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# Interactivity in online discussions and learning outcomes

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ABSTRACT

The increased use of online discussions in learning environments both formal and informal, positions the construct of interactivity as central to learning. Interactivity in learning communities' online discourse is viewed in this study as a socio-constructivist process. It is the network of interactions among content items and participants which drives a collective knowledge construction process. Conceptualizing interactivity in the literature is still unclear and not enough is known about its role in knowledge construction and about its relationship to learning outcomes. In addition, assessing learning outcomes using analytics has not matured fully and is still subject to intense development. This study thus sets out to investigate the role of interactivity as a process of knowledge construction within online discussions, and in particular, its association with learning outcomes, as measured by formal assessment tasks. We present significant positive correlations between various interactivity measures, taken from various learning communities, and a set of well-known learning assessments. We suggest that patterns of interactivity among learners can be measured, and teach us, not just about group dynamics and collaboration, but also about the actual individual learning process.



## 1. Introduction

Interactivity is a central design and evaluation construct for online communities. Among the intended outcomes of interactivity in online communities are engagement, sociability, the group's potential to stick together, cooperation, and longevity (Rafaeli & Sudweeks, 1997). Specifically, the focus of this paper is on interactivity in online discussions within learning communities. Social interactions are thought of as scaffolds in the construction of the individual learner's knowledge (Anderson & Dron, 2010). Online discussions are commonly used to complement learning in blended courses, or as the sole or main communication channel among learners and their teachers, in fully online courses, such as MOOCs (Massive Online Open Courses) (Brinton, Christopher, Lam, Chiang, Zhenming, Shalil & Wong, 2014).

Conceptualizing interactivity in online communities has been ambiguous and varied (McMillan, 2006; Stromer-Galley, 2004). Specifically, one line of research views interactivity as situated within the medium (Evans & Sabry, 2003; Sundar, 2004), while Rafaeli (1988) examines interactivity as a process-related variable and thus focused on human to human rather than human to machine interaction. In his definition, interactivity is predicated on the relatedness of sequential posts in a threaded online discussion. Based on this definition, we proposed that interactivity in learning communities is a socio-constructivist process, in which learning results from the interactive exchange of information, while learners develop the

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explicit relatedness among posts (Kent & Rafaeli, 2016). To provide empirical validation, we presented a hyperlinked discussion tool, Ligilo (Kent & Rafaeli, 2015), in which each post is expressed as a node in a network of posts, where the semantic relations among posts are generated by the students, who were directed to overtly tag the relationship of their post to the previous one using one of a set or prescribed phrases or clauses to link the two. We also presented a quantitative operationalization framework for interactivity, used within a field experiment. This experiment resulted in significantly higher levels of interactivity in learning communities, when using the semantic networked topology discussion platform over the classical thread based discussion platform (Kent & Rafaeli, 2016). This is evidence that the hyperlinked (structurally constructed) nature of the discussion platform had a significant positive impact on interactivity. In this paper we take the relationship between interactivity and learning one step further, to examine how interactivity correlates with learning outcomes, as assessed in various formats.

CSCL (Computer Supported Collaborative Learning) research views learning through the prism of process vs. outcome (Jeong, 2015). "Interactivity is an iterative process, leading to jointly produced meaning" (Rafaeli & Sudweeks, 1997). "Collaboration is analyzed as a process that gradually can lead to convergence of meaning" (Roschelle, 1999). Thus our main aim is not only to examine the process, but to also learn about its relationship with common assessed outcomes down the road. Specifically, we focus on the learning outcomes each individual gain from interacting within their learning community (Vygotsky, 1978), measured as learner's performance.

Assessment of learning outcomes, as originated from the behaviorist approach, was summative in nature. Behaviorism refers to the outcome or output of the process, and not to the process itself. In that sense, being able to answer correctly an exam question, by rote learning for example, counts for a reasonable outcome of learning. In contrast, formative assessment relates to the process, and is based on the constructivist approach (Duit & Treagust, 1998). In this approach, the process of learning is based on the assimilation of new knowledge by relating it to existing knowledge (Ausubel, 1968). Learners' performance can be assessed summatively or formatively, by factors such as successful completion of a course, exams grades and gain of new knowledge as compared to the beginning of a course. In any case, the assessment depends upon the content of the course, the pedagogic design and the nature of the students (Picciano, 2002). Thus we collected data from various courses, entailing different designs, goals and backgrounds. Eventually, our attempt to learn about the relationship between interactivity and learning outcomes raises the question of whether interactivity in a learning community, for itself, should be seen as a collaborative learning process, as its outcome, or even both.

In the rest of this section, we will briefly review the theoretical relation between interactivity and social constructivism in the context of learning communities' online discussions. We will point to existing literature correlating interactivity in online discussions to learners performance, for example, Balaji and Chakrabarti (2010). In our Method section, we show collected and analyzed quantitative data from multiple learning communities' online discussions. In the Results section we present significant positive correlations between a subset of interactivity measures and various types of summative and formative assessments of learning outcomes (such as multiple choice exams' grades, expert's evaluation of the learners' knowledge and more). Finally, we examine the relationship between interactivity behavioral patterns and outcome assessments of individual learners in various settings of learning communities. We hope to gain initial insights about the association between learners' online interactions and learning outcome assessments in different community and moderation settings.

