Designing OLMs for Reflection about Group Brainstorming at Interactive Tabletops

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Abstract. Brainstorming is a valuable and widely-used group technique to enhance creativity. Interactive tabletops have the potential to support brainstorming and, by exploiting learners' trace data, they can provide Open Learner Models (OLMs) to support reflection on a brainstorming session. We describe our design of such OLMs to enable an individual to answer core questions: C1) how much did I contribute? C2) at what times was the group or an individual stuck? and C3) where did group members seem to 'spark' off each other? We conducted 24 brainstorming sessions and analysed them to create core brainstorming models underlying the OLMs. We evaluated the OLMs in a think-aloud study designed to see whether learners could interpret the OLMs to answer the core questions. Results indicate the OLMs were effective and that it is valuable, that learners benefit from guidance in their reflection and from drawing on an example of an excellent group's OLM. Our contributions are: i) the first OLMs supporting reflection on brainstorming; ii) models of brainstorming that underlie the OLMs; and iii) a user study demonstrating that learners can use the OLMs to answer the core reflection questions.

Keywords: Open Learner Models, Brainstorming, Reflection

1 Introduction

Brainstorming is a valuable and widely used technique to produce creative solutions to a problem [11]. It is particularly useful when innovation is needed to break out of established ways of thinking, to generate new ideas. When the brainstorming activity is run in small groups, it encourages participants to contribute to the free flow of ideas around a topic, bringing their own creativity, experiences or expertise into play, and increasing the opportunities of enhanced production of rich ideas for the solution. Osborn, the creator [16] promoted the use of brainstorming for creativity. He emphasised that, to be effective, core rules should be followed to reduce members social inhibitions and stimulate idea generation: the focus should be on the *quantity* of ideas; there should be *no early evaluation*; particularly *no criticism*; and *un-usual or divergent ideas welcomed*. Therefore, all participants are encouraged to contribute fully and equally. Discussion should be limited to cases where people are *stuck* and cannot create ideas.

Multi-touch interactive tabletops have proved effective in facilitating face-to-face brainstorming in small-groups [6]. They can support free flow of ideas by providing a shared group interface so that people can generate many ideas in parallel, then interact with digital representations of these ideas, and save the generated ideas offering all team members equal opportunities to contribute [7]. A less explored potential of interactive tabletops is to exploit data about the interaction to capture the processes through the brainstorming session and then show key information about group and individual performance as Open Learner Models (OLMs) [4]. OLMs are those representations of learners' (knowledge, developed skills, performance, understanding, etc.) that are accessible to the learner or group of learners they represent. They can then serve several roles, including support for reflection [5], formative assessment [2] and facilitate collaborative interaction [3]. We particularly focus on the potential value of Open Learner Models (OLMs) as a driver for individuals to reflect on their individual and group performance after a brainstorming session.

The rest of the paper is organised as follows. Next, we outline related research work on OLMs for group work and interactive tabletops. Section 3 describes ScriptStorm, our tabletop system for brainstorming. Section 4 describes the design of our OLM and our evaluation is presented in Section 5. We conclude with a discussion of the results and future work.

2 Related Work

OLMs have been used to facilitate group interaction by enabling learners to identify peers for collaboration [2]. It has been shown that there is value in providing multiple OLM representations helping support higher levels of reflection, because different learners prefer different forms of OLMs, particularly to meet differing concerns [12]. There has also been some exploration of how an ITS can help a learner in brainstorming [18]. Some of the ways such systems can be beneficial is to help learners realise whether they followed recommended practices for brainstorming effectively, particularly in terms of avoiding early evaluation and whether group members suffered blocks [9] in the session.

