An Appraisal of a Collaboration-Metric Model based on Text Discourse

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Abstract. This paper presents a more in-depth analysis based on discourse of the collaboration-metric model, Word-Count/Gini-coefficient measure of symmetry (WC/GCMS) which was introduced in [3]. We discuss the validity of the model in regards to how well it represents what happens in the groups' discourse content. We discuss the application and implication of WC/GCMS based on the goal to incorporate collaborative learning and its cognitive advantages to E-Learning environments.

Keywords: Group discourse, online group, E-learning, collaboration-metrics

1 Introduction and related work

Online learning provides access to education for millions of learners through many environments offered by Universities and other organizations world-wide (e.g. Mass Open Online Courses). This motivates Computer Supported Collaborative Learning (CSCL) research towards leveraging the cognitive advantages of collaboration [5, 16, 24, 26, 32] for online learning, as it is preeminent in traditional classroom settings.
Online collaboration however has two major concerns: (i) media richness- the degree to which a virtual medium conveys the immediacy of face-to-face (F2F) conversation [28] and (ii) social presence- communication that fosters immediate interaction/feedback and permits people to communicate with multiple senses (e.g. verbal and visual clues) [28]. Media richness and online social presence are inter-dependent; the richer a media, the more social presence it conveys during online collaboration. For example, there is more social presence in teleconferencing which conveys both the verbal and real-time image of collaborators compared to email exchange or other text-based conversation media. However, implementing robust media that conveys both verbal and visual clues for online programs comes with costs and complexity of deployment, which may inhibit the integration of group learning. Also, a group that is media enabled with verbal and visual interaction is most times synchronous; this excludes the time flexibility to participate, to think, and to search for extra information, and to contribute in a group discussion, which comes with on-line collaboration (e.g. in asynchronous text-based media) [11, 25, 27]. Text-based group media is cost efficient and prospectively effective for online collaborative learning; De Wever et al. [11] posit that, text-based discussion makes individual contributions more explicit and provides a better reflection of the process of collaboration for both researchers and instructors. It is a good data source to evaluate both collaboration and individual participation within group [18, 23].

Online learners who interact via a text-based environment strive to maximize the social presence in the media [28]; a comparative study between text-based & F2F verbal discourse attests to similarities in both, despite a lack of facial expressions and gestures in the former [7]. Features such as frequency of agreement or disagreement, use of negative affect terms and frequency of punctuation use in text contributions reveal emotions of discussants, which is similar to facial expressions and gestures in F2F verbal discussions [14].

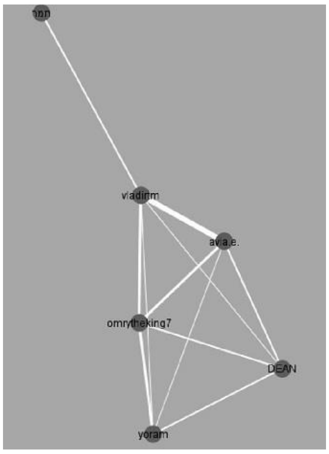
Online discussions provide evidence of collaboration as seen in F2F, although it has different representations in both; text or verbal information containing the same content will provide the same emotional or cognitive effect although processed differently [10]. Soller [31] corroborated this position stating that learners pose the natural inclination to adapt and maximize social presence when they use text-based media to interact; she however suggested that CSCL research needs to design a new adaptive method to support interaction in this environment.

1.1 Measure of Collaboration with Text Discourse

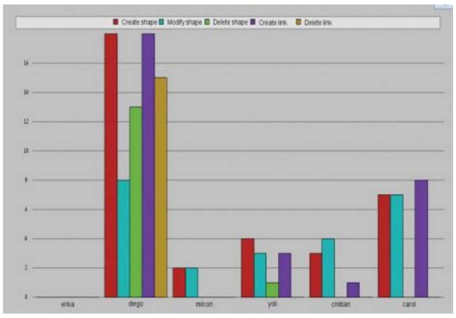
The instructors' view of collaboration via textual interaction had depended on a review of the transcripts of the groups' discourse [12]; analysis about how well groups have collaborated is possible only after the Joint Problem Solving (JPS) process has ended and any feedback from such analysis is useful to moderate future group work. In order to accord online groups the kind of real-time support obtainable in F2F groups, we require a real-time approach to view what goes on during online JPS.

Schwarz and Asterhan [29] explored this objective and presented a real-time view of group interaction using the social network of the connections between the activities within the group (see Fig. 1 a); the measure of participation by members was visualized with a bar charts, each bar representing different variables of activities involved in the task, for each group member (see Fig. 1 b).

