Mirroring participation level during joint problem solving, as an adaptive support for collaboration within online groups

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Abstract. This paper presents the findings of a study which explore supporting collaboration within online groups, during Joint problem solving (JPS) activities. We investigated the effect of mirroring the participation level of individual member, on the groups' collaboration. We explored existing work in adaptive support for collaboration and the theoretical perspective about the effect of self-performance reflection to improve the performance.
Using a control experiment, we studied JPS process of 10 groups (4 members in each group); 5 groups interacted using an adaptive interface (i.e. with mirror of participation level), while the other 5 groups interacted via a non-adaptive interface (i.e. without participation level mirror), of a text-based chat-room for online group interaction.
We made a qualitative assessment of the groups discourse and a quantitative analysis to investigate significant difference between the experimental conditions i.e. adaptive versus non-adaptive, using ANOVA. Our findings show that, real-time mirror of individuals' participation improves group collaboration, during JPS.

Keywords: Mirroring · participation level · collaboration level · adaptive support.

1 Introduction and related work

The cognitive benefits of group learning have been well researched [29,16,19,23,27] and literature has established that it helps learners to articulate and construct new knowledge through arguments and coordination during joint problem solving (JPS). In traditional classrooms, group learners benefit from the physical presence of an instructor that manages and guides collaboration during the teamwork; this advantage is not available to online groups.

One of the principal objectives of Computer Supported Collaborative Learning (CSCL) research is to incorporate group learning and its benefits for distance education over the web, in such a way that online groups are supported to have experiences that are similar to what exists for face-to-face groups [10,26]. Findings in existing studies posited that an *effective and efficient system adaptation*, and an *"unobtrusive"* intervention of a remote teacher or a computer agent can

provide this kind of support and scaffold collaboration within an online group [17].

Collaboration itself, in the context of learning, is theoretically rooted in *Vygotskys work* and Piagets constructivist idea about "social field"; it was argued that the interaction, shared understanding and joint problem solving (JPS) activities during teamwork propagates cognition. These theoretical conjectures, formed the basis for CSCL research, to pursue leveraging the ubiquity of computing technology to support the *social* and *constructive* element of group learning. Aside the goal to provide an environment that enables group interaction, research in CSCL is also tasked to capture and model group activities, to monitor and determine support needs, and provide efficient and effective support that can optimize collaboration and maximize learning during JPS [17].

1.1 Adaptive support for collaboration

In early work on adaptive support for education via computer supported environments, *adaptive educational systems (AES)* were conceptualized, to adapt key features of a learning system (e.g. *content presentation* or *navigation support*) to suit an individual's need; similarly *intelligent tutoring systems (ITS)* were conceived to individualize support to learners, through an agent model of a teacher in computer based problem solving [10,17].

Most studies on *AES* and *ITS* targeted helping an individual learner in a computer supported environment. Adaptation for group learning environments started to emerge in literature later; a succinct review of some of the existing studies, with respect to the concepts explored and a summary of their findings are presented in Table 1.

We found that, the *adaptive intervention* proposed by most of the studies, was based on *user profile* or/and *data of users' interaction/activities* with the group environment; the adaptation decisions were proposed to change the system environment to suit users' (individual or group) preference or to inform an instructor (agent/remote human) about the most suitable intervention for the current user (or group).

The approach in this study is to *mirror participation level* of member within group, in real-time during a joint problem solving discussion. We hypothesize that this reflection will stimulate positive participatory behaviour that can improve interaction within the group. This proposition is in accord with Soller, Amy's [26] position, that *reflection of the information about individuals' participation in a JPS*, can significantly influence (stimulate) a positive attitude towards the joint task and in turn scaffold collaboration.

1.2 Theoretical Perspective & Justification of Study

Performance feedback (Mirroring), is connected to the *"social cognitive theory and self-regulated learning behaviour"* [24]; which idealizes that, reflection about learners capabilities can positively influence their behaviour in a learning process/context."*Human functioning* is a reciprocal interaction between the

Table 1: Relate work: Adaptive support for group learning.