### *1.1. Online discussions in learning communities*

Online discussions hold a promise for collaborative knowledge construction: participants in online communities are afforded the opportunity to share ideas, learn from peers and build knowledge collectively, while reading and reflecting on each other's thoughts. The virtual settings enable less-assertive participants to compose their thoughts (Hewitt, 2001), while allowing more time for all participants to reflect on and respond to the contributions of others (Poole, 2000). Pedagogically, rationales for learning by online discourse typically make references to the collaborative construction of meaning within online communities (Lander, 2015). It has been suggested that this mode of learning offers opportunities for 'group-centered' rather than 'authority-centered' modes of learning. When learners build on the comments of others, a higher flow of communication and inference is being shown, compared to the "turn-taking" face-to-face environment (Garrison, 2006). In practice, however, quite often online discussions do not meet expectations for engagement (Dennen, 2008; Palmer, Holt, & Bray, 2008); contributions frequently do not respond to or build on one another (Thomas, 2002); and threaded discussions are inherently divergent (Hewitt, 2001), often shallow (Webb, Jones, Barker, & van Schaik, 2004) and disjointed (Zhu, 2006).

This study examines the knowledge construction process of learning communities through interactions among the learners and among their curated content during online discussions. Among a wide range of interactivity conceptualizations, from the field of CMC (Computer Mediated Communication) we follow Rafaeli (1988) who viewed interactivity as a process-related, variable characteristic of communication settings, and conceptualize it as the extent to which posts in a sequence relate to each other. Next, we rationalize the link between this CMC-originated conceptualization of interactivity to theoretical frameworks of human learning.

### *1.2. Interactivity in online learning communities as a socio-constructivist tool*

Online asynchronous discussions provide learners with the opportunity to interact when reading and responding to peers' and teachers' postings. Interaction, as suggested by educational research, is one of the most important tools for learning

(Barker, 1994; Vygotsky, 1978). Therefore, we propose that interactivity is an essential metric when evaluating learning communities.

Social Constructivism extends constructivism by pointing to the central role the community plays in the individual learning process (Vygotsky, 1978). Vygotsky argued that all cognitive functions originate in social interactions and that learning is the process by which learners are integrated into a knowledge community. Interactivity in knowledge communities is thus a constructivist process (Vygotsky, 1986); Interactivity's conceptualization as a process of relating to each other's postings (by taking conversational turns) (Rafaeli & Sudweeks, 1997) emphasizes the foundations of social interactions for constructing knowledge, hence learning. We extend it to emphasize not only interactions among community participants, but also interactions or hyperlinking (curated by community participants) among posts and other information resources (Kent & Rafaeli, 2016).

In this paper we concentrate on the theoretical framework of social constructivism to explain the strong relation of our conceptualization of interactivity to learning. However, other frameworks may also be applicable to the notion of relating, hyperlinking and interacting among learners and information resources as a learning process. Examples for such frameworks are Connectivism (Downes, 2007; Siemens, 2005), which explicitly relies on the ubiquity of networked connections between people, digital artifacts, and content; and the Community of Inquiry (COI), whose goal is of creating a community where students are fully engaged in collaboratively constructing meaningful knowledge through reflection and discourse (Garrison, 2006). Regardless of the theoretical framework however, evaluating interactivity in online learning discussions is crucial, not only to learn purely about social and motivational factors (for example, Song & McNary, 2011) but also in order to learn about its influence on the quality of online learning (Trentin, 2000) and achievement (Andresen, 2009). The rest of the introduction will be devoted to evaluating learners' performance and its relation to interactivity.

### 1.3. Learning outcomes

Learning outcomes are assessed or measured according to learning goals and educational approaches (Shavelson & Huang, 2003). Millar (2013) maintained that assessment operationalizes outcomes and thus defined them by clarifying the learning that is intended by any given learning objective. Traditional approaches of the teaching-centered paradigm were quantitatively measured by summative scores, concerned with certifying learning, where outcomes are often a mark or a grade. The transition to alternative contextual teaching methods, learner-centered paradigms, such as constructivism, transformed the perception of evaluating achievements. This approach perceives teaching not as oriented to knowledge transfer, but rather to knowledge construction by the learner. Consequently, formative assessment was designed to support learning, with outcomes that are focused on providing task-related feedback (Birenbaum et al., 2006; Black, 2013; Millar, 2013).

Social constructivism perceives knowledge as constructed between people by a social process of interacting, and less as structured within individuals (Burr, 2015). Assessment of collaborative learning should integrate individual and peer assessment. For example, the practical inquiry model incorporates the shared and the private worlds, where self-reflections and shared discussions enable, construct and confirm meaning (Garrison, Anderson, & Archer, 2001). Doubleday et al. (2015) suggest integrating peer-assessment, self-assessment and formative assessment of learning, in addition to summative assessment, in a course of collaborative problem-based learning process.

### 1.4. Interactivity and learning outcome

As briefly shown in the previous sub-section, a wide range of frameworks and metrics is used to conceptualize and operationalize learning outcomes. Likewise, Interactivity in learning communities has many definitions (Rafaeli & Ariel, 2007; Wei, Peng, & Chou, 2015). Furthermore, operationalizations and learning analytics measures abound in the research community.

