, participants interacted the most while documenting the ideas rather than solving the problem together. Interestingly, on the measure of divergent thinking, DT1C1X scored better than both same-gender groups in C1 but whether these ideas were developed as a team or not was unknown. Through protocol analysis and visualisations, we found that in this group, the boy (P2) was proactive but the girl (P1) was hesitant and refrained from any kind of interaction. As shown in Fig. 41.4, during the design process, P1 shared two ideas out of which P2 accepted and improvised one and the second idea was initially rejected (the second circle below the timeline) but later accepted (the last star is an improvised idea). Hence, although groups under C1 came up with multiple solutions for the design problem, represented here by the number of stars in Figs. 41.3, 41.4 and 41.5, respectively; very few of them were found to be collaborative (coloured black stars). There were none out of five solutions in DT1C1F, two out of five in DT1C1M and only one collaborative idea in DT1C1X out of six. This explains that even though teams score high on ideational fluency and flexibility, their ideas may not be an outcome of group work.

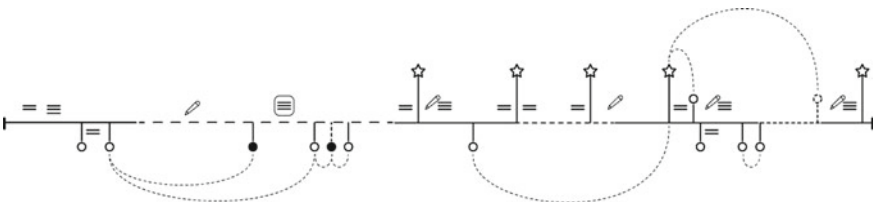

Fig. 41.5 Timeline visualisation for DT1C2F

41.6 Design Trial 1-Condition 2

The visualisations of C2 revealed similar findings as C1 in terms of collaboration. Figures 41.5, 41.6 and 41.7 show visualisations of C2's three groups (F, M and X). Again, the divergent thinking scores and nature of team interaction did not correlate.

In terms of collaborative ideation as seen in Figs. 41.5, 41.6 and 41.7, respectively, none out of five solutions in DT1C2F, only two out of nine appropriate ideas in DT1C2M and none again in DT1C2X out of four ideas were found to be collaborative. It was observed that in groups F and X, the participants who were given the design task first (P1) did not talk much and were less active than the new participants (P2). This could be due to lack of ability to describe and articulate, a skill which is usually not developed in typical Indian classrooms. The second participants' limited understanding and dependency on the information provided by their teammate clearly limited the expansion of the problem and solution space which affected idea generation. This led to confusion and as evident from the visualisations, esp. Figures 41.5 and 41.6, there were far more inappropriate ideas here as compared to other conditions. Girls especially were shy and felt hesitant to participate actively. As shown in Fig. 41.7, there is no evidence of communication amongst the mixed-gender group for long intervals. Although P1s could not communicate the task well, they were often observed assessing and correcting ideas suggested by the new members. Such conversations elicited discussions, questioning and clarifications which helped in ideation but at times this also led to conflicts and frustration in the group.

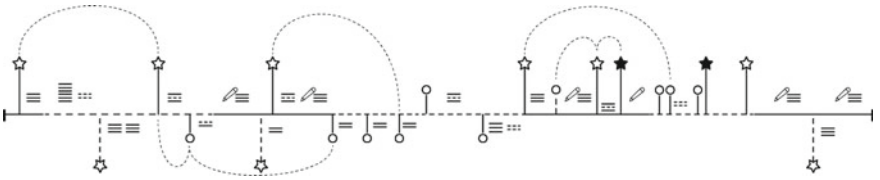

Fig. 41.6 Timeline visualisation for DT1C2M

Fig. 41.7 Timeline visualisation for DT1C2X

41.6.1 Design Trial 1- Condition 3

Figures 41.8, 41.9 and 41.10 show the timeline visualisations of C3 groups (F, M and X). These clearly show the difference between individuals' ideation in the first phase.