Literature	Adaptation, method/mechanism & aim	Adaptation effect metric
Tsovaltzi et al. [28]	Prompts and scaffolds using *collaboration scripts*, to guide students to collaborate in a virtual chemistry laboratory.	* Feedback from participant, * speed and efficiency of solving learning task (between *scripted* & *unscripted* groups of two member learners).
Chen [11]	* Agent-based monitor and visualization of collaborative process based on contribution messages and update on learners *webTop* which in-turn update the *knowledge building module*. * The aim was to provide an adaptive rule-based update on *knowledge building module* to provide automated, effective and efficient intervention that will aid the groups' collaboration	Feedback from teachers versus agents' performance as regards effectiveness and efficiency of intervention to groups
Marcos-Garca et al. [18]	* Interaction analysis with *Role-AdaptIA* using social network analysis method, to characterize and detect changes in learners' role in during JPS. The aim was to inform teachers about emergence of roles and undesired interaction patterns, to aid regulation and support to JPS process within a computer supported learning groups	Qualitative comparison social representation of groups before and after teachers' intervention
Adamson et al. [2]	* Conversational agent is employed to instill adaptive scaffolding of collaboration within online an online group, * this approach termed *"Academically productive Talk" (APT)* provides a generic prompt to encourage learners to articulate and expand their line of reasoning, * the agent provide positive feedback to learners when they apply APT facilitation moves in their interaction during JPS	* ANOVA measure of learning between pre- and post-test, - measure of this learning as it differs between conditions using ANCOVA, * process analysis to measure improvement in interaction with APT intervention
Rumetshofer & W [22]	* User-centric approach to improve usability and acceptance, * Integrating psychological factor into the system, transforming general object into personalized learning object based on user profile and adaptation rules. * system layout and navigation is also adapted to learners' preference	

behaviour change, *environmental variables* and *cognition*" (which includes the awareness of their performance level) (see Figure 1) [24]. Self-awareness of ones performance can encourage actions to attain a "designated performance level", influence achievement behaviour, "persistence, effort expenditure and skill acquisition" [24]. A feedback on performance level of student can provide the motivation for continued learning [7].

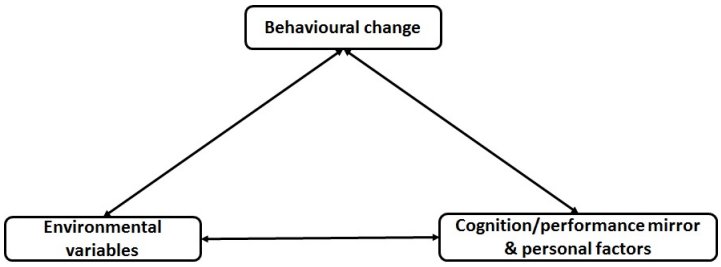

Fig. 1: Human functioning as reciprocal interactions between behaviors, environmental variables, and cognition/reflection about performance and other personal factors [24]

Albert Bandura [8], advanced an *"agentic sociocognitive view"* that perceived an individuals as proactive, self-reflecting and self-regulating rather than "an organism shaped and shepereded only by external events" like *prompt*, *scripted interaction*, *agent-teacher intervention*, *change in system environment*, as considered in existing studies on adaptive group learning system [2,11,18,22,28].

Leon Festinger [13] hypothesized that, humans are driven to evaluate their "opinion and ability; that a persons' cognition or reflection about the context in which he exits and his appraisal of what he is capable of doing will together have bearing on his behaviour" [13]. Our approach to quantify individual participation level based on relative comparison within the groups [5,4] is corroborated by Leons [13] hypothesis, that, in social context, reflection on self-performance, is in comparison with performance of others within the context.

1.3 Mirroring participation to scaffold collaboration

DiMicco Bender in [12] investigated the effect of the awareness of participation activities, on the goal(s) of JPS; a real-time feedback on individual participation was provided during JPS discussion and its effect was evaluated through participants' self-report, as regards how well the *provided feedback* has informed, stimulated or regulated their activity during the meetings.

Similarly, Janssen, Jeroen & other [14] studied the impact of *visualizing of participation level* on the collaboration within computer supported learning groups; they advanced that there is evidence of positive effect on collaboration, when the participation level of members is reflected back to them.