In practice (for example, in MOOCs or in LMSs, Learning Management Systems) interactivity is rarely evaluated or considered as a learning evaluation metric. Learning analytics in these systems are usually designed to report on students' task completion, or to raise 'red flags' for students at risk of failure or dropping out, predicted by late assignment submissions, low grades and such (Gaševi, Dawson, & Siemens, 2015). Moreover, the learning process itself, whether reflecting on the progress of the learner's understanding, their ability to build on existing knowledge, to ask, or to impact their own community, is usually not tracked or traced quantitatively at all (Reich, 2015).

This lack of standards and of a robust theoretical foundation, makes it very hard to learn about the relation between interactivity and learning outcome (De Wever, Schellens, Valcke, & Van Keer, 2006), and indeed little is known about this relationship (Song & McNary, 2011).

To date, learning analytics research is focused on measures derived from data traced within learning systems, that is, counts of logs of various activities. Less attention has been given to the way these activities affect learning products (Gaševi et al., 2015). Those studies which do exist have shown a positive correlation between participation in asynchronous discussions (measured often by the number of postings and logins) and grades or classroom performance (see Song & McNary, 2011; Zhu, 2006; Wei et al., 2015; Adeyinka & Abdulmumin, 2011 and Andresen, 2009). Other studies found positive correlations between number of read posts and achievements (see Asterhan & Hever, 2015). However, some other studies found no consistent results about the correlation between the two (see Song & McNary, 2011 and Picciano, 2002). Instructional and pedagogical designs are often found to moderate the relations between participation, social presence or interactivity and

learners' performance (Gaševi et al., 2015), and are likely to be responsible for at least some of this inconsistency. The instructors' moderation mechanisms, discussion structuring and its adaptation to the designed learning outcomes of a course cannot be thought of as external to this equation (Zhu, 2006).

Our conceptualization of interactivity as a socio-constructivist process reflects on the importance of relating (constructing by hyperlinking) to others in a discussion. In Kent and Rafaeli (2015) we presented Ligilo, a hyperlinked discussion platform which is used in blended, as well as in purely online, a-synchronous learning contexts. In Ligilo, each discussion contribution and content item is expressed as a node in a semantic network of posts. This way, learning communities actually create collective concept maps while online discussing. The relations among posts are semantically tagged by community members (examples for such relation tags are “reminds me of”, “makes me ask”, “for example”, “as opposed to” and so forth). The tagged relations enable for a clearer comprehension of the information structured by community peers. In addition, Ligilo enables a zoomable map view of the emergent knowledge base in order to better grasp the high-level context of the constructed model, as well as voting, following, notifications and other common social features. Some screenshots are available at Appendix B.

Ligilo is implemented as a two-fold network: a network of hyperlinked posts, which underlines a social network of learners, interacting based on the network of posts. In Ligilo, learners contribute to their community, not only by posting, voting and reading, but also by relating to other learners' postings and by tagging these relations. This is based on the known theoretical notion that meaningful learning is located in contexts and relationships rather than merely in the minds of individuals (Ausubel, 1968; Novak, 2010). In this view, we operationalize interactivity as a multivariate construct, measuring the relatedness among content items and posts, and among the learners themselves (Kent & Rafaeli, 2016).

It is important to observe the learning process, as well as its outcomes, in order to explore learning from the angle of interactivity patterns. Apart from community building and socializing, can interactivity contribute to the understanding of the field of learning assessment? Next, in the Method section, we describe some datasets collected and analyzed in order to learn about the relationship between interactivity as a socio-constructivist process and a set of learning outcome assessments.

## 2. Method

We examine the relationship between students' online interaction patterns and their learning outcome as assessed in four different higher education, blended courses. This section begins by presenting our framework for interactivity quantitative evaluation. Then we will describe our collected datasets and the learning outcomes assessed in each one of them. In the Results section, the significant associations between interactivity measures and various outcome measures (as described in this section) will be presented.

### 2.1. Operationalizing interactivity in online discussion

CMC researchers have operationalized interactivity differently, using feedback options, presence of website features (e.g., hyperlinks, chats, downloads), ease of navigation, and scale (Rafaeli & Ariel, 2007; Sohn, 2011). Research into interactivity as a process-related variable within online communities (Kelleher, 2009; Rafaeli & Sudweeks, 1997; Wise, Hamman, & Thorson, 2006) has focused on the process of message transition and responsiveness in a communication setting. Education studies on interactivity range from the purely quantitative (for example posting frequency) to pre-existing coding schemes, and to survey-driven (Lander, 2015). Other studies added structural analysis of the discussion by using social network analysis or cluster analysis (Durairaj & Umar, 2015; Rabbany, Takaffoli, & Za, 2011; Zhu, 2006).

Our multi-dimensional operationalization framework of interactivity presented in Kent and Rafaeli (2016) is learner-centered (in terms of the unit of analysis) and is based on interactions and turn-taking, as well as on network analysis characteristics like level of relatedness of a post to other posts in a discussion. Among a wide set of purely quantitative metrics, we have chosen just a limited set of measures, all of which relate to actual behaviours of learners (as opposed to perceived interactivity). Those learning analytics are extracted from Ligilo, our hyperlinked discussion platform. The structural analytics are enabled due to the inherent structuring of discussions in Ligilo as a semantic network (Kent & Rafaeli, 2015; Scardamalia, 2004).