Our model contributes to existing knowledge by providing a simpler, scalable and generically adaptable computational mechanism that informs the level of collaboration during online JPS; applicable in real-time. In the following sections, we assess submissions from existing work about indicators and metrics of collaboration. The ideas from these studies are aggregated and extrapolated for text-based online interaction. Additionally, we present the rationale and mathematical relation that inform the Word-count/Gini-coefficient measure of symmetry (WC/GCMS) model [3]. Finally, we discuss the method we used to validate this model by triangulating qualitative assessment of the groups' discourse transcript, with the output of the WC/GCMS model. We conclude with a discussion on the implications of the model in regard to a design framework for sustainable and effective online group learning environments.



(a) Group collaboration measure with Social network



(b) Individual group members' ac-

Fig. 1: E-moderation of online group collaboration, Schwarz and Asterhan [28]

1.2 Indicators and Metrics of Collaboration within Groups

Much work has been done to identify indicators of collaboration during group JPS; more of these studies explored F2F or co-located groups. For example, Martinez et al. [19] mined the frequent sequential pattern of the log trace of groups' JPS activities around a table-top application to categorize groups into high achieving and low achieving. In a similar study, Martinez et al. [20] proposed an approach to automatically distinguish between groups that engaged in a collaborative or non-collaborative activity during JPS.

Meier et al. [22] presented a rating scheme to quantify collaboration, Cukurova et al. [9] explored how group synchrony and individual accountability, equality and intra-individual variability informs good collaboration. The consensus found in these existing studies in regards to indicators of collaboration during JPS are: (i) ***Symmetry of contribution*** (ii) ***Volume of contribution*** (iii) ***Connectivity/links between contributions of different group members*** and (iv) ***the quality of contributions with respect to context of JPS***. In the next section, we will discuss how this informed the WC/GCMS collaboration metric model.

2 Word-count/gini-coefficient measure of symmetry

The components of the WC/GCMS presented in [3] are given by:

WC/GCMS metric of collaboration is given by:

$$G_{cl} = \frac{G(w_{ct})}{G_c} \qquad (1)$$

$G(w_{ct})$: represents the volume of activities/texts that the group generate during JPS; assuming that this volume informs the quality of the JPS process [21].
G_c: represents the symmetry of the activities within the group and is based on the gini-coefficient measure of symmetry. It ranges from 0-1; 0 being perfect symmetry and 1 asymmetry. Assuming that symmetry of JPS activities is an indication of group collaboration, the numerical value of the G_c is inversely proportional to the group collaboration level i.e. $collaboration = \frac{1}{G_c}$.
G_{cl}: measures the collaboration within a group.

Volume of group activities: A member *i* within a group contributes textual Statements $\overrightarrow{S_\iota}, \overrightarrow{S_2}, \dots, \overrightarrow{S_m}$, at time intervals during JPS. All text contributions by member *i* is a collection of statements, $\overrightarrow{k_\iota}$. The measure of contribution during JPS by member i, is thus given by equation 2.

$$w_{ct}^i = \sum_{j=1}^{m} \overrightarrow{S_J}, where\ m = \overrightarrow{k_\iota} \qquad (2)$$

Hence, within a group of 4 members, we have contributions $w_{ct}^1, w_{ct}^2, w_{ct}^3, w_{ct}^4$. Considering that a non-collaborating member may contribute very little and an extrovert may provide an excessively high text contribution, we represent the group activity volume measure, $G(w_{ct})$ with the median w_{ct}^i in the group:

$$G(w_{ct}) = median(w_{ct}^1, w_{ct}^2, w_{ct}^3, w_{ct}^4) \qquad (3)$$

Symmetry of activity within group: This is based on the gini-coefficient measure of symmetry adapted from [20]. Firstly, we compute the mean number of contributions by group members (equation 4a), then the symmetry of contributions within the group (equation 4b):

$$k_{mean} = \frac{1}{n}\sum_{i=1}^{n} |k_i| \qquad (4a)$$

$$G_c = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} |k_i - k_j|}{2n^2 k_{mean}} \qquad (4b)$$

Next, we describe the output of WC/GCMS with data from 5 groups. The study procedure, a brief discussion about the model and findings was presented in [3]. Here we provide an expanded and more exploratory discussion on the validity of WC/GCMS for quantifying collaboration with text-based discourse.