In this study, we further further previous investigation [12,14] about the effect of *the mirror of participation level* on collaboration; firstly, we studied online groups that interact via a text-based environment, rather than face-to-face verbal interaction [12]. Also, we evaluated this effect through a controlled experiment (***"with"*** versus ***"without"*** the *mirror of participation*), rather than judging from the perception of participants [12].

Secondly, in the design of group interaction environment, we ensured that the only distinguishing factor between treatments is *the mirror of participation level*. We opined that, the access to *participation tool* by one of the treatments in Janssen, Jeroen & other [14] can influence participation and consequently impact collaboration. Besides, unequal size of the treatment groups i.e. 57 in experiment groups and 17 participants in the control group [14], have been predicated in research, to influence collaboration within a group [15,21]; considering these gaps, we ensured randomness and equal sized grouping for all groups and the following research question is addressed in this study:

Research question: Can the *mirror of members' participation level*, stimulate improved participatory activities, that consequently scaffold collaboration during JPS?

In the remainder of this paper, we discussed the study design & procedure, observation, visualization and analysis of group JPS activity data (i.e. textual discourse of groups), a summative evaluation [20] to determine the effect of the adaptation i.e. *mirroring participation level*.

2 Conceptual framework of study

The adaptive approach and group interaction context in this study is depicted in layers [9,20] as shown in Figure 4. Indicators of collaboration during a JPS discussion have been established from literature [3] and studied on face-to-face JPS [6] which informed *layer 1.1*. The characteristic features of a text-based JPS discourse and a metric model for participation and collaboration level, the *Word Count/Gini-coefficient Measure of Symmetry*, WC-GCMS, within online groups [5,4], formed the basis for the respective *layer 1.2* and *1.3* in Figure 4.

Our *adaptive decision* [9,20] described in *layer 2* of the Figure 4, is a feedback path that reflect level of participation, output from *layer 1.2*, back to group members during JPS (see Figure 3). Our goal, is to establish an evidence of positive impact of the feedback on the group collaboration i.e. the output from *layer 1.3*. We compared output from *layer 1.3* between: ***with*** versus ***without*** the feedback path from *layer 2* as in Figure 4.

2.1 Study design

We employed control experiment design, with two treatments; the E-treatment (adaptive) and C-treatment (non-adaptive). A convenient sample of 40 students participated in this study, the participants were randomly grouped into 10 groups