We examine interactivity as a two dimensional construct: (1) *the access mode* determines whether an interactive behavioral pattern is about writing/creating content ('speaking') or about reading/consuming content ('listening') (Wise, Hausknecht, & Zhao, 2013); and (2) *the level of granularity* will classify the unit of reference. We suggest looking at four levels of granularity of a discussion, its content, structure and participants: (a) the explicit content within a post; (b) the semantic or structural context of the post within the network of posts; (c) the social map that spans it: the network of community members as reflected in their contribution, readings, and interactions; and finally (d) interactivity with informational resources, external to the discussion. Table 1 depicts the two dimensions' layers along with some metrics produced by Ligilo for each layer, all of which are log-based and automatically extracted (as opposed to manually coded).

The explicit post content layer contains traditional log based measures of participation, such that focuses directly on activities and content related to a single post, while overlooking its surrounding context of related posts and people. The context layer offers structural metrics which depict networked based analysis (Zhu, 2006) of the context of the single post in relation to its 'neighbourhood': number of posts explicitly related to it, from it, and its depth (the length of the thread of posts beginning from the root post, and on to this specific post). The social layer analyses the discussion's Interaction graph (Wilson,

**Table 1**
Interactivity dimensions and metrics.

| Granularity/Access | Content creation | Content consumption |
|---|---|---|
| Explicit post content | # of contributed posts<br>Average# of images attached to a post | # of views |
| Context | Average depth of contributed posts<br>Average# of posts explicitly related from contributed posts<br>Average# of posts explicitly related into contributed posts | Average depth of viewed posts |
| Social | # of posts with author X related to posts with author other than X<br>Average time elapsed from the creation of a post to the creation of related post | # of views by participant X on posts with author other than X<br>Average# of views by of participants other than X on posts authored by X<br>Average# of followers<br>Average# of votes on contributed posts |
| External | Average# of links (URLs) added to contributed posts | # of clicks on links within posts<br># of clicks on files within posts |

Sala, Puttaswamy, & Zhao, 2012). A link between two learners in an interaction graph refers to a direct social interaction between them. Such interaction might be any communication or an application like voting, following, viewing or responding to one another. Interaction of the constructed knowledge base with external resources is depicted in the fourth level. Distributed cognition does not posit a gulf between "cognitive" processes and an "external" world (Hollan, Hutchins, & Kirsh, 2000). Thus media artifacts might be seen as interactions between information and people within and outside of the community via external resources. In terms of knowledge construction, these kinds of outbound interactions might result in new inferences, insights and new knowledge.

Next we describe the datasets from which we extracted the analytics described here, in addition to the various types of learning outcome assessed for each of the datasets.

### 2.2. Data sets

231 students, in eights classes from four different courses, each from a different faculty and knowledge domain, in three universities, instructed separately by two different instructors (who are also co-authors of this paper) used Ligilo for discussions accompanying entire courses. As each course had its own learning goals, a discussion skeleton was structured in advance by each instructor to frame the nature and scope of the discussion (Al-Samarraie, Teo, & Abbas, 2013). In all cases, the expected product was a collaborative knowledge base. These bases were built within the discussion itself, in a moderated week-by-week process, so that the students will be able to use it as a reference when studying for their final exams. Participation in the discussion was rewarded by a portion of 15–20% of the final grade. We collected interactivity metrics for all students, following the operationalization framework presented at the previous sub-section, and correlated those metrics with assessment grades, which were measured separately, as described in Table 2 below.

Factors like instructional design, pedagogical goals, assessment tools and the varied background of the students might moderate the relation of interest here (Gaševi et al., 2015). Thus we chose four very different courses, consisting of various types of academic levels, instructional designs; pedagogical goals, assessment tools and moderation levels (see Table 2).

In each of the four courses we used different qualitative assessment tools, emphasizing the initial pedagogical goal. In the Biology course, two assessment tools were combined. The first of these was grading the learners' answers to the guiding questions in the online discussion. The criteria were the correctness and coverage of the answers, as well as whether this answer gave some added and new value to the existing answers of other learners. The second assessment tool was the oral exam. A question, taken from the online discussion's guiding questions was presented to the learner, while their answer was assessed for the depth of their understanding, and the level of implementing the discussed material in the practical labs (Bloom, 1974). Assessment of the learners' knowledge in the e-business course was performed by a multiple choice exam, focused on conceptual coverage and inferences (Haladyna, 2012). The discussion was also constructed by conceptual coverage on the same bank of concepts, and thus was used to collaboratively assimilate the assessed material. In the philosophy course, two assessment tools were combined. The first was grading the learners' contributions within the online discussions. The indicator for assessment was based on the level of demonstrated thinking skills: relevance, renewal, integration, synthesis, analysis and evaluation (Bloom, 1974). The second assessment consisted of assignments (seemingly external to the online discussion). The assessment criteria were integration of the material discussed in the structured online discussion with the learner's own ideas and subjective experiences and impressions with regards to the subject domain. In the Virtual Communities course, the assessment goal was to measure the delta of knowledge gained by the course for each learner, instead of just their final level of knowledge at the end of the course, a summative assessment which ignores the learners' initial background knowledge on the subject domain. The learners' knowledge was thus assessed twice: pre and post the course, and the difference between the two was used to assess their learning (Campbell & Stanley, 1963).

