# Creative Collaboration and Flow: Validating the Use of Trace Data to Measure Dynamics of Creative Flow in Collaborative Design Teams

Lorraine Kisselburgh, Purdue University, lorraine@purdue.edu
Ninger Zhou, Purdue University, zhoun@purdue.edu,
Senthil Chandrasegaran, Purdue University, senthil@purdue.edu,
S. Karthik Badam, University of Maryland, sriram.karthik6@gmail.com
Niklas Elmqvist, University of Maryland, elm@umd.edu
Kylie Peppler, Indiana University, kpeppler@indiana.edu
Karthik Ramani, Purdue University, ramani@purdue.edu

**Abstract:** We use sociometric trace data to create an index of dynamic group flow in collaborative design teams. Sixteen students in four teams worked on a collaborative engineering design task, while wearing sociometric devices to collect real-time data on team interaction. Results indicate that group flow as measured by dynamic trace data is partially correlated with self-reported flow. This finding implies the potential to use trace data to provide reliable and dynamic measures of task engagement during collaborative learning.

**Keywords**: group flow, creative collaboration, sociometrics, engineering design

## Introduction

In the field of engineering design, where high demands on creativity and collaboration are prevalent, *flow* is been regarded as critical element in enhancing the quality of creative and collaborative outcomes. Csikszentmihalyi (1990) defined the experience of flow as a peak experience, or state of heightened consciousness, during high-challenge, high-skill moments when performing autotelic or intrinsically-motivated tasks (Nakamura & Csikszentmihalyi, 2002). *Group flow* describes the situation when the collaborative group is performing at maximum effectiveness, and is closely associated with higher creativity (Sawyer, 2008). Several characteristics, such as close listening, characterized by listening and responding without preconceived notions, and equal participation, shown by each participant assuming equal roles in group activity, are considered to be crucial dynamic behaviors for the emergence of group flow. In extending the concept of flow from the individual to the group, Sawyer (2008) proposed a set of ten characteristics that constitute or contribute to the state of group flow, including conditions that set the stage for good flow, as well as dynamic behavior characteristics that contribute to group flow.

Despite efforts devoted to promoting flow and collaborative outcomes in engineering design, existing measures of flow suffer from two important drawbacks. First, they are typically administered infrequently (e.g., probing after a task, or a few times during a task), and are thereby likely to miss moments of maximum or high task engagement that occur at times other than the probe. Second, they rely upon self-reported data from students and participants, which are disruptive and time-consuming to administer, sometimes biased, and potentially unreliable measures of task engagement (especially in younger audiences).

Recent developments in wearable sociometric sensor technologies (Olguín et al., 2009) enable researchers to capture data about vocal, speech, and body activity using unobtrusive methods. Wearable sociometric technologies are useful in capturing data about interaction in groups, including syntactic, prosodic, and body movement cues that are produced by speakers. These data reveal important information about the speech and conversational dynamics of collaborative learning, including how speakers coordinate or tune their speaking with one another by using various cues during conversation.

In this study we test and validate the use of trace data from wearable technologies to measure group flow collected continuously and unobtrusively from wearable sociometric badges that roughly correlate with five of the ten characteristics modeled by Sawyer for group flow. We create an index of group flow, and then test the validity of this index by correlating the dynamically generated measures of task engagement with self-reported (individual) flow surveys. Then we map these measures over time to provide a visualization of flow dynamics over the course of a collaborative design learning session, to indicate the process of flow during collaborative learning tasks. In doing so, we demonstrate the use of novel wearable technologies to measure group flow as a dynamic process of engagement with a task and with collaborative peers in design processes.

## Methods

Sixteen students ranging in age from 21-37 years (M=25.25, SD=3.92) were recruited from a graduate mechanical engineering course on global design and randomly assigned to four teams. Each team was given one toy and instructed to redesign the toy, using sketching to collaboratively design new ideas (Taborda et al., 2012). Teams sketched their ideas using either paper or digital sketching tablets. The *skWiki* sketching system includes 10-inch tablets interfaced with a web-based sketching application that allows users to sketch with a capacitive-touch styli and synchronize design sketches across devices (Zhao et al., 2014).

To collect information about *collaboration dynamics,* we used wearable sociometric sensors to capture real-time data on a series of non-linguistic social signals. We recorded seven measures: participants' speech activity (*speaking, listening, overlap*, *participation*) and conversational *turn-taking* (by and after each speaker) and *successful interrupts*. Data were captured in 1-second intervals, and analyzed in 10-second speaking intervals. The item for *listening* exhibited a negative average covariance among the items and was removed from the scale, yielding a 6-item index ($\alpha = 0.88$).

To assess *creative flow,* we created an 8-item scale with questions probing cognitive engagement (activity was exciting, challenging, and required concentration), skill (participants were skilled or successful at task), and affective engagement (participants enjoyed the task, found it important, and were satisfied with performance) (Arici, 2008). Items were measured on a 5-point Likert scale, and aggregated ($\alpha = 0.91$).

## Findings

The partial correlation between the Group Flow Index and Individual flow index was not significant. We then assessed correlations between individual items of both indices, and found significant correlations between dynamically measured flow and self-reported indications of whether the activity was considered challenging.

## Conclusions and implications

We use continuously and unobtrusively collected trace data to create an index of group flow based upon 5 of the 10 characteristics of Sawyer's (2008) model of group flow: communication, close listening, equal participation, blending egos, and moving it forward. The Group Flow Index allows us to dynamically measure two important indicators of the process of collaborative learning: a) the *communicative engagement* and participation of members (Sawyer's communication, close listening, and equal participation) and the characteristics of *collaborative elaboration* (represented by Sawyer as blending egos and moving it forward), in which the conversation of members becomes more synchronized, overlapping one another, and participants begin to successfully build upon and elaborate the ideas and knowledge that are contributed by others on the team. In future work, we will continue validating the Group Flow Index in a diverse set of design tasks, and correlate this index with specific events during collaboration, in order to analyze the relationship of group flow to collaborative events and outcomes. This work includes the development of predictive models relating speech, conversational, and body signals to a variety of collaborative learning processes and outcomes.

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