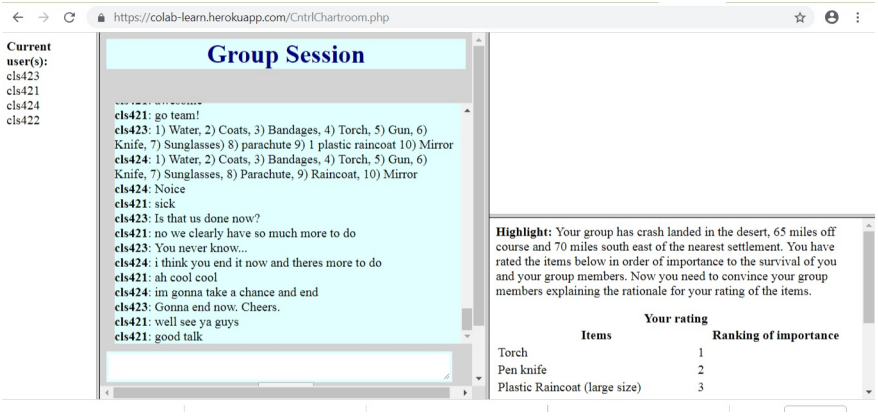

Fig. 2: Control groups' non-adaptive JPSD chat-room interface

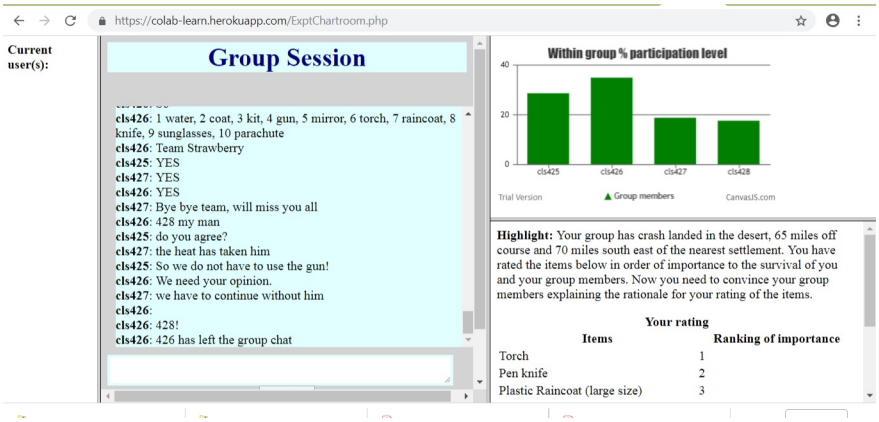

Fig. 3: Experiment groups' adaptive JPSD chat-room interface

with four members in each group. Each of the 10 groups were randomly selected into either treatments, so that we have 5 different groups for each of the treatments; demographic data of participant is shown in Table 2.

The study was completely online, members of the same group interacted via a text-based media, the Joint Problem Solving Discourse (JPSD) chat-room [5,4]. JPSD interface used by the groups under the E-treatment (adaptive) is enhanced with the feedback path i.e. *layer 2* in Figure 4, which is implemented as shown in Figure 3; the groups under the C-treatment were not provided with the feedback (See Figure 2).

2.2 Procedure of study

We applied a problem-based learning concept where each group was asked to solve a task. We used the "*desert on the moon*" task, where a scenario was

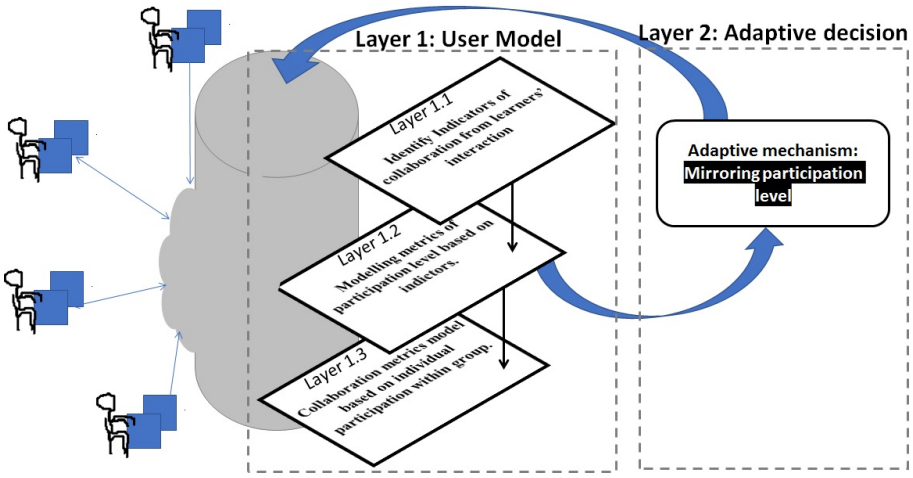

Fig. 4: Framework of Study.

Table 2: Participants' demographic data

Groups	Gender	Age	Edu
Group 1	female (1) male (3)	18-25 (4)	Undergrad(4)
Group 2	male (4)	18-25 (4)	Undergrad(4)
Group 3	male (4)	18-25 (4)	Undergrad(4)
Group 4	female (1) male (3)	18-25 (4)	Undergrad(4)
Group 5	female (1) male (3)	18-25 (4)	Undergrad(4)
Group 6	male (4)	18-25 (4)	Undergrad(4)
Group 7	female(3) male (1)	18-25 (4)	Undergrad(4)
Group 8	female(2) male (1), Not disclosed (1)	18-25 (4)	Undergrad(4)
Group 9	female (1) male (1) Not disclosed (2)	18-25 (4)	Undergrad(4)
Group 10	male (4)	18-25 (4)	Undergrad(4)

painted that the group has crash landed in the desert, 65 miles off course and 70 miles south east of the nearest settlement. The group members were to rate some items left with them in the order of importance to their survival [1]. Group members were tasked to explain the rationale for their item ratings and attempt to convince other members of the group. The participation procedure was as follows:

1. Participants provided their consent to participate by agreeing to the statement in the consent page of the study web application.
2. They filled out a collaborative attitudes/skills questionnaire.
3. They studied the task and rated the items individually.
4. They joined the chat-room where they took part in a group discussion to agree on a rating of the items.