Some research has started to explore OLM visualisations that represent collaborative learning at interactive tabletops. Martinez-Maldonado et al. [14] validated a set of such OLMs with teachers, showing they could identify the level of collaboration. Al-Qaraghuli et al. [1] presented a visualisation that showed detailed information of students actions at a tabletop over time to foster deep analysis of the process they followed. These authors also provided a small pie chart on the interactive tabletop showing students a real time indication of each learners' participation. Martinez-Maldonado et al. [15] built a dashboard OLM for the teacher to see real-time information about aspects of collaboration for multiple groups in a classroom of interactive tabletops. These examples aimed either to show 'learner models' to the teacher or have been used for research purposes only. Our work goes beyond this by evaluating OLMs that can be presented to learners at an interactive tabletop to promote self-reflection at the end of a brainstorming session. In this sense, it is similar to Do-Lenh's [10] work,

for a multi-tabletop classroom where a simple form OLM gave indication of the progress of each group on a wall display for all students to see.

3 Foundations for design of the Open Learner Models

The need for OLMs to support reflection at a tabletop for brainstorming was identified when we evaluated *Scriptstorm* [8], a scripted tabletop brainstorming system (Figure 1). ScriptStorm had three main stages: (1) idea generation – the "storming" to create ideas; (2) idea categorisation – to organise ideas under category headings; and (3) reflection – to support learners by reflection-on-action [17]. While the scripting proved valuable, the reflection stage did not enable participants to appreciate how well they had followed the recommended brainstorming process. We analysed the data from the study to explore how to create OLMs that could provide more effective support for reflection.

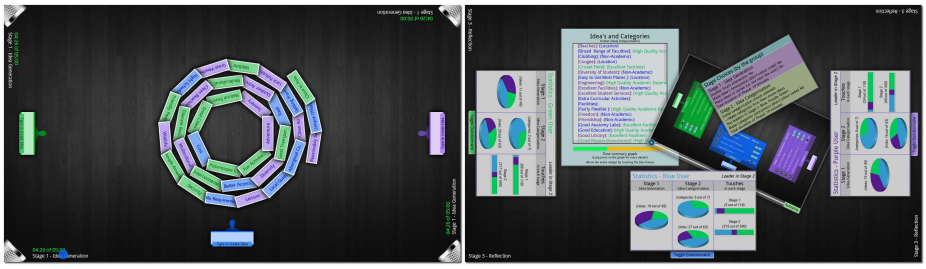

Fig. 1. ScriptStorm: Idea Generation Stage (left), Reflection Stage (right).

We describe *Scriptstorm*, the study, the data collected and the analyses conducted for this work. *Scriptstorm* uses physical keyboards at a multi-touch tabletop. Figure 1-left shows an example table-shot after a group has created several ideas, visible in a circle at the centre of the table. This layout reduces the sense of ownership of ideas and the circular orientation avoids favouring any one user's reading. Ideas are colour coded to indicate the author, giving an indication of each person's level of contribution. Figure 1-right shows the elements available in the reflection stage. Each user has a set of charts showing each person's contributions. Pie charts show how many ideas each person made in Stage 1, how many categories and classification of ideas into them in Stage 2. A bar chart shows touches by each user in each stage. There is a list of the ideas with their categories in the middle, details of the scripting choices made and a replay of the table. Touches were logged by the tabletop and linked to the user making use of a depth camera [13].

The evaluation had 12 groups, each with 3 people (36 participants, 22 male, 14 female, all university students, from diverse degrees – medicine, social science and computer science, aged 19-30, mean age 23). Each group did 2 brainstorms, counter-balanced on scripting condition and topic. Each group was instructed of the rules of brainstorming to follow. Careful analysis of the data indicated the topic and scripting conditions were comparable, making for 24 sessions of data for analysis. All sessions were video recorded.

We analysed the study data to create a model of brainstorming as a foundation for the OLMs. This model provides a bound on the time-between-ideas when the brainstorm is running well. This is important since we can then use it to automatically determine when a group or individual is stuck, and determine if ideas from different users are sparked off each other. Groups created 16 to 104 ideas per session (average = 48; standard deviation = 24), average time between ideas 7.32 seconds (SD = 4.2) range of 2.88 − 17.93 seconds. We explored the frequency distribution of times, a single hump, slightly left of the peak at 7 seconds. For the individual, average time between ideas was 26.16 seconds (SD = 21.64), range 5.75 − 110.5 seconds. We arrived at a maximum idle time for a group before being classified as stuck as 22 seconds (mean group time difference + SD), and for an individual 49 seconds (three times the mean). We also used 22 seconds to scan for ideas that potentially sparked other ideas. These values are used as measures in our OLM to highlight interesting periods. Additionally we analysed output in terms of 15 second periods, resulting in a range of 0 to 13 ideas, accounting for outliers, the average being 4 ideas. We used this in our OLM as the basis for a colour coding scheme (red, orange, green), representing: below, average and above average performance.