The next section will review our findings about the relation between interactivity variables and outcome assessments, and among all interactivity variables themselves.

**Table 2**
Our data sets and measured learning outcomes.

| Course domain | Academic level | Number of students | Structure of discussion | Moderation level | Discuss-ion duration | Purposed outcome | Grading discussion participation | Assessment tool |
|---|---|---|---|---|---|---|---|---|
| Cellular Biology, Biology department | Under graduate | 37, in two parallel classes | Question answering, structured by different labs. Underneath each lab, the instructor added 3–4 guiding questions. | Medium. No instructor intervention except for the initial skeleton structuring and guidelines. | 13 weeks | Basic and technical knowledge about lab procedures. | Grading quality and quantity of postings. | 1) Qualitative Expert's evaluation of knowledge in posts within discussions;<br>2) grading of an oral exam, examining the implementation of the knowledge discussed theoretically online – to implications in the lab. |
| e-business, Management department | Graduate | 89, in three parallel classes | Mapping concepts, reading materials (e.g., articles and academic papers) and subjective insights to 4 main questions. | Medium. No instructor intervention except for the initial skeleton structuring and guidelines. | 8 weeks | Conceptual coverage. | General grading for participating. | Multiple choice exams at the end of the course mainly covering learned and discussed concepts. |
| Philosophy of education, Education department | Graduate | 77, in two parallel classes | Discussion around reading materials, sub-structured by guiding questions | Medium. No instructor intervention except for the initial skeleton structuring and guidelines. | 10 weeks | Integration of reading materials with learners' subjective experiences and insights. | Grading quality and quantity of postings. | 1) Qualitative Expert's evaluation of knowledge in posts within discussions;<br>2) grading assignments built on the discussed material. |
| Virtual Communities, Information School | Graduate | 28 | Mapping concepts, reading materials (e.g., articles and academic papers) and subjective insights to 9 syllabus subjects. | Low. No instructor intervention except for the initial skeleton structuring. No guidelines were given. | 8 weeks | Free-form discussion on the course's subjects, guided by conceptual coverage. | General grading for participating. | Multiple choice exams, pre and post the course, focused on learned and discussed concepts. |

## 3. Results

Table 3 provides Pearson's correlation coefficients between the interactivity measures presented in the Method section, and the chosen outcome assessments tools at all four courses. All the correlations presented in Table 3 were statistically significant at the 0.05 level or better. The significant correlation found with the interactivity measure of 'Time elapsed from the creation of a post to the creation of related post' is negative, since lower values actually present higher level of interactivity. All other significant correlations were positive. The dataset describing the Virtual Communities class was screened for one statistical outlier, of a student who did not complete her pre-exam. Some of the interactivity measures were consistently not correlated significantly with any of the assessments tools. These were: the number of links (URLs) added to posts, the number of views ('listening'), and the number of views by participant X on posts with author other than X ('reactive listening') and the number of followers.

### 3.1. Pearson correlations among interactivity variables

In order to better understand the validity of our operationalization framework, and to grasp the essence of interactivity, we extracted Pearson's correlation coefficients among all interactivity measures themselves, independently in each course. We noticed a set of significant correlations, repeating in almost all of our datasets. Despite obvious limitation of the size of our dataset, some interesting findings might direct the research on interactivity in learning communities to an extended examination of a model. The repeating significant correlations are detailed in Appendix A. Here we summarize some of the more notable findings.

Three pairs of variables were consistently and significantly highly correlated (all higher than 0.8 in all datasets): the pair of # of contributed posts and # of reactive contributed posts (# of posts with author X related to posts with author other than X), the pair of # of views and # of reactive views (# of views by participant X on posts with author other than X) and the pair of average # of posts explicitly related from contributed posts and average # of reactive posts explicitly related from contributed posts (# of posts with author X related to posts with author other than X). These highly correlated pairs suggest that some constructs of sole participation behave similarly to the constructs of interactive participation, as defined in Rafaeli (1988).

Some variables showed consistent correlations clustered in two main groups, with respect to repeating correlations among variables within those groups. Because of different scaling origins, factor analysis cannot be conducted on these variables. Nevertheless, a quantitative examination of the Pearson correlations of interactivity variables yields a differentiation between variables. This correlation-based grouping may suggest a division of the variables to dimensions, which is different than the theoretical-based division presented at Section 2.1. One such group of variables consisted of the variables: # of contributed posts, # of views, # of views by participant X on posts with author other than X, average depth of viewed posts, average depth of contributed posts, # of clicks on links within posts and # of clicks on files within posts. The second group consisted of the variables: average # of posts explicitly related from contributed posts, # of posts with author X related to