The study took about 45 minutes to complete.

3 Data extraction, analysis, observation & discussion of result

We evaluated and visualized relative collaboration level between the ten groups using on WC/GCMS collaboration metric [5], We obtained a time-series visualization of the collaboration levels between groups (See Figure 5) and the the same measure based on the overall content of discourse within each group (See Figure 6).

3.1 Observation

From Figure 5 and 6, we observed that most of the groups in *E-treatment* spent more time discussing in the chat-room, compared to groups in *C-treatment* (See Figure 5). Secondly, the collaboration measure for E-treatment groups is relatively better than the groups in C-treatment.

Although, the most collaborative group emerges from the C-treatment based on Figure 6, this is practical in that, other factors come into play with respect to participation in a group; for example knowledge level with respect to learning context, personality of individual group member, language use, coordination, leadership e.t.c. [6]. From the transcript extracted from discourse content of *group 4* (i.e. the most collaborative group as visualized by Figure 6) (see Table 3), the positive factors and indicators of collaboration in a discourse [6,25] are well observed, which explains groups' higher relative level of collaboration (See Figure 6).
[1]

However, despite group 4 from C-treatment have relatively highest measure of collaboration, visualization from Figure 5 and 6 show that, E-treatment groups collaborate relatively better than the C-treatment groups. To corroborate this, we define a simple quantitative *groupsOfTreatments* (gOT) measure, scoring each group based on the number of groups bellow its level of collaboration, e.g. group4 score is 9 as it is the most collaborative group shown in Figure 6). The score for all groups is shown in Table 4. The average score for the *E-treatment* is 5.4, while that for the *C-treatment* is 3.6, which support the notion that, *the mirror participation level* aided collaboration within the E-treatment groups.

[1] http://colab-learn.herokuapp.com/s4groupX.php, X=3 for *group1*, 4 for *group 2*, 5 for *group3*, 6 for *group4*, 7 for *group5*, 8 for *group6*, 9 for *group7*, 10 for *group8*, 12 for *group9* and 15 for *group10*

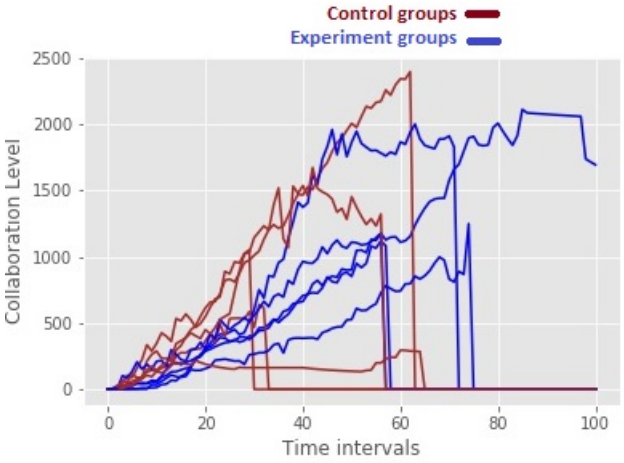

Fig. 5: Time series simulation of real-time measure of collaboration using WC/GCMS model [5]

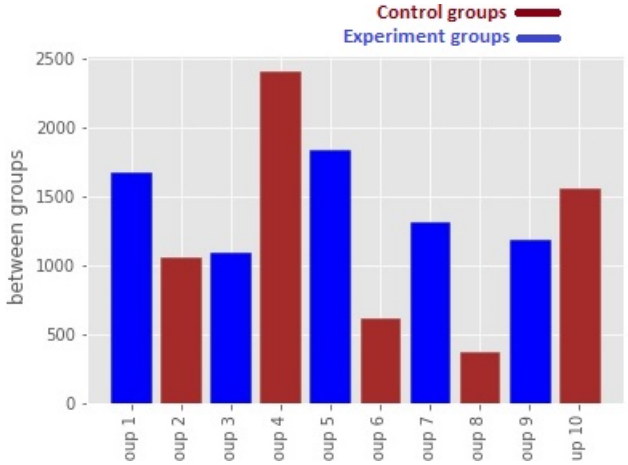

Fig. 6: WC/GCMS measure of collaboration based on whole discourse content [5]

