

# The CUBE: A Tangible for Embodied Learning, Balanced Engagement, and Classroom Orchestration

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**Abstract:** This classic interactive demo paper presents the CUBE, a recently developed Arduino-based tangible that can be used in collocated collaboration for a multitude of research and teaching purposes. The CUBE was designed with three instructional needs in mind: (a) offer opportunities for embodied learning to the students, (b) monitor and enhance balanced engagement in a group, and (c) allow the teacher to monitor and orchestrate a classroom.

## Improving collaboration in collocated settings

The CUBE presented in this paper focuses on monitoring, analyzing, and supporting collocated collaboration by offering opportunities for embodied learning and providing immediate and summative individual/group feedback on the collaboration activity and on each person's contribution, to motivate students towards balanced engagement. Via Wi-Fi connectivity and a dashboard, the CUBE can inform the teacher on the state and progress of collaborating groups, allowing real-time classroom orchestration.

Embodied learning has recently been established as an important field (Lindgren & Johnson-Glenbegr, 2013). Incorporating movement of the entire body or embodied phenomena as gestures and hand movements, the embodied learning paradigm suggests that body and environment are linked to cognitive processes (Shapiro, 2010). Tangible interfaces, often with cubic shapes, have been used in embodied learning in several ways (e.g., Sapounidis, Demetriadis, Papadopoulos, & Stamovlasis, 2018; Terrenghi, Kranz, Holleis, & Schmidt, 2006), for example for making interface elements directly available to all participants or to enhance group self-organization around the manipulation of a single tangible.

Balanced engagement in collocated collaboration settings is crucial as lower participation is often linked to poor academic performance (Bachour, Kaplan & Dillenbourg, 2010). By combining microphones and visual representations of participants' speaking time, the Reflect table (ibid.) provided immediate feedback to discussants. Similarly, the Conversation Clock (Bergstrom & Karahalios, 2007) provided visualizations of audio patterns in a spiral timeline, offering a representation of how much and when each discussant talked during collaboration.

Finally, tangibles such as the Lantern (Alavi & Dillenbourg, 2012) and FireFlies2 (Verweij, Bakker, & Eggen, 2017) have been used for classroom orchestration, focusing on enhancing communication between students, teachers, and groups.

These characteristics along with additional ones can be found in the CUBE tangible presented next.

## CUBE description

This section presents the basic technical characteristics of the CUBE, along with its main functionalities. Since the artifact was developed recently, there is no empirical evidence at this point to validate which combination of the offered affordances would be more effective/efficient in a learning scenario. A series of research activities involving the CUBE will commence in Spring 2019.

## Technical characteristics

Figure 1 presents the first, fully functional, version of the CUBE. The CUBE is an Arduino-based system that includes screens, monitors, microphones, and a set of sensors and modules. It has a cubic shape, with 11 cm long edges and weighs a bit less than 1 kg (including the batteries). Each side has a square 2.8" in. TFT screen (the actual screen is bigger, but covered for symmetry). In addition, the screens offer touch capabilities, but this characteristic has not been used in this prototype. The model (i.e., skeleton and sides) was produced in a standard FDM 3D printer, using PLA material. Improved models printed in a high-end SLS printer have also been produced, but not used yet.



Figure 1. The CUBE prototype.

## Functionalities

The list below describes the functionalities of the current prototype, while additional functionalities could be added in near future, either by extending or by combining the current ones. Arguably, it is not expected that all the affordances of the CUBE will be necessary for the envisioned learning scenarios. For example, rotation detection might not be important in situations where the CUBE is used as ambient technology.

