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 report of a study on how to support online group for optimal collaboration. We investigated the effect of mirroring the participation level of individual group member, on the groups' collaboration, during a Joint Problem Solving (JPS). We explored existing work in adaptive support for collaboration and the theoretical perspective about supporting group collaboration by reflecting members participatory 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 benefit of group learning has been well researched [28,15,18,22,26] and literature have established that it help learners to articulate, and construct new knowledge through conflict and coordination during a joint problem solving (JPS). In traditional classroom, group learning benefits from the physical presence of instructor, to manage and guide collaboration within the teams of students. This advantage is not available to online learning groups and in a quest for robust distance education over the web, computer supported collaborative learning (CSCL) research is motivated towards support for online learning groups; that will be similar to what exists in a traditional classroom [9,25]. Findings in existing studies have posited that an *effective and efficient system adaptation*, and an *"unobtrusive"* intervention of a remote teacher or a computer agent, can provide this support to online groups for improved collaboration [16].

Collaboration itself, is theoretically rooted in *Vygotskys work* and Piagets constructivist idea about "social field", it was posited that the interaction, shared understanding and joint problem solving (JPS) activities within groups, propagates cognition. Thus, the objectives of CSCL research includes leveraging the ubiquity of computing technology, to support the *social* and *constructive* element of group learning. This is not limited to providing environment that enable virtual collaboration among learners, with a platform and the connectivity to mediate interaction; CSCL research is also tasked towards capturing and modelling the groups activities; to monitor, determine support need and provide efficient & effective support that will optimize collaboration and maximize learning during joint problem solving [16].

1.1 Adaptive support for collaboration

Much studies exists that have investigated adaptive support for education, they exploit the modelling power of computing technology, to research, design and develop adaptive systems that can aid learning. Adaptive support in existing work and designs have been channelled to support diverse aspect of learning; an example is the *adaptive educational systems (AES)*, which was designed to adapt key feature of the system e.g. *content presentation* or *navigation support* to suit an individuals' need [9,16]. *Intelligent tutoring system (ITS)* is another example; ITS is a computer-based learning system that is adapted with an agent model of a teacher to individualize support to a learner during problem solving. The concept of adaptation in *AES* and *ITS* were explored and designed to help an individual learner. Not until recently, that research effort is increasingly geared toward adaptive support for computer-based group learning. Some of the existing studies in literature that have explored adaptation for group learning are summarize in Table 1.

In most of the studies discussed in Table 1, an *adaptive intervention* was determined based on user profile or/and data of users' interaction/activities with the proposed systems. The adaptive interventions or decision were designed in most cases to change (i.e. adapt) the system environment to the preference of the current user (or group) or to inform an instructor (agent/remote human) about the most suitable intervention for the current user (or group). The proposed approach in this study is, *mirroring participation level* to stimulate further positive participation which is expected to improve group collaboration during online JPS. Soller, Amy [25] explained that such adaptive measure i.e. information about individuals' participation in a JPS, when presented as a feedback, can significantly influence (stimulate) a positive behaviour to participate and in turn scaffold collaboration.

Our system design in this respect, is made to "collect and aggregate data about students' interaction", we'll then reflect this information back in real-time in a form of graphical visualization of participation level of students in JPS. This adaptive mechanism is slightly differ from the conventional adaptive learning system, in that, rather than the adapting (*change*) the system environment to suit users (in our case groups), or to provide a personalized intervention

Table 1: Relate work in adaptive CSCL.

Literature	Adaption, method/mechanism & aim	Adaptation effect metric
Tsovaltzi, Dimitra, et al. [27]	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, Weiqin. [10]	* 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, Jos Antonio, et al. [17]	* 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, David, 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, H., & W, W. [21]	* 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	

during JPS, our conjecture is that the real-time performance reflection (i.e. mirror of participation level) will adapt participants' activities (positively improved participation) in a way that will scaffold collaboration.