**Table 3**
Interactivity parameters significantly correlated with learning outcomes.

| Assessment tool/Interactivity measure | # of added posts | Ave.# of images attached to a post | Ave. depth of added posts | Ave.# of posts related from contributed posts | # of posts with author X related to posts with author other than X | Ave. time elapsed from the creation of a post to the creation of related post | Average depth of viewed posts | Ave.# of views by of particip-ants other than X on posts authored by X | Ave.# of votes | # of clicks on links in posts | # of clicks on files in posts |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cellular Biology: Total grade (expert's evaluation + exams' grades) | 0.36* | | 0.60** | | 0.47** | −0.50** | 0.41* | 0.48** | 0.34* | 0.38* | 0.37* |
| e-business: exam's grades | 0.22* | 0.29** | 0.29** | | | | 0.31** | | | | |
| Virtual Communities: delta between pre & post exams | | | 0.47* | | | | | | | | |
| Philosophy of education: total grade (expert's evaluation + assignments) | 0.27* | | | 0.25* | 0.27* | | | | | | |

*Correlation is significant at the 0.05 level (two-tailed test).**Correlation is significant at the 0.01 level (two-tailed test).

posts with author other than X, average response time, and average # of votes on contributed posts. Other variables were not significantly correlated consistently across all (or almost all) datasets.

## 4. Discussion

It is not obvious that interactivity in online discussions will correlate with learning outcomes. While most of the research supports the relationship between interactivity and satisfaction or engagement in online learning, substantial research raises concerns regarding the overwhelming nature of asynchronous discussions (Picciano, 2002). In Kent and Rafaeli (2016) we showed that structuring the discussion, by the students who have created the semantic network, has positive effects on the levels of interactivity. Here, we have established a statistical relation between interactivity and learning outcomes. Transitively, these may further suggest a relation between structuring of the discussion and learning outcome.

### 4.1. Limitations

The quasi-experimental setting and presence of confounding variables presented a research design challenge. Each dataset was created under different conditions, some of our courses did not use pre and post measures, and the outcome assessments were not normalized. Thus, causality inferences are curtailed. In addition, a bias hazard in judgement potentially exists, since the evaluating experts are also co-authors of this paper. The evaluation though, was done independently, and was blinded to the research questions and dependent variables. Despite all these limitations, we felt that an ecological field study has a better potential of revealing associations and behavioral patterns arising from an authentic and continuous process of social learning. Thus, we chose four courses which gave us the broadest span of discussion structuring, outcome assessments, moderation levels, academic levels and knowledge domains within blended settings. Even though our set of course designs, disciplinary coverage and students' background is limited, it is still varied enough to reflect on some interesting relations which arise clearly from the data, and to call for future research about this complex relation.

It is essential to note that our operationalization framework is based on structural and contextual properties alone. While some of our assessment tools did use content analysis with regards to interactivity (for example, when evaluating synthesis and integration of content in already existing posts), content analysis is currently out of scope of our interactivity measures in this study, and should be undertaken in the future to triangulate its findings.

### 4.2. Discussion of findings

#### 4.2.1. The virtual communities class showed significantly less correlations with its assessments tool

That might be due to the fact that the online discussion in this class was the least moderated and most emergent. The variable '# of contributed posts' was correlated positively with outcomes in all other communities. Most papers examining the relation between interactivity and learning outcome in an online discourse measure interactivity as the number of contributed posts (Picciano, 2002). This finding, while suggesting that quantity does correlate with quality (Wilkinson & Huberman, 2007), still focus on the 'shallow participation' angle of interactivity, and doesn't entail the context or relation or connectedness. As can be seen from Table 3, evaluating learning only by the number of posts contributed and viewed does not begin to describe the whole behavioral and social picture of online learning. Capturing the context and structure of those contributions and views may point us to different learning and teaching (or moderating) styles. Some such findings are detailed below.

#### 4.2.2. Depth of contributed posts actually reflects the length of paths, or threads within the discussion, a learner browsed through (and presumably viewed or read) before they decided to add their own contribution

In terms of interactivity, this metric, which showed relatively strong positive correlations with various assessment tools, might hint at two learning patterns. First, the depth of drilling down a specific subject, and second, the tendency to 'listen', that is – read (or at least scan), before a learner decides to 'speak out', that is – post. Further research should extend the variable set and add a variable measuring the time spent on each post, in order to distinguish between scan and read (Wise, Zhao, & Hausknecht, 2014).

#### 4.2.3. The metric counting '# of posts with author X related to posts with author other than X' actually measures the number of reactive postings in a community

That is how much of the contributions were actually written in response to other learners (as opposed to extending their own posts and 'reacting to themselves'). This metric is in the core of the original theoretical framework of interactivity (Rafaeli, 1988), and was found to positively correlate with the direct assessments of the discussions (and indeed, reactive behavior was 'rewarded' by expert's evaluation). This correlation remained significant regardless of whether the exam and assignment grades were added to or removed from the analysis.

*4.2.4. In general, most significant correlations were shown in interactivity patterns of content creation, rather than in patterns of content consumption*

This may suggest that, at least in the view of our chosen assessment tools, the active learning behaviors, rather than the passive, are those encouraging stronger learning outcomes in terms of knowledge assessment (Freeman et al., 2014; Prince, 2004). The only community that showed significant correlations in consumption behaviors was the Cellular Biology class. That might be due to their novice background (the only undergraduate class) or due to the nature of their discussion scene, which implicitly required them to read other learner's answers to questions in order to learn for their exam.