3.2 Quantitative evaluation of *Mirroring* effect with ANOVA

Firstly, we assume that the adaptive *mirror of participation level* directly induce and increase participation rate [8,13,24], which consequently scaffolds collaboration level. To investigate this conception, we extracted time-stamp of each contribution, $t_{c_k}^i$ (this is the *system time*, when member i of a group made kth contribution to the groups' JPS discussion). This data for a member i, considering the whole discourse content of a group is represented as a collection: $t_{c1}^i, t_{c2}^i, ..., t_{cm}^i$ m, being the number of different text contributions made by member i during JPS. Given time interval for the first contribution set as, $t_{c1}^i = 0$,

Table 3: Extracted transcript from group 4 discussion: [2]

Coordination:

```
cls421: Hey
cls423: I think we are still missing someone.
cls421: it seems like it
cls424: yeah, lets wait a little longer
```

Leadership

```
cls423: I take it we now need to rationalise the ordering of our items?
cls424: yes
cls422: I guess
cls424: Okay, what does everyone have for number 1?
```

Argue/agree/disagree

```
cls421: not me
cls423: But they were just involved in a plane crash an  although there are no
        injuries they will still need some medical items following the crash.
cls424: Youre not going to be able to do anything with heatstroke too
cls424: You can die within 3 hours without shelter
cls421: water would help with heatstroke surely
cls421: would one plastic raincoat help more than one coat per person
cls423: Very valid point. Both equally important, personally i chose the bandage
        stopping infections and bleeding will be more useful then providing some
        shade during the day.
cls424: i would argue that the sun is a more immediate enemy to us than the
        possibility of infection
cls424: we know that the sun and the cold are going to come
```

Table 4: Groups between treatment with comparative rating of collaboration level

Experiment	Control
Grp1=> 7 Grp3=> 3 Grp5=> 8 Grp7=> 5 Grp9=> 4	Grp2=> 2 Grp4=> 9 Grp6=> 1 Grp8=> 0 Grp10=> 6
Total=> 27	Total=> 18
Avg=> 5.4	Avg=> 3.6

we calculated time interval between all other consecutive contributions, t_k^i, for all k>0 is given by equation 1.

$$t_k^i = t_{c}{}_k^i - t_{c}{}_{k-1}^i \forall k > 1, \in \{1, 2, ..., m\} \tag{1}$$

Mean time intervals between contributions by a member i is given by equation 2 bellow:

$$T_{mean}^i = \frac{t_1^i + t_2^i + ... + t_m^i}{m} \tag{2}$$

The mean frequency of contribution by a member of i in a group is thus be given by equation 3:

$$f^i_{mean} = \frac{1}{T^i_{mean}} \tag{3}$$

The count of contribution by each member of a group i.e. m varies within all groups and i ∈ {1,2,3,4} ∀ groups in either treatment. We obtain f^i_{mean} data for each individual within all the groups, as shown in Table 5.

Table 5: Experiment group: username & f_{mean}(Hz)

Group1	Group3	Group5	Group7	Group9
cls412—0.014	cls417— 0.038	cls425— 0.028	cls433— 0.027	cls445— 0.023
cls411—0.028	cls418— 0.012	cls426— 0.037	cls434— 0.019	cls446— 0.021
cls410—0.028	cls419— 0.034	cls427— 0.028	cls435— 0.041	cls447— 0.033
cls409—0.035	cls420— 0.026	cls428— 0.028	cls436— 0.024	cls448— 0.007

Table 6: Control group: username & f_{mean}(Hz)

Group2	Group3	Group5	Group7	Group9
cls414— 0.010	cls421— 0.028	cls429— 0.018	cls437— 0.032	cls457— 0.020
cls415— 0.019	cls422— 0.021	cls430— 0.015	cls438— 0.011	cls458— 0.013
cls416— 0.018	cls423— 0.021	cls431— 0.000	cls439— 0.014	cls459— 0.009
cls413— 0.025	cls424— 0.029	cls432— 0.020	cls440— 0.021	cls460— 0.027

We reinforced our assumption that, the increased rate of individuals participation f^i_{mean} within a group, is directly proportional to measure of collaboration level of the group. We analyze for correlation between f^g_{mean} ($f^g_{mean} = mean(f^1_{mean}, f^2_{mean}, f^3_{mean}, f^4_{mean})$ of a group, with members $i \in \{1, 2, 3, 4\}$) and WC/GCMS measure of group collaboration, the correlation analysis is shown in Figure 7 and 8.