1.2 Theoretical perspective

The idea in this study is connected to the *"social cognitive theory and self-regulated learning behaviour"* [23], where students' believe or reflection about their capabilities is emphasized to influence their behaviour in the context of learning process. Dale H. Schunk [23] depicted *human functioning* based on the *social cognitive learning theory* as a reciprocal interaction between the *behaviour change*, *environmental variables* and *cognition*, which include awareness of performance level, as described in Figure 1. Dale H. Schunk exemplify on *perceived/reflected self-efficacy* as it influence actions to attain designated performance level, he explained with reference to existing literature, that this reflection on self-efficacy impact on achievement behaviour, persistence, effort expenditure and skill acquisition. For example, in learning context a student progress indicator when conveyed back to the student can enhance self-efficacy for continued learning, which is posited to be, *"motivational process"* of reflection on self-performance in [6].

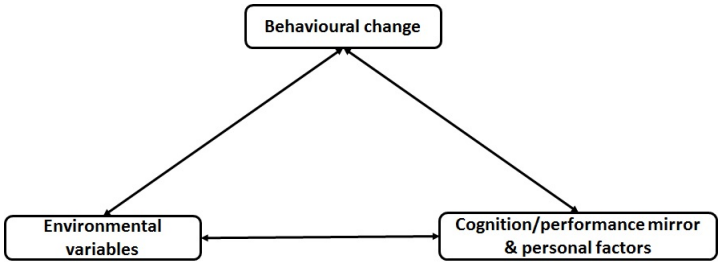

Fig. 1: Human functioning as reciprocal interactions between behaviors, environmental variables, and cognition/reflection about performance and other personal factors [23]

Albert Bandura [7], elaborating on *"agentic sociocognitive view"*, he 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* with respect to the context of adaptive system. Leon Festinger [12] also hypothesized that, "there exist in human organism a drive to evaluate his 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 [12]". Corroborating our use of relative comparison within a group as regards individuals measure of participation in JPS, Leons' [12] posit in another

hypothesis that in social context, reflection on self-performance, is in comparison with performance of other within the context.

1.3 Mirroring participation to scaffold collaboration

There are few studies that have explored this idea of self-regulation, using performance feedback as adaptive mechanism to scaffold group collaboration. An example is DiMicco Bender [11], they studied how individual member of a group respond to feedback on participation level during meetings. Their rationale, is in agreement with ours in this study, that is, the awareness of participation activities within a group can instill self-regulation of individuals' activities in a positive manner towards the goal(s) of the JPS. DiMicco Bender [11] however, did not capture, nor evaluate *effect of this feedback* based on the *actual activities* that *the feedback* is expected to affect. Real-time feedback was implemented though, but the evaluation of its effect was based on a post-study about the perception of participants, as regards how well the *provided feedback* has informed, stimulated or regulated their activity during the meetings.

We employ a different approach that can elucidate the real effect of *mirror of participation level*, we evaluated this effect through analysis of actual collaboration activities, rather than feedback from participants as in [11]. Another variation from DiMicco & Bender's [11] work is that, they studied face-to-face group collaboration (verbal interaction), while we investigate similar phenomenon within *online groups* that interact via text.

Janssen, Jeroen & other [13] is a closer related study as it explore computer-based group learning; they investigated *if visualizing participation* actually contribute to successful CSCL. The study recorded evidence of more participation and consequently improved collaboration within the treatment group (i.e. with the use of participation tool and visualizing participation level), in comparison with the control group (i.e. without participation tool nor able to visualize participation level). Our observed gap in this study is that, the concluded differences between the experiment and control groups cannot be solely attributed to *performance mirror effect*.

Firstly, because access to *participation tool* as designed in the study, might have influence more participation and not only dependent on the *mirror of participation level* within the group. Secondly, unequal size of the treatment groups i.e. 57 in experiment groups and 17 participants in the control group, can influence participation level within the groups, as group size has been researched and posited to be a factor of group collaboration [14,20].

Furthering on existing work as discussed above, and to establish the effect of *real-time mirroring of participation level* on collaboration within online groups, we studied randomly formed groups of equal size, that are also randomly selected to either treatments (i.e. experiment & control). All groups interact via joint problem solving discourse (JPSD) chat-room [5], a text-based group discussion web application (see Figure 3 & 2). The only factor between treatment is that, experiment groups are provided with real-time graphical visualization of their participation level i.e. *mirror of participation level* as seen in Figure 3, while

this *visualization display* was hidden for groups in the control treatments' JPSD chatroom as shown in Figure 2.