Interestingly, in all the groups, P1s seemed to have trouble understanding the task and had long idle periods with barely producing any appropriate ideas. On the other hand, P2s produced many ideas in the first stage itself. We anticipated that such imbalance would rather motivate P1s as they form a group. But, protocol analysis of C3 revealed an initial reluctance towards sharing of ideas. This could be a result of being possessive of their ideas especially when they figured out that the other did not do much. Only after repeated intervention by the researcher they agreed to work together. From the DAC analysis, we found that the groups mostly indulged in sharing information and asking for clarifications with very few discussions or

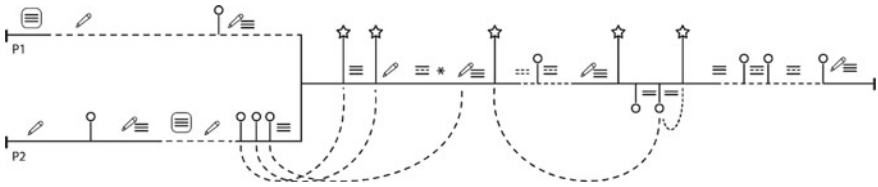

Fig. 41.8 Timeline visualisation of DT1C3F

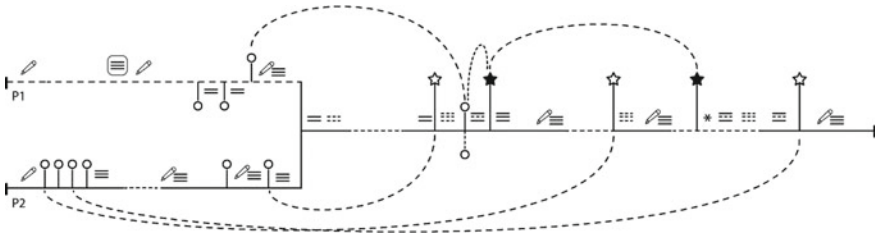

Fig. 41.9 Timeline visualisation of DT1C3M

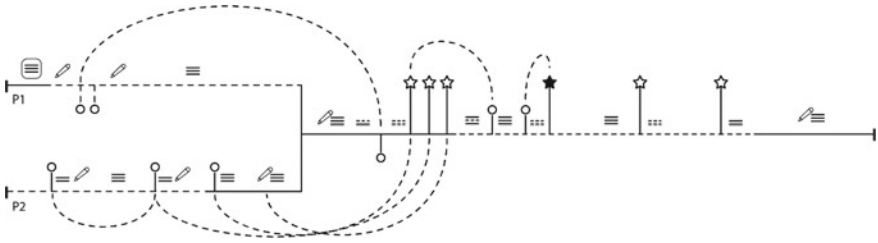

Fig. 41.10 Timeline visualisation of DT1C3X

argumentation. The visualisation correlates with the above finding as we found that there were no collaborative ideas out of five solutions in DT1C3F, two out of five in DT1C3M and only one collaborative idea in DT1C3X out of six. As evident in Fig. 41.8 P2 of the DTIC3F group led the design process and contribution of P1 was minimum except her help in documentation. We can see a similar pattern in DT1C3X as well, almost all the final solutions came from P2 and only once P1's contribution can be seen which resulted in a collaborative idea (see Fig. 41.10). Interestingly, in DT1C3M, although most ideas which were carried forward to the second phase of group work were P2's we saw both the collaborative ideas evolved from P1's idea (see Fig. 41.9). Oddly, the grouping structure of C3 was conceptualised with the idea that the initial individual thinking time will benefit co-workers but in reality, it increased their dependency on the one with more ideas, resulting in one of them becoming a free rider.

41.6.2 Design Trial 1-Condition 4

Figures 41.11, 41.12 and 41.13 show timeline visualisations of C4 groups (F1, M1 and X1), where team members of two teams were swapped during the design process.

Swapping came as a surprise to the participants and initially there was resistance to leave their teams and join new partners. But, once they were swapped, it was evident that the same-gender groups were more comfortable with new partners than the mixed groups. We noted that the participants in DT1C4F1 group were active listeners,