### Display information

The cubic shape of the artifact and the sitting arrangement of a group of students around a table create two distinctive spaces (Figure 2). Each side screen is visible by only one student (private space), while the top screen is visible by all, including the teacher (public space). This split between private and public could be useful in a learning design. For example, feedback can be directed to a specific student or to the whole group. In addition, the side screens can be used for detailed information, while the top one could be used to denote the state of the group. It should be mentioned that information targeted to all students should be presented in the side screens, since the top screen is flat and (text) orientation will be an issue for three of the students. The analysis of the (visible) screen is 320x320 pixels, which means that it is suitable for short messages and graphs. Longer blocks of information could be divided into several screen pages (e.g., 1/2, 2/2, etc.). Finally, due to the processing power of the Arduino, the screens are updated sequentially, while the frame rate is very low. This means that the screens are not suitable for playing videos, while there is a small lag between screens (30-300 ms, depending on the size of information presented). However, this lag does not pose an issue, since students can only see the screen in front of them (and the top) and such lag is not critical in learning scenarios.

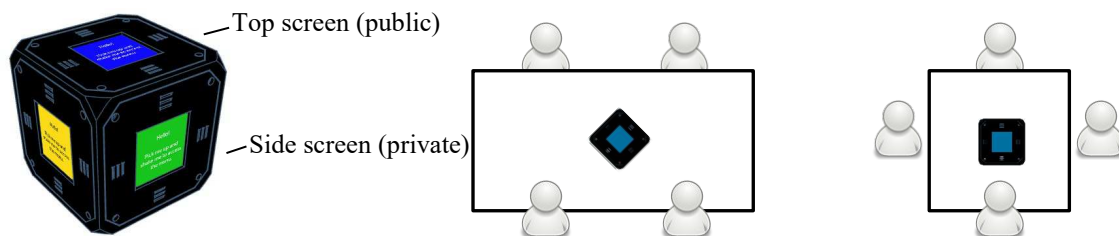


Figure 2. Sitting arrangement and private/public spaces.

### Rotation detection

The CUBE can detect rotation on the x- and y-axis. Rotation on the z-axis is considered turning and cannot be detected accurately by the sensors used. At any given moment, the CUBE can identify the side that is on top and as such, rotation can be used as a selection action. For example, the screens may show different options, asking students to make a choice. The students could rotate the CUBE to have their selection on the top. As it is expected that the students may move around the artifact or hold them in their hands during a selection task, the final option is confirmed when the CUBE detects that it has stopped moving for three seconds. Then, the side that is on top is considered the students' choice.

### Shaking detection

Because of the physical characteristics of the CUBE, shaking requires both hands. As such, shaking is a more powerful move than rotation and can be used during significant moments of the activity. For example, shaking can be used to tell the CUBE to wake up (and start an activity) or to interrupt the ongoing activity. Similarly, it can be used as a celebratory gesture denoting the successful completion of a task, a strong disagreement between group members, or the need for teacher's intervention.

### Vibration

The CUBE can vibrate to provide haptic feedback to the students. This functionality can be used to confirm a selection, draw the attention of the person holding it, or accompany audio/visual feedback. The intensity and duration of vibration can be modified according to the learning scenario needs to denote different types of haptic feedback. Vibration, along with rotation and shaking can be used in embodied learning settings.

### Audio play

A small speaker inside the CUBE is capable of playing tone sounds and midi files loud enough for a surrounding group of people to hear clearly. Playing voice files or sounds of higher quality would require a larger and heavier speaker, along with the need for audio controls (i.e., pause, stop, rewind, etc.). As such, audio is used primarily as auditory feedback to confirm an action, or draw attention.

### Audio recording

The system can record the discussion that occurs around it and saves it in an SD card. The recording could cover the whole activity or start/stop according to an event triggered by the students (e.g., rotation), the teacher (e.g., remote control through a dashboard), the system itself (e.g., pre-defined script conditions). The recording can be a single file, or several, and can be used after the activity for post hoc analysis of the interaction or become available to the students as feedback. Functionalities such as rotation and shaking can be used in parallel to the audio recording to allow the students to self-annotate. For example, during an argumentation task, students can rotate the CUBE in different directions to mark when a fact or a warrant has been mentioned. Self-annotation information could later be used along with the audio file of the discussion.