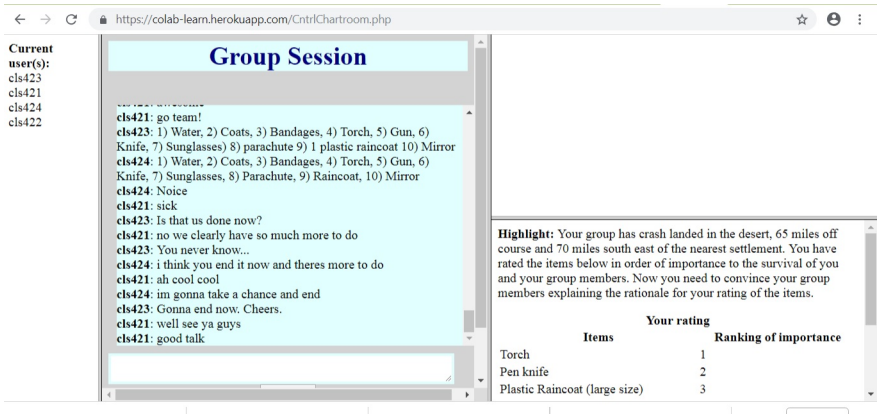

Fig. 2: Control groups' non-adaptive JPSD chat-room interface

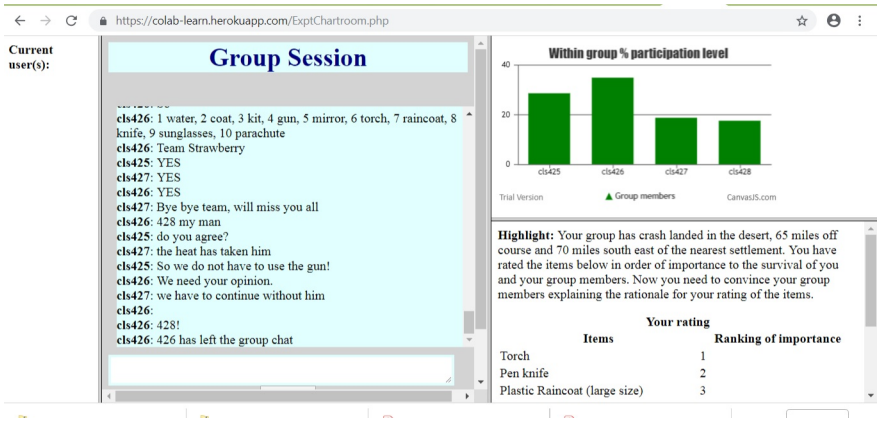

Fig. 3: Experiment groups' adaptive JPSD chat-room interface

The following research question is addressed in this study:

Research question: Do students who have real-time access to the *mirror of their participation level measure* during JPS participate more and consequently collaborate better than those that are not aware of their relative measure of participation within their group?

In the remainder of this paper, we will discuss our study design and procedure, our observation, visualization and analysis of data (i.e. text discourse contents of groups), a summative evaluation [19] to determine the effect of adaptation (i.e. mirroring participation level).

2 Study design and procedure

2.1 System design for the study

Our environment for group interaction is text based, we call it joint problem solving discourse (JPSD) chat-room [5]. JPSD chat-room was designed and implemented for the purpose of our study and has been used in previous work [5]. JPSD chat-room is enhanced for this study to *mirror individuals' participation level* within a group and in real-time, during JPS. The framework of the enhanced JPSD chat-room i.e. the *adaptive JPSD chat-room*, conform to the layered model of adaptive system discussed in [8,19]; the distinct layers of our *adaptive JPSD chat-room* is described in Figure 4.