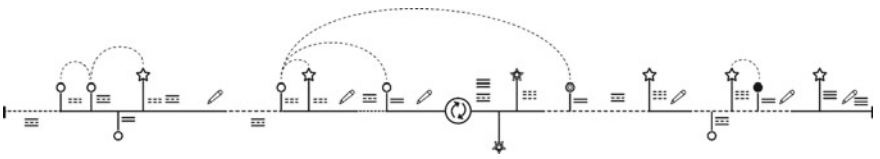

Fig. 41.11 Timeline visualisation of DT1C4F1

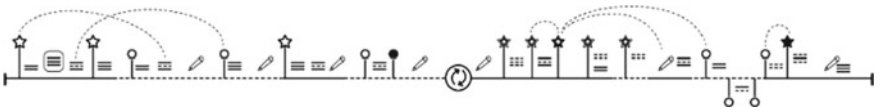

Fig. 41.12 Timeline visualisation of DT1C4M1

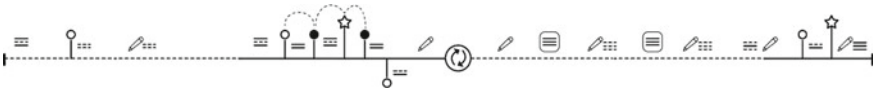

Fig. 41.13 Timeline visualisation for DT1C4X1

vocalised their thoughts and built on each other's ideas. They complimented each other and collaborated on both ideation and documentation. P1 contributed mostly to contextualise and P2 focused on generating ideas. After swapping P1 and new P2 shared their ideas enthusiastically. After some initial discussion, new P2 commented that the ideas were not appropriate (see the star below the timeline in Fig. 41.11) and think how she did. P1 followed and actively generated more ideas towards the end. The male group DT1C4M1 also showed similar collaborative pattern in the design process. Here, P2 shared ideas and new P1 listened patiently. Then, new P1 also shared ideas which actually were thought of by his earlier team partner. These ideas were improvised by P2, which resulted in a new collaborative idea. This group generated the maximum number of solutions out of which three were collaborative ideas (Fig. 41.12). In the same-gender groups, we saw that non-ideators in the first phase became critical thinkers and contributed actively in their new teams. On the other hand, we noticed contrasting group interactions in the mixed group post-swapping. One of the mixed-gender groups became very uncomfortable and did not interact at all (see the long hesitant dashed line in Fig. 41.13). It was observed that post-swapping, situation altered and an active member (P2-girl) from group 2 did not get an opportunity to contribute as P1 (boy) from group 1 did not interact at all. P2 tried to initiate conversation but P1 continued doing his work. Only when P1 was out of ideas, he told P2 to add two of her ideas without any discussions. However, the divergent thinking scores of mixed-gender groups were high they hardly worked together especially after swapping. Hence, we are assertive that only the measure of divergent thinking is insufficient to understand groups efforts in the context of design idea generation.

41.6.3 Design Trial 2

Similar to DT1, visualisations were created for all the groups for DT2. The findings correlated with DT1; hence, we can say that the group organisation did have an impact on team interactions and design ideation. Here, we present an illustrative example, a comparison of two male groups under two conditions DT2C1M and DT2C4M2, to inspect group work. Our analysis on the measure of divergent thinking showed no significant difference between these two groups. The visualisations helped us trace the development of ideas to understand that those scores as a single method to investigate ideational divergence in a group were not sufficient.

In DT2C1M, we noticed there was a lot of enthusiasm initially and they quickly produced two solutions. But in the middle of the design process, they did not interact much and struggled with ideation. Their ideas were a mix of appropriate and inappropriate ideas, which were revisited and improvised later. They were mostly in agreement with each other and hardly questioned or argued on anything. As can be seen in the visualisation (Fig. 41.14), collaborative ideation was observed only in the later phase. Let us now look at the distribution and progression of ideas in DT2C4M2. In this group, as per the group composition, four male students (Mi, Mii, Miii and