4 Open Learner Model Design

We needed to enable learners to answer our core questions: *C1) how much did I contribute? C2) at what times was the group or an individual stuck?* and *C3) where did group members seem to 'spark' off each other?* To help learners find answers to these questions, we designed the OLMs in Figure 2 to present six different views of the user trace data. The pie chart (chart 1) shows the number of ideas each person created (C1). Following, there are four aligned timelines. Chart 2 shows when each idea was created with by a dot, the colour of which indicating authorship. The vertical axis indicates the category from the second phase of the brainstorm. Stuck periods are shown as coloured rectangles for the group (2a) and coloured bars for individuals (2b). In the figure the group got stuck twice between 183-209 and 222-244 seconds, the green user stuck between 148-209 and 211-266 seconds, the purple user stuck between 146-245 seconds and the blue user not stuck at all. To model where people sparked off each other, we identified cases where one persons idea was closely followed by another according to the category classification. This measure is shown with yellow bars (2c). There are seven of these in the diagram, for example on category reference 6 between 65-81 seconds (ideas 65s-C, 77s-B, 81s-B). This measure is clearly an inexact measure that is sensitive to the particular categories chosen, however it is indicative of sparking and showing it in an OLM helps users consider this aspect (C2,3). The next timeline (chart 3) shows the performance of each learner in 30 second snapshots (C1,2). The timeline after that (chart 4) shows cumulative progress with segments colour coded according to the rate of contribution (C2). The final timeline (chart 5) is a spectrogram indicating when a group was talking. Learners were instructed to call out each idea they generated in the idea generation stage and we expected discussion if a group was stuck (C2,3). The last view (label 6)

is a table with categories and associated ideas annotated with author and time of creation.