3 Text-based discourse data source

The text-based discourse of 5 groups was collected in a study by Adeniran et al. [3]. The groups were formed from a convenience sample of undergraduate/postgraduate students. Each group had 4 members: (Group 1) 3 male, 1 female, all aged 18-25; (Group 2) 3 male, 1 non-disclosed; all 18-25; (Group 3) 2 male, 2 female; all 18-25; (Group 4) 4 male, all 26-35; (Group 5) 4 male, 3 26-35, 1 36-45. In the study, the groups solved a joint task, the task [1], is an open-ended problem without clear cut answers as recommended by [8] for group work. JPS was via a text-based chatroom designed for the study [3]. Discourse is collected in a database; contributions are time-stamped, and uniquely but anonymously identified with the contributor. This data serves as input for our WC/GCMS model, which tells how well the groups have collaborated relatively.

3.1 Visualization with WC/GCMS metric

Figure 2a shows the relative measure of collaboration between groups based on total discourse, Figure 3 simulates a real-time view of this measure during JPS. Figures 2 and 3 can inform a remote teacher about which group is collaborating less well. We did not define a measure for a collaborative or non-collaborative group; WC/GCMS depends on the comparison between the groups to determine which group needs attention most, at a given time during JPS.

The measure of individuals' participation within the group (shown in Figure 2 b) provides a hint about non-participating members; for example, M3 in group 1 or M4 in group 4. The components of WC/GCMS i.e. $G(w_{ct})$ & G_c, are viewed in real-time as shown in Figure 4; this provides information about the groups' JPS process as discussed below. Figure 4a visualizes $G(w_{ct})$, we can observe a higher ripple in the line representing Groups 3 and 5, showing that the symmetry of contribution within the group changes more rapidly during JPS. It is a sign of high frequency of contribution within the groups which can be hypothesized as an indication of members' interest in the discussion or a relatively higher knowledge about the task (i.e. the members have more to contribute). On the contrary, the lines representing Groups 1 and 2 are smoother and the Group 4 line the smoothest, indicating that the participation rate in these groups is lower.

From Figure 4 b, which visualizes G_c, we can observe that the volume of text contribution in Groups 3 and 5 is higher and increases steadily during their JPS discussion, corroborating that if the contribution rate is higher, then the contribution volume will be higher. This also confirms the position of Maldonado [19], that a high verbal activity is an indication of collaboration; in our context: *high textual contribution indicates collaboration in a text-based discourse.*

4 Validation: WC/GCMS output versus Qualitative Assessment of Discourse

To validate the WC/GCMS's visualizations, we use the groups' discourse transcripts to make a comparative analysis with the inferences from the visualization. Contributions that aid collaboration were conjectured to assume one of the following activity-states:

task coordination, acknowledgement, request, inform, argue and motivate [2, 30]. We assess groups' discourse to determine how much evidence of these collaborative activity-states exist therein and compare these between the groups. Firstly, at the group discourse start, there is evidence of initial coordination within Groups 3 and 5, indicating an interest and enthusiasm to participate; contrary to our observation in the discourse of Groups 1, 2, and 4. Participants in the latter groups did not make any effort to familiarize with the task nor with group members; they went ahead to give suggested solutions (See Table 1).

Secondly, there is evidence of informed argument and planning in Groups 1,2, and 4, where the contributions were mostly erroneous. These groups suggested solutions with blind acceptance and acknowledgement. Most contributions from Groups 1,2, and 4 are similar to what Webb [33] refers to as "giving and receiving non-elaborated help" (i.e. unexplained solutions to the JPS task). Such contributions during group learning provide no cognitive benefit to the giver of the information nor to other members. The extract from Group 5 discourse particularly contains cognitive elaboration, which is posited to be an evidence of collaboration [33]. The relative level of collaboration between groups shown by WC/GCMS (as shown in Figures 2a and 3) is thus justified.

(a) Group measure (b) Individual Activity Measure within group

Fig. 2: Final collaboration measure between groups based on discourse content (a), and individual participation measure (of members M1-M4) within groups based on the number and word count of contributions (b).