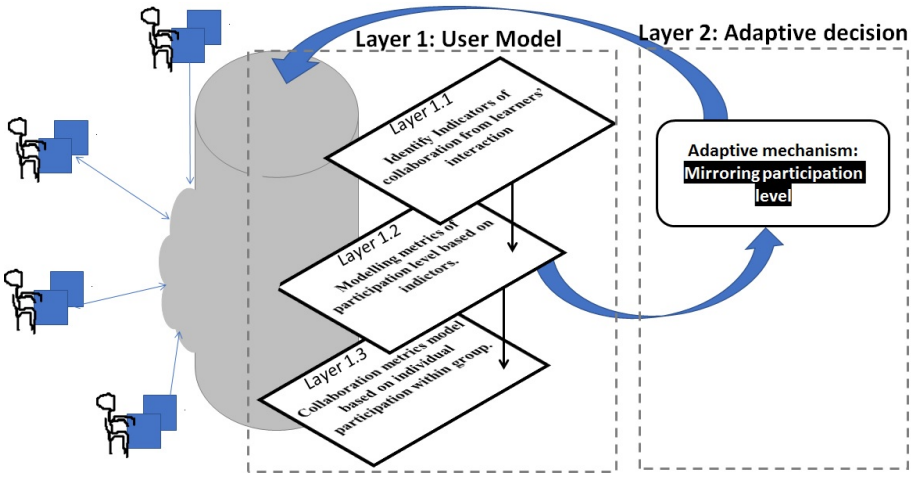

Fig. 4: Layered framework of adaptive JPSD chat-room for JPS discourse.

User model layer We capture and model user data in view of our objectives which is towards evaluating, monitoring and supporting collaboration within online group. We progressed from identifying indicators of collaboration during JPS discussion shown as layer 1.1 of Figure 4. These indicators were established based on existing literature and were adapted for our investigation purposes [3,24]. Then, we modelled discourse content to evaluate collaboration using the identified indicators, we studied the correctness of this model with verbal discussion within face-to-face groups and recorded satisfactory result as regards true representation of JPS activities and level of collaboration within the groups; our findings was reported in Adeniran et al. [4]. Given our context of group learning, we adapt and extrapolate the model for text-based online groups' discourse [5]. We developed the word-count/gini-coefficient measure of symmetry

(WC/GCMS), a collaboration-metric model for text based JPS discourse [5]. WC/GCMS was studied and evaluated with respect to how well its output represents relative measure of participation within groups and collaboration between groups [5]. Findings shows that WC/GCMS is an effective proxy-metric model to visualize relative measure of participation within and collaboration between text-based online groups JPS [5]. User model layer of our adaptive JPSD chat-room [8], encompasses *layer 1.1*, *layer 1.2* and *layer 1.3* as shown in Figure 4.

Adaptation decision As explained earlier, the adaptive mechanism we apply in this study is to reflect individuals' participation level (i.e. participation level mirror) in real-time during JPS. Our adaptive decision is based on the output of layer 1.2 in Figure 4 where we captured participation level based on word-count (WC) and frequency of textual contribution by individual group member. The visualization of this measure is displayed and updated every 5 second intervals during JPS discourse within groups.

2.2 Study design and procedure

We employ a control experiment design, with two treatments: i. experiment treatment that uses adaptive JPSD chat-room to interact (i.e. with participation level mirror) and ii. control treatment that uses non-adaptive JPSD chat-room (i.e. without participation level mirror). Both treatments condition was repeated for 5 different groups, each of the group have 4 members, total number of participant is 40. Participants were sought among the undergraduates and postgraduate students of the university of Aberdeen, interested participants were randomly selected into groups, each group is randomly slated for either treatment. Demographic data of participant is shown in Table 2.

Procedure of study We applied problem-based learning concept where each groups were asked to solve a task, we used the "*desert on the moon*" task, where a scenario was 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 rationale for their rating of the items and attempt to convince other member of the group.

The study was completely online and the procedure to participate is enumerated bellow:

1. first, the participants were asked to provide their consent to participate by agreeing to the statement in the consent page of the study web application,
2. secondly, they fill out a collaborative attitudes/skills questionnaire,
3. third, they were asked to study the task and rate the item individually.
4. Fourth, they will join the chat-room where they discuss within group to agree on rating the items. This study take about 45minutes to participate

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)

3 Data extraction, analysis, observation & discussion of result

3.1 Visualizing collaboration level between all group samples

We evaluated and visualized relative collaboration level between the ten groups, based on WC/GCMS [5]. Figure 5 shows a time-series measure of the collaboration between groups and Figure 6 visualizes the overall collaboration level measure based on the whole discourse content of each group during JPS.