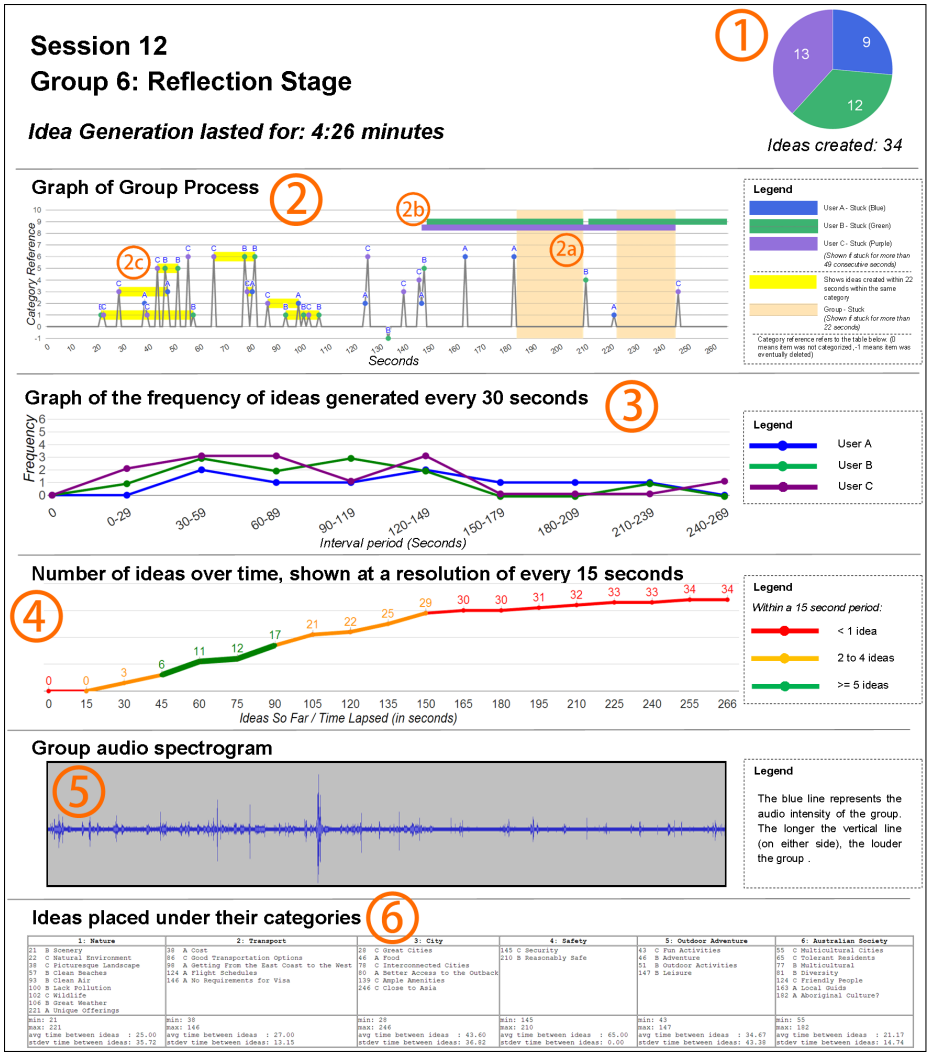

Fig. 2. Open Learner Model Visualisations.

5 Evaluation

We conducted an interview/think-aloud study with 15 participants drawn from the earlier brainstorming study (10 male, 5 female, age range 21-30, mean age 24), each interviewed separately. The study consisted of analysing 3 anonymised brainstorming sessions from the earlier study (the same 3 anonymised sessions across all interviews). The visualisations were presented on laminated A3 sheets of paper to aid visibility, and contained the different OLMs like the one shown

in Figure 2 – which allowed learners to quickly point to the different items when answering the questions. These questions, listed in Table 1, investigated whether participants, could obtain information, about individual/group contributions (Q1−4), if they could identify periods when the group or its members got 'stuck' (Q5-6) or if they could define whether the group members sparked off of each other (Q7−9). Questions 10 and 11 served as self-assessment of the group and individual performance respectively. The interview questions (Table 1) linked to our core research questions as shown in Table 2. The interview process had the following steps:

Step 1 Participants were asked to pretend to be a learner that produced 13 ideas in a group who made 34 ideas (i.e. to be the purple user in Figure 2), and answer the questions in Table 1.

Step 2 Participants were shown a numerically well performing group whom created 80 ideas and asked to review their answers to Q10 and Q11. We did this to see if people would change their response, given extra information.

Step 3 Participants were asked to pretend to be a learner with 52 ideas in a group with 98 ideas, and answer the questions in Table 1.

Step 4 Participants were asked three general questions: (1) Whether they would like to see these visualisations as part of a reflection stage on a tabletop; (2) Whether they thought the visualisations would enable a group to become more effective; and (3) If you were a user with a low number of ideas, would the visualisations make you more aware and conscious about your performance.

	Interview Questions	
Q1	I could work how much was my contribution	(C1)
Q2	I could figure out when we made the most ideas in the session	(C1)
Q3	I could see who created each idea	(C1)
Q4	I could see when the group was talking	(C1)
Q5	I could figure out when the group got stuck	(C2)
Q6	I could figure out when I got stuck in the session	(C2)
Q7	I could figure out the times when the group created a burst of ideas that ended out in the same category	(C3)
Q8	I could figure out periods when the group was on a roll (i.e. good sustained idea generation)	(C3)
Q9	I could see how the ideas were categorised (i.e. how ideas were grouped)	(C3)
Q10	I thought the group did a good job in the brainstorm	
Q11	I thought I did a good job in the brainstorm	

Table 1. Interview questions investigating the usefulness of the group OLMs.