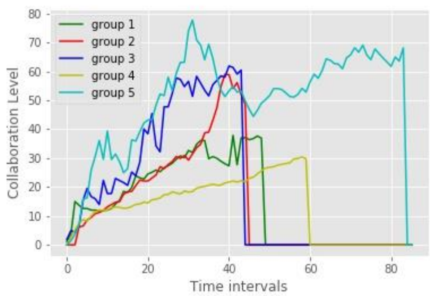
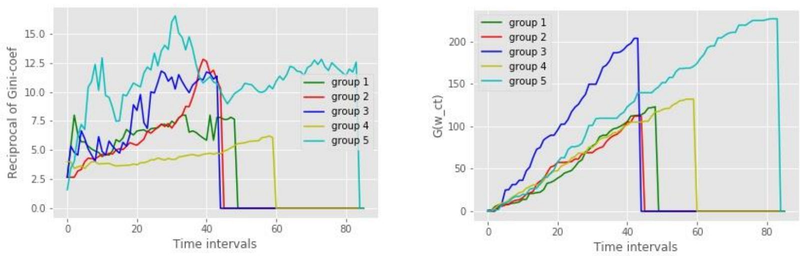


Fig. 3: Simulated Real-time view of collaboration level



(a) $\frac{1}{G_c}$ measure between groups (b) $G(w_{ct})$ measure between groups

Fig. 4: Components of WC/GCMS model

Table 1. Evidence of Coordination.

Group 3	Group 5

Beowulf: Good Morning everybody
Epigha: What item do we think should have the highest ranking of 1? I suggest oxygen
Epigha: Any other suggestion?
Anonymous1: I think safety is most important, so life raft is my suggestion
Beowulf: My ratings were based on a few things know about the moon.
// First: there is no atmosphere
// Second: It is very cold
// Third: there is no magnetic field
Epigha: If there is no atmosphere, how can you breathe without oxygen? I think you need to breathe before considering safety
	sir D: Hello
	Cg: Hello
	Cg: I have just been writing notes on all the items whilst waiting.
	Mide: Hi Cg
	Cg: I just submitted my thoughts on the items and the system deleted the message.
	Cg: Hi
	Ku: hi everyone

Group 1	Group 2	Group 4
Lucas: Hello... **charis**: how are we starting the ranking **charis**: … **Ranco**: Watson **Lucas**: Guess we are waiting for one more participant **Ranco**: Can we start pls? **Ranco**: Most important (1) oxygen **Lucas**: "I think we can Charis, still online?" **Lucas** : I will go for oxygen as the most important (1). **Ranco**: Opinion pls? **Ranco**: Hello.... **Lucas** : I think water should be 2	**olu**: which do you think should be first fellas? **Carbon**: Since we dont knw when d 4th member will be available **smith**: I think oxygen **Carbon**: Stellar mapYeahNo 1 item = oxygen **olu**: what about first aid? **olu**: I think I agree with map i.e directionmap, compass, first aid **smith**: Oxygen should be the most important **smith**: Oxygen is needed for survival in space **Carbon**: First aid should be later	**smart** : Oya, so what is your view? Swiftly **Swift**: Obviously, first place important thing is oxygen **Swift**: Then water, followed by food **Swift**: What do you think? **smart**: Yes, oxygen... Correct **smart**: Yes.. In that order **smart**: Without it **smart**: All those in order, **Swift**: So, what do you think should be the next?

Non-participating group members: Logically, the rate of participation by an individual group member is directly proportional to the collaboration level within the group.

The discourse transcript shows that member "charis" in Group 3 and "unknown" in Group 4 did not participate relatively well within their respective groups. This explains the low bar for M3 in Group 2 and M4 in Group 4 as shown in 2 and further validates the WC/GCMS output.

Quality of contribution and knowledge about task: Assessment of discourse of Groups 2 and 5, shows evidence of information sharing, of new knowledge, and suggestions based on logical reasoning about the task. Their discussion conveyed knowledge of context (the moon environment) and transfer of knowledge (see Table 2). This kind of elaborated discussion indicates participants' socializing during small group discussion as posited by [15]. On the contrary, the discourse of Groups 1,2, and 3 lacks such knowledge-based interaction; this inhibits socialization within the groups [15]. In line with the Vygotskian perspective as mentioned in [33] that collaboration provides cognitive benefits when “a more expert member helps less-expert ones”. Studies have also shown that there is a knowledge level threshold for a task that can foster optimum collaboration within groups; below it, a group will not attempt a solution at all or suggest unexplained erroneous solutions which hinders collaboration and cognition [4].