Observation Striking observations from the visualized measures of collaboration are: Firstly, in Figure 5, most of the groups in *experiment treatment* spend more time in the chat-room compared to groups in *control treatment*, Secondly, we can observe from Figure 6, that groups in experiment treatment collaborate relatively better than the groups in control treatment.

Although, the most collaborative group is from the control treatment, which contrasts our ideal expectation. Our conjecture is that, ideally, *mirroring participation level* will stimulate increased participation and scaffold collaboration. However, in a real situation, other factors come into play with respect to participation in a JPS, for example knowledge level with respect to learning context, personality of individual group member, language use, coordination, leadership e.t.c. [4]. Indicators that shows existence of the positive factors to collaboration, is well observed within the transcript extracted from discourse content of *group*

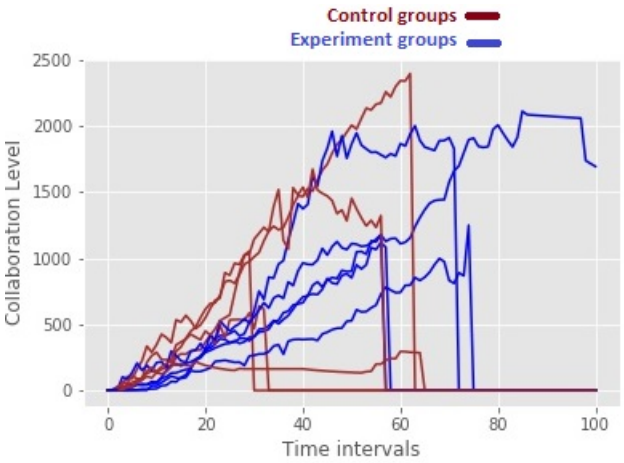

Fig. 5: Time series simulation of real-time measure of collaboration using WC/GCMS model [5]

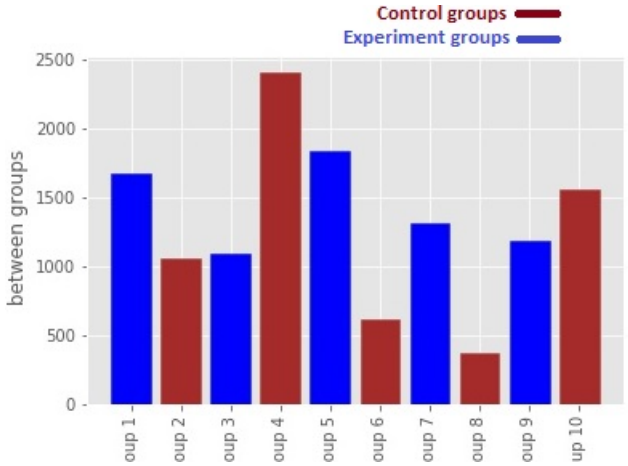

Fig. 6: WC/GCMS measure of collaboration based on whole discourse content [5]

4 (i.e. the most collaborative group as in Figure 6). For example as seen the extracted transcript bellow:

Extracted transcript from group 4 discussion: **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?
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Argue/agree/disagree