	Abbreviation	Core research question	Revealed in:
(C1)	Contributions	How much did I contribute?	Q1, Q2, Q3, Q4
(C2)	Stuck	At what times was the group or an individual stuck?	Q5, Q6
(C3)	Sparking	Where did group members seem to 'spark' off each other?	Q7, Q8, Q9
	Other impact	The impact of showing learners OLMs of different groups	Q10, Q11

Table 2. Relationship between research questions and interview questions.

Responses were given on a 6-point Likert scale (1 for strongly disagree, 6 for strongly agree). Participants were instructed to point to any items (the charts/table) that influenced their response as well as provide an explanation for each item chosen. Results are summarised in Table 3.

		Contributions				Stuck		Sparking			Other impact	
Questions		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Step 1	Likert	5.07	5.53	4.87	5.40	5.67	5.87	4.20	5.00	5.20	4.40	4.73
34 idea group	Item	1,3	4,3	2,6	5,2	2,4	2,3	2,6	4,2	6,2	1,2	3, 2
Step 2	Likert										**3.40**	**4.40**
80 idea group												
Step 3	Likert	5.53	4.93	5.33	5.20	5.27	5.40	**5.20**	5.20	5.27	5.20	5.60
98 idea group	Item	1,6	4,2	6,2	5	2,4	2,3	2,6	4,3	6,2	1,4	1,3

Table 3. Results of the interview. Item refers to those as labelled in Figure 2, briefly: 1–pie chart; 2–graph of group process; 3–graph of frequency of ideas; 4–number of ideas over time; 5–group audio spectrogram; and 6–the table. The two most commonly referenced items are included. Bold indicates a statistically significant change from Step 1 to 2 (Q10,11) and from Step 1 to 3 (Q1-9).

Most of the learners agreed that the OLM visualisations provided key information about the group brainstorm ($\geq$4.20 across the Likert scores). While participants thought aloud, more than half mentioned ease of understandability, especially by the time they saw the third groups OLMs. Some users had initial difficulties understanding certain visualisations, for example four users initially found chart 2 to be very complex, though by the end of the activity, only two of these four still found the visualisation complex.

6 Discussion

6.1 Group members contributions to the brainstorm

In the absence of a benchmark to compare the number of ideas generated, participants determined if a group did a good job, by judging levels of equality, referring to charts 1 and 3. When additional group OLMs were introduced, participants focused on the amount of ideas produced. For individual contribution – Q1, participants drew from charts 1 and 3 and the table. Chart 1 presented overall contribution in a simple form: *P4– "easy to understand"*; *P5– "very clear"*; and *P3– "I have the biggest cut of the pie"*. Chart 3 revealed contributions over time: *P6– "I generated the most ideas in the first 90 seconds"*; and *P2– "I compared the number of ideas generated and saw that I created just as many as the others"*. For determination of active periods (Q2), 12 people (P1,2,3,4,8,9,10,12,13,15) consulted chart 4 – referencing the colour scheme. A small number of participants referred to chart 3, looking at times when frequency of ideas generated was high across all members. For whom created each idea – Q3, chart 2 and the table were referenced. For chart 2 – the coloured dots representing authors were used (P1,5,7,8,9,10,11), and for chart 6 – the author written alongside the idea (P2,3,6,12,14). Overall, the following were referred to the most: chart 1 – for individual contribution; chart 2 – for whom created each idea; and chart 4 – for periods containing a large number of ideas.

6.2 Periods where the group or individuals got stuck

For Q5 − identify when the group was stuck and Q6 − identify when individuals were stuck, the average Likert score was above 5 (Q5: 5.70 & 5.27, Q6: 5.87 & 5.40). Participants utilised charts 2, 3 and 4. For chart 2 − the shaded regions and horizontal bars were referenced (P1,7,8,9,10,11,12,15): *P9– "I looked at the interval between ideas"*; *P3– "I looked for the shades to see if they were stuck, when I couldn't see any, so I checked this one [chart 4] to see if there were any red lines"*; and *P10– "easy to see when I was stuck, because of the highlights"*. For chart 3 – participants looked for when groups tapered off, shown as dips (P1,2,3,4,6,9,14): *P2– "The graph plateaued at the end, showing me they got stuck"*, similarly in chart 4 – the gradient of the line combined with the colour coded segments (P4,5,9,11,13): *P5– "because of the red"*. Overall, chart 2 proved to be most useful for identifying stuck periods. These observations reinforce the usefulness of the information added from our brainstorming model, in providing potentially useful visual indicators to learners. These indicators (the shading, bars and coloured segments) can be the basis for discussion, reflecting on actions that led to identified periods of inactivity.