Having uphold the assumption that the individuals' participation rate f^i_{mean}, scaffolds the group collaboration level, we analyzes for a significant difference in the participation rate, f^i_{mean} between the treatments i.e. E-treatment (Table 5) and C-treatment (Table 6). Using a one-way ANOVA analysis in SPSS, we test the following hypothesis:

1. That there is enough evidence that *mirror of participation level adaptively* scaffold the rate of participation within group i.e. a significant difference in the f^i_{mean} between E-treatment and C-treatment.
2. That, group membership does not affect the rate of participation by members, i.e. there is not significant difference in f^i_{mean} between the 10 groups.

3.3 ANOVA result and discussion

The obtain the following results for the ANOVA test:

	Group Freq	Group Colab
Grp 1	0.0262	1674.95
Grp 3	0.0275	1092.00
Grp 5	0.0301	1831.25
Grp 7	0.0276	1312.00
Grp 9	0.0208	1180.00
Grp 2	0.0178	1051.42
Grp 4	0.0246	2405.13
Grp 6	0.0132	616.00
Grp 8	0.0196	370.06
Grp 10	0.0173	1560.49

	Group Freq	*Group Colab*
Group Freq	1	
Group Colab	0.539662028	1
Key:		
E-Treatment		
C-Treatment		

Fig. 7: Analysis of correlation between f^i_{mean} and WC/GCMS measure of collaboration [5]

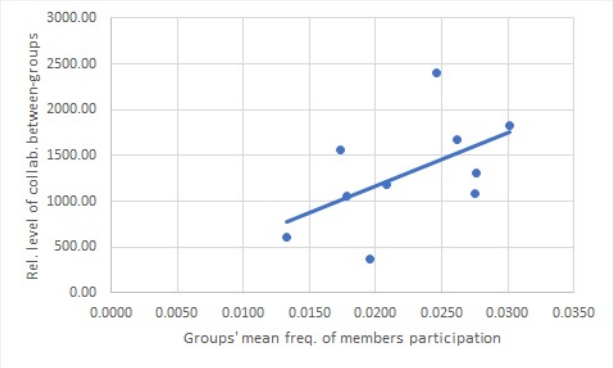

Fig. 8: Illustration of correlation between f^g_{mean} and WC/GCMS measure of collaboration [5]

Between treatments: That is, ANOVA between E-treatment and C-treatment; using the $\alpha = 0.05$ level of significance, we obtained F value= 9.18 and p-value $= 0.004 < 0.05$ alpha level. This result indicates enough evidence of a significant difference between the frequency of participation within the groups considering the treatments as a factor. We thus accept our hypothesis 1, that *mirror of participation level*, stimulates participation rate within group.

Between groups : Considering group membership as a factor; ANOVA between all groups with $\alpha = 0.05$ level of significance, we obtained a F value $= 1.700$ and p-value $= 0.133 > 0.05$. This implies that, not enough evidence of difference in the rate of members participation between groups. We therefore accept the hypothesis 2, that group membership does not affect the rate of individual participation.

4 Conclusion

Based on our qualitative observation of groups' discourse content, the visualized relative measure of collaboration between the groups, using WC/GCMS collaboration metrics model [5], ANOVA between treatments and between groups, we

are able to reinforce our conjecture that *mirroring participation level measure* in real-time during online JPS, serves an adaptive mecahnism that can scaffold collaboration within the group.

However, there are other factors that impact on individuals' participation and group collaboration in a JPS; given that all these factors are randomized between groups, *mirroring participation level* as observed in this study, is an effective computational mechanism to stimulate participation and scaffold collaboration within online learning groups.

In future work, we will investigate other forms of adaptive support for online group collaboration; for example, we'll like to explore *knowledge levels* of group members and a measure of members *inclination to participate* in a group work. We aim to investigate pattern of these variables between-groups and observe how it differs between groups that collaborate optimally and those with relatively low collaboration. We pre-conceive that this pattern mining, can inform an algorithm that can automatically select members into a group, forming a group that will collaborate well.

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