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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
```

Other groups that measure high with respect to level of collaboration as shown in Figure 6, also display some of the characteristic indication of collaboration, that correlates to their measure in the visualization. This re-validates WC/GCMS collaborative metric model as presented in [5]. Discourse content of groups can be found at 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*.

However, despite the fact that the most collaborative group emerges from the groups in the control treatment, a quantitative comparison between treatment show that, the groups in the experiment treatment *i.e. uses adaptive JPSD chat-room* collaborate relatively better than those in the control treatment. We define a simple *groupOfgroups* (gOg) measure to attest to this; we score 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, as visualized in Figure 6. The score for all groups and for either treatment is shown in Table 3, the average score for the *experiment treatment* is 5.4, while that for the *control treatment*

is 3.6. This simple arithmetic measure based on visualized level of collaboration in Figure 6 support the notion that, *mirroring participation level* positively aids collaboration.

Table 3: 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

3.2 Quantitative evaluation of adaptation effect using Two-way repeated measure ANOVA

For a robust quantitative support to reinforce our observation and hypothesis, we assume that, if the adaptive measure truly stimulate participation, frequency of contribution will be much higher within the groups; member of experiment treatment. We thus postulate a significant difference in the frequency of contribution of members within groups; this between experiment and control treatment. to investigate this conception, we extracted time-stamp of each contribution, t_{ck}^{i}, that is the 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 will is represented as a collection: $t_{c1}^{i}, t_{c2}^{i}, ..., t_{cm}^{i}$ m, being the count of contribution at different time, made by member i during JPS. Given time interval for the first contribution $t_1^i = 0$, we calculated time interval between all other consecutive contributions k as shown in consecutive contributions t_{ck}^{i} and t_{ck-1}^{i} for all k>0 as shown in equation 1.

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

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 of any of the groups will 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, i= {1,2,3,4} for all group in either treatment. We obtain f^i_{mean} data as shown in Table 4 for the five groups in both the experiment and control treatments, with members username.

Table 4: 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 5: 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 assume that *mirror of participation level* will stimulate frequency of participation by members, which consequently influenced increase in the collaboration observed for the adaptive treatment condition as shown in Figure 6 and evaluated in Table 3. Baed on this assumption, we analyze for a significant difference in the frequency of group members participation, between treatment (i.e. Table 5 versus Table 4), using a one-way ANOVA i.e. with treatments (adaptive and non-adaptive) as the factor. Also, analyze for a significant difference in the frequency of group members participation between groups (i.e. group membership as factor)

We performed the analysis using SPSS and test the following hypothesis:

1. That there is enough evidence of the effect of *mirroring participation level* on the rate of participation of members within group during JPS, i.e. a significant difference in the frequency of members' participation between adaptive and non-adaptive treatments.
2. That, group membership does not affect the rate of participation by members, i.e. there is not significant difference in the frequency of participation of members among all the 10 groups studied.

3.3 ANOVA result and discussion

The obtain the following results for the ANOVA test:

Between treatments: Analyzing significant difference between adaptive and non-adaptive treatments, 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 increase in participation rate within group.

Between groups : Considering group membership as a factor, we analyze to investigate significant difference in participation between groups. We obtained a F value = 1.700 and p-value = $0.133 > 0.05$;not enough evidence of difference in the rate of participation within the groups using a factor of group membership. This corroborates our hypothesis that group membership does not interact with how or rate at which the members' participate during JPS.

The main goal of our investigation is to investigation a real-time mechanism to support collaboration within online groups. Our analysis in here is based on frequency of members contribution to group JPS, the idea is when the rate of contribution is stimulated, it will scaffold level of collaboration. To support this conjecture by evaluating correlation between mean frequency of participation by member of the groups and relative level of collaboration within the group as indicated in Figure 6. We obtained a positive correlation measure of ***0.54***, a graphical illustration is shown in Figure 7.

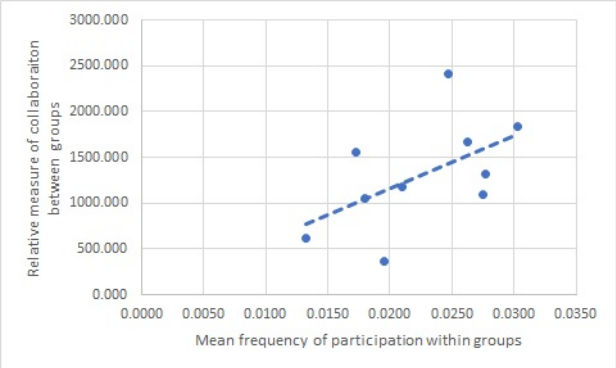

Fig. 7: Graphical illustration of correction between relative measure of collaboration between groups and mean frequency of participation between groups

4 Conclusion

Based on our qualitative observation of groups' discourse content, the visualized relative measure of collaborating between the groups, using WC/GCMS collaboration metrics model [5], ANOVA measure of significant difference in participation within groups; between adaptive and non-adaptive treatments, we are able to reinforce our hypothesis that *mirroring participation level measure*, as real-time feedback during JPS within an online groups will 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.

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