Table 2: Evidence of Other collaborative activity-states

Group 3	Group 5
	Cg: The parachute is useful in that it is a large piece of material. But I do not think that high
Beowulf: My ratings were based on a few things I know about the moon. // First: there is no atmosphere // Second: It is very cold // Third: there is no magnetic field	**sir D**: no gravity **Cg**: It can be used for things other than its intended use. **Cg**: There is gravity but no atmosphere.
Epigha: If there is no atmosphere, how can you breathe without oxygen? I think you need to breathe before considering safety	**Mide**: U WIL NEED PARACHUTE SINCE U ARE AIR, FOR LANDIND, SAFETY
cls603: I rated Solar-powered FM receiver-transmitter 1st because the to communicate with their base **Epigha**: Beowulf and cls603, what is your contribution?	**Cg**: Was the scenario that you had landed, or were away to land? Also there is no information about the parachute. How big is it?
Epigha: cls603, I think communication can come after survival and safety **Beowulf**: I rated the oxygen tanks as the most important item, for breathing	**Ku**: I think we should first have clusters like A. survival B. Safety and C. Set Objective Then from this clusters we rank the items in each cluster. And naturally we solve the problem
Epigha: I give oxygen tank highest priority too	**Cg**: Is it not your objective to survive?
Epigha: Do we all agree with oxygen tank = 1	**sir D**: yes it is
Beowulf: I agree with that **cls603**: Alright I agree with the oxygen	**sir D**: "and the scenario says "" mother ship on the lighted surface of the moon """
Anonymous1: Oxygen OK **Epigha**:We move to the next item then. what item is the second highest priority? **Beowulf**: Water is a priority, but because the moon is cold, the heater is needed to make the water liquid rather than frozen.	**Cg**: "I think we need to start with either the number 1 or the number 15 and say ""OK, which item would leave behind if we had to"". That is 15. Then do it again, again etc."

Group 1	Group 2	Group 4
Luca: I think water should be 2	**smith**: I think oxygen	**smart**: Yes, oxygen... Correct
Ranco: Ok....same here...good	**Carbon**: Stellar mapYeahNo 1 item = oxygen	**smart**: Yes.. In that order
Lucas: "Ranco, Any suggestion for 3?"	**olu**: what about first aid?	**smart**: Without it
Ranco: One case of dehydrated milk	**olu**: I think I agree with map i.e directionmap, compass, first aid	**smart**: All those in order,
Ranco: ???	**smith**: Oxygen should be the most important	**Swift**: So, what do you think should be the next?
Lucas: Hmmm....is that really important? Remember we have water already	**smith**: Oxygen is needed for survival in space	**smart**: A feel a magnetic compass
Lucas: "With oxygen and water, i think the instruments to get them to their location should come next"	**Carbon**: First aid should be later	**smart**: Cos they would have to knw
Ranco: "Ok, at what point do think we will need milk and food? Jst asking?"	**olu**: oxygen is as well important	**smart**: Where they wanna go
Lucas: After the basic instruments; So the stellar map, United	**Carbon**: After all navigation tools has been pick	**Swift**: Yeahh...I agree
	olu :you can fix oxygen without the first aid kit	**smart**: Then the receiver-transmitter To keep contact
	smith: first aid is as well important	**smart**: What do u think?
	smith: but proactive measures should be taken before reactive measures	**Swift**: The stellar map should come before the compass
	olu: 1. map2. compass3. oxygen	**Swift**: Then the receiver-transmitter should come after the compass
	Carbon: Health first	**smart**: Oh
	olu: 4. first aid	**smart**: That true
	Carbon: I think first aid and oxygen shoyld be first	**smart**: What about the heating unit
	olu: any other opinion for the first four rating	**smart**: I feel the moon is kinda cold u know
		smart: For a 200miles journey

5 Conclusion

The major contributions of this paper are: first, based on literature, we argue that a text-based media is efficient and can be optimized to maximize social presence within an online group [7, 11, 25, 27, 28]. Second, existing studies proposed measures of collaboration that use the text discourse transcript, providing an analysis after the discourse has been completed [6, 13, 17], whilst WC/GCMS is intended to be used in a real-time group monitoring dashboard for a remote teacher. Third, we present an explicit comparative analysis of the WC/GCMS metric output with an assessment of the groups' discourse, to validate the model's sensitivity in regards to quantifying text-based group collaboration. We posit that WC/GCMS can provide simple, easily interpretable graphical outputs is upgradeable (to capture verbal and visual clues when using richer interaction media) and generic (can be extrapolated to the collaboration context).

Whilst the indicators of collaboration exceed the characteristics of the text discourse content used in this paper, WC/GCMS is sensitive enough to serve as a proxy-effective metric of collaboration and participation within online groups. We plan to run a larger scale study to further investigate the indicators, factors and models presented. We will also investigate the use of our metrics and visualizations to provide real-time feedback to learners to scaffold collaboration, and measure both quantitatively and qualitatively the effect of such feedback on JPS. We further aim to develop algorithms for a computer agent (taking our models as input) to stimulate participation and consequently scaffold collaboration.

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