*4.2.5. The number of followers reflects the learner's impact on the community and showed no correlation with any assessment tool*

This might be due to the 'formal' context of the discussions, in comparison to informal discussions in social media. Other metrics for the learner's impact on their community, namely '# of posts related from a certain post', '# of views by of participants other than X on posts authored by X′ and '# of votes', also didn't show repeating correlations. Communal Constructivism is an approach to learning in which learners not only construct their own knowledge (constructivism), thanks to interacting with their environment (social constructivism), but are also actively engaged in the process of constructing knowledge for their community (Fountain, 2007). The question about the learners' impact on their learning community, and its relation with the gained knowledge of the individual learner is subject to our further research.

### *4.3. Conclusions and future work*

This study focuses on individual learner's behavior rather than on community-wide measures. Our investigation examined a range of community discussion aspects. Future research should transfer the spotlight to the entire community as a unit of analysis, in order to better understand which community's characteristics (for example, structuring, moderating mechanism, assessment tools and more) might result which learning interactions.

The analysis of significant correlations among the interactivity variables themselves suggested that interactivity can be viewed as a two-dimensional construct, as opposed to our suggested theoretical-based model. A reliable grouping of the variables is still subject to extended data collection and analysis, but a rough division might shed some light for the sake of future research. The first group of variables can be seen as representing pure participation or engagement, and perhaps this dimension was more traditionally researched until now, in the context of interactivity. The second grouping can be seen as representing the community oriented behavior, or simply the impact that the learner has on her community.

Conceptualizing interactivity is still hard (McMillan, 2006; Stromer-Galley, 2004). Its role in human learning is still unclear (Picciano, 2002). Assessing learning outcomes using analytics has not matured fully, and is thus subject to intense development. In this paper we tried to further the understanding of interactivity in the context of online learning. Here we are particularly interested in its relationship with learning outcomes. Our approach here was to study this in a field, naturalistic study. Future work might examine the same question under laboratory, controlled conditions as well.

It is our belief that discussions are a major and growing player in online learning. Generally, in a world of continuous learning, achieved by an environment of constant connectedness and accessibility to knowledge and co-learners, assessing learning processes and summative outcomes separately, might act as an obstacle to holistic and authentic learning. Clearly, interactivity is just one among many process-constructs of learning, although central to the concept of social learning. Yet we believe that 21st century's learning assessment should refer to the process of social learning, and specifically to interactivity in online discussions as one of its main building blocks. Thus, in this paper we have begun to explore the relation between the assessment of interactivity as a learning process and traditional summative learning outcomes. The fact that there is such an association should position interactivity assessment as a significant player within the learning assessment scene, not only because we can learn from interactivity patterns about learning, but also because interactivity itself is a learning goal. Showing that online collaboration is an integral part of learning is not enough, we also have to realize how to consistently measure and assess it. Here we have suggested a learning analytics approach to interactivity, which is informed and based on theoretical frameworks both from the area of learning, as well as from the area of computer mediated communication. Future work will extend from this anchor and further develop this learning analytics framework to inform more aspects of collaborative learning.

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## Appendix A. Repeated significant correlations among interactivity variables

| Interactivity measures | # of posts with author X related to posts with author other than X | # of views by participant X on posts with author other than X | # of clicks on links in posts | # of clicks on files in posts | Ave. depth of contr-ibuted posts | Aver. depth of viewed posts | Ave.# of posts related from contribu-ted posts | Ave.# of posts contrib-ute by X, related from posts contribute by other than X | Ave.# of vot-es | Ave. respon-se time |
|---|---|---|---|---|---|---|---|---|---|---|
| # of added posts | 0.81** | NS | | | 0.56** | 0.48* | | | | |
| | 0.87** | 0.49** | | | 0.58** | 0.56** | | | | |
| | 0.99** | 0.81** | | | 0.57* | 0.42* | | | | |
| | 0.98** | 0.23* | | | 0.37** | NS | | | | |
| # of posts with author X related to posts with author other than X | | | | | 0.48* | | | | | |
| | | | | | 0.35** | | | | | |
| | | | | | 0.58** | | | | | |
| | | | | | 0.34* | | | | | |
| # of views | | 0.99** | 0.72** | 0.77** | | | | | | |
| | | 0.99** | 0.50** | 0.63** | | | | | | |
| | | 0.99** | 0.75** | 0.42* | | | | | | |
| | | 0.99** | 0.52** | 0.28* | | | | | | |
| # of views by participant X on posts with author other than X | | | 0.71** | | | | | | | |
| | | | 0.42** | | | | | | | |
| | | | 0.73** | | | | | | | |
| | | | 0.30* | | | | | | | |
| # of clicks on files in posts | | | | | | 0.55** | | | | |
| | | | | | | 0.29* | | | | |
| | | | | | | NS | | | | |
| | | | | | | 0.37** | | | | |
| # of clicks on files in posts | | | | | | 0.55** | | | | |
| | | | | | | 0.29* | | | | |
| | | | | | | NS | | | | |
| | | | | | | 0.37** | | | | |
| Ave. depth of contr-ibuted posts | | | | | | 0.59** | | | | |
| | | | | | | 0.83** | | | | |
| | | | | | | 0.62** | | | | |
| | | | | | | 0.51** | | | | |
| # of views by others on own posts | | | | | | | 0.54** | 0.58** | 0.56** | |
| | | | | | | | 0.54** | 0.50** | 0.45** | |
| | | | | | | | 0.65** | 0.73** | 0.67** | |
| | | | | | | | 0.82** | 0.83** | 0.74** | |
| Ave.# of posts related from contributed posts | | | | | | | | 0.89** | NS | |
| | | | | | | | | 0.96** | 0.64** | |
| | | | | | | | | 0.93** | 0.43*. | |
| | | | | | | | | 0.97** | 0.56** | |
| Ave.# of votes on posts | | | | | | | | | | −0.44* |
| | | | | | | | | | | −0.24* |
| | | | | | | | | | | NS |
| | | | | | | | | | | −0.49** |