6.3 Evidence that group members 'sparked' off of each other

Question 7 asked whether a burst of ideas ended up in the same category. For this question, chart 2 was referenced, but with mixed responses. 8 participants said the yellow highlight in chart 2 was obvious: *P13– "I looked at the yellow lines, as it easily caught my attention"*, but 4 participants did not find the highlight obvious and instead horizontally scanned the grey line present on each row. Three participants mentioned the table, and said that if they spent more time they could of worked out which ideas from whom sparked other ideas, but were off put by the presentation, being heavy in text, compared to the other items. Determining when a large number of ideas was created, without the constraint of them being in the same category, participants shifted focus to chart 4. Overall, chart 2 was most useful for showing when members sparked off of each other. This can be used as a starting point for discussion in a reflection stage to talk about sparking and what led to it, and how often it occurred.

6.4 The impact of showing learners OLMs of different groups

Participants were shown an example of a particularly productive group after the first group and asked to reflect on Q10 and Q11, questions which related to performance. For group performance (Q10), upon seeing another group, with a higher number of ideas, 8 people (P2,3,7,9,10,13,14) downgraded their answer with an average reduction of 2 Likert points, resulting in a statistically significant decrease (from 4.4 to 3.4), representing a switch from the agree to the disagree side of the Likert scale. The primary reason cited was the difference in the number of ideas created (P2,3,7,9,10), and the lack of stuck periods in the new group (P13,14). Three participants (P11,12,15) kept their original answer stating

whether a group performed well is more complex than a numerical figure, raising issues of group dynamics, questions about quality, and requested other group OLMs to have more information to compare against: *P12– "I only have 2 groups to go off, not a complete average, also I don't know if their quality was the same"* and *P7– "The first group generated longer multiple word ideas, while this group created single word ideas, I think that's why the first group had less ideas"*. For Q11, 5 participants changed their response, with the bulk of participants pointing out that the user with 13 ideas (the purple user) made the most ideas of the group (P1,4,8,9,11,13,15); and *P9– "purple did a good job in his group, and his performance is also dependent on his team members, so I decide to keep my original answer the same"*. Two participants (P6,11) mentioned they wanted to have an average value, to put the number of created ideas into perspective.

These comparisons point to the fact that participants are not only influenced through their own contributions within a group, but also the performance of related groups brainstorming. An apparent strong feeling of success can be changed when exposed to other group OLMs. This is helpful in promoting reflection, in order to promote a deeper understanding of performance, and also possibly to inspire learners to develop skills to improve themselves.

Overall, the impact of showing different group OLMs was helpful with participants commenting on the use of charts 1 and 3 for individual performance and charts 2, 4 and 5 for group performance. Comments: *P12– "It gives good ideas of how their process was, and this is good for feedback which is important and it also gives a summary of what we did, and the graphs are cool to look at"*; *P13– "Users might be interested to see how they performance and if they worked together, self-reflection is really useful"*; and *P14– "It can tell users a lot of information and may help them next time and [identifying] who is least active might be encouraging to try to do better"*.

7 Conclusion

We built a series of OLM visualisations for the purpose of analysing whether individuals could understand group and individual processes in order to support reflection in group brainstorming. Results showed learners found the OLMs relatively easy to comprehend and were able to answer our core questions. In the process of the study, we learnt which visualisations were most commonly referred to and why, leading to a greater understanding of the importance of different views for reflection. Our future work will be to build this into our tabletop brainstorming system, and show the visualisations through a scripted approach, to determine the effects of the OLMs when in real use.

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