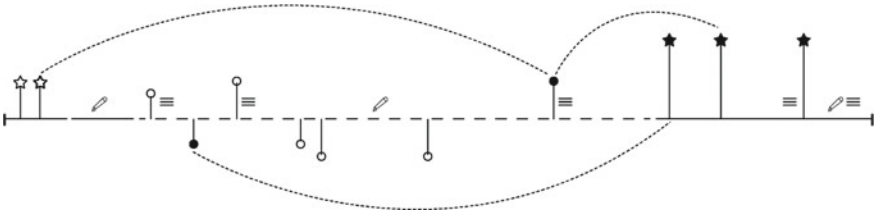

Fig. 41.14 Timeline visualisation of DT2C1M

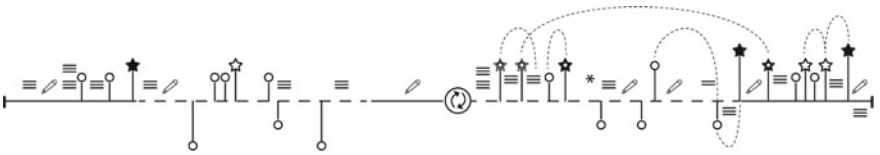

Fig. 41.15 Timeline visualisation of DT2C4M2

Miv) participated as pairs. Fifteen minutes later, the participants were swapped. So, in Fig. 41.15, first half of the timeline represents interaction between Mi and Mii and the second half represents interaction between Mi and Miii. Overall, the group produced more than eight solutions and developed a collaborative idea in the first half itself. Post-swapping, their ideation amplified and the group was able to come up with four more solutions which were developed together as a team. Solutions developed in phase one were critiqued with a new lens and questions were raised. Such conversations led to reflection and improved appropriateness and uniqueness of borrowed ideas. Constant talking and counter questioning helped in newer thoughts which became potential solutions. From the visualisation (Fig. 41.15), it can also be seen that this group was focused on idea generation and reserved detailed documentation for the last phase. The comparison of C1 and C4 illustrates an overview of teamwork along with a representation of quantity, progression and collaborative nature of ideas. It is evident that group work was more productive in C4 as compared to C1.

41.7 Summary and Discussion

The objective of creating timeline visualisations was to visually represent the progression of ideas and inspect collaborative ideation in a group. Prominent insights generated using the visualisations are summarised here. Maximum collaboration happened mainly in the later phases of the design process. As the participants became familiar with the design task and their team partners, they interacted more. Grouping conditions where students spent time alone in the initial phase of the design process like

condition 3 were found to be least collaborative. Across all groups under this condition, one of the team members emerged as a dominant member while the other was perceived as a dependent. Detailing and elaboration were more prominent while sharing or documenting an idea. Elaborating an idea, either verbally or graphically often resulted in making unexpected connections resulting in new ideas. Similarly, while documenting an idea at any stage of the design process led to improvisation of that particular idea. In all the grouping conditions, we noticed active and inactive phases. Mostly, the initial phase had a lot of active participant involvement which was either problem-centred or solution-centred. Almost all the groups under all four conditions were found to be sluggish during the middle phase of the design process where they struggled with idea generation. Maximum number of inappropriate ideas were generated during this phase. Interestingly, revisiting the design task often helped in the transition from inactive phase to active phase of idea generation, which was then observed as collaborative in conditions like C4 or cooperative like the C2. Through our study, we found that certain factors support collaborative ideation such as active listening, being responsive and encouraging. On the other hand, we also report factors which may hinder collaboration for example, certain group compositions may promote dominant behaviour leading to idea fixation. Hesitation either due to gender differences or lack of skill of drawing, communication or articulation can also play a role. The grouping conditions which supported diversity of thought aided collaborative ideation which is consistent with the earlier findings that groups with diverse views can create more ideas, representations, justifications and solution proposals, especially when group members value one another's diverse contributions [11–13]. Milliken, Bartel, and Kurtzberg [14] stated that just like fitting jigsaw pieces together, group members also can put together ideas to create a new idea. It was found that group members with diverse outlooks built on one another's ideas. This may happen instantly or later in the process as a reflective action which helps in improvisation or proposing a new idea.

To illustrate the application of this work, we propose that visualisation of design process is a useful tool to discover instances of idea generation and collaboration. The visualisations mapped participants' behaviour and aided in interpretation of the data in order to build meaningful relationships and inferences. Such visual mapping also revealed that a group's design output, although good, need not necessarily be a result of collaboration. This research study has some limitations of generalisability with respect to the data and sample. All the participants were from the same socio-economic background so the results cannot be generalised for all middle school students. Also, the conditions under investigation were based on possibilities of a dyad's group formation. There can be other possibilities for structuring the groups which were out of the scope of this study. Lastly, these design trials were tested in an isolated controlled setup which is different from a regular classroom. It will be necessary to test the findings of this study in an actual classroom setup.

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