*Correlation is significant at the 0.05 level (two-tailed test).

**Correlation is significant at the 0.01 level (two-tailed test). Correlations are written for the courses Biology, e-business, Virtual Communities and Philosophy respectively from top to bottom in each cell.

## Appendix B. Ligilo screenshots

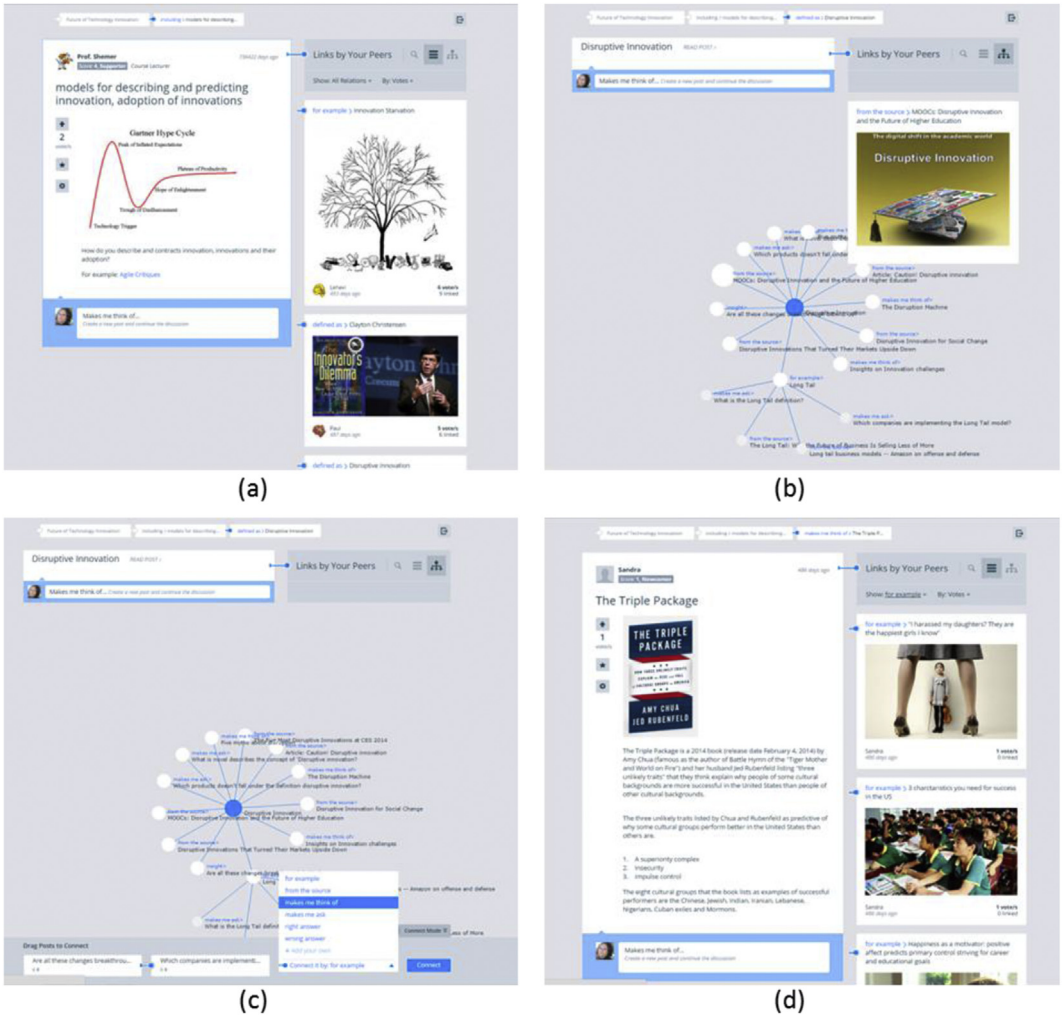


**Fig. 1.** (a) Ligilo's basic view: posts at the left side of the screen are connected with blue tagged relations to posts on the right; (b) bird's eye view of posts: the learner has requested to see the knowledge map around the post designated in blue, at the center of the screen; (c) the learner is relating two existing posts by tagging a new relation between them; (d) the learner has filtered to view only posts related with the relation 'for example' with the post at the left.

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