### Audio source monitoring

Each side of the CUBE is equipped with a microphone. By comparing the sound received by each microphone, the system can infer in which side a speaker is sitting. The system cannot understand what a student is saying, since the analysis and monitoring of the audio source are based only the volume of the sound. This function is similar to the two tables cited earlier (Bachour, Kaplan, & Dillenbourg, 2010; Bergstrom & Karahalios, 2007), with an added benefit that the CUBE is portable and can be used in more settings. The ability to monitor the audio source can be used to support balance engagement during a discussion.

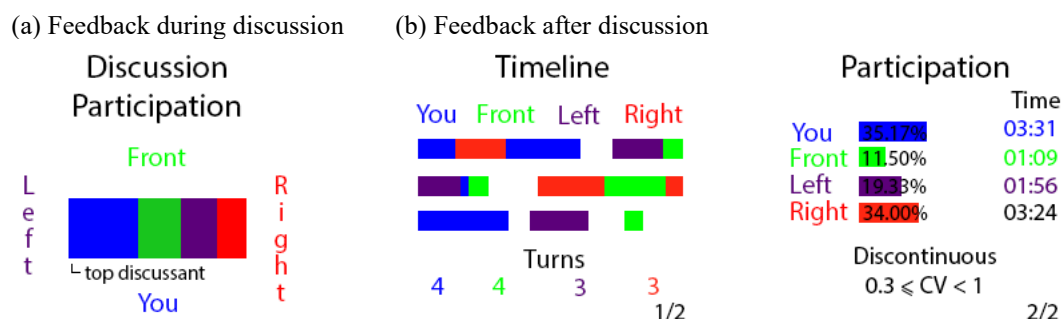


Figure 3. Feedback that appears in the side screens during and after peer discussion.

The system can provide both immediate and summative feedback, focusing on the length of a person's talk and not on its content. Figure 3 shows some of the feedback metrics the prototype can offer during and after the discussion. So, during the discussion (Figure 3, a), the students can see how much each student talked (%). Each color represents a different student, with the top screen colored in the color of the person that spoke the most. This graph is updated every five seconds. After the discussion (Figure 3, b), additional metadata on students' engagement are presented. First, the timeline shows the order and length of each person's speaking time, while gaps in the timeline denote periods of silence. In the same screen, the students can also see how many times each person talked. In the second post-discussion feedback screen, the students can see aggregated feedback on their participation in terms of actual time and percentage. The Balanced/Discontinuous/Unbalanced indication is based on the coefficient of variation (Lovie, 2005) for the group and it is an example of additional metrics that could be used as feedback.

After a CUBE rotation, the audio source monitoring will start a new session, unless provisions are taken in the learning scenario so that the rotated CUBE can link previous and current sitting arrangements.

### Connectivity

As mentioned earlier, the CUBE is equipped with a Wi-Fi module allowing it to communicate with the server, and through that with other CUBEs and with the teacher's dashboard, thus supporting classroom orchestration. Because of the technical limitations of the Arduino, the wireless connection is established periodically every few seconds and data from and to the CUBE are transmitted in short bursts. This is the reason why the CUBE cannot transmit the audio of the discussion in real-time to the server, acting also as a fly-on-the-wall for the teacher. However, this limitation is not crucial for the envisioned learning scenarios and the few seconds (<2") delay in updating the teacher's dashboard is not expected to raise significant issues for the participants.

### Script editor

During the testing period of the CUBE, collaboration scripts are coded directly in the Arduino IDE. However, an online script editor is also under development to allow non-technical teacher/researchers to design their own learning scenarios with the CUBE.

### Activity monitor

Currently, monitoring a test activity with the CUBE occurs by observing the server's database. The activity monitor, which is also under development, refers to the dashboard the teacher/researcher will be able to use in the classroom during the runtime of a CUBE activity. Apart from monitoring, the dashboard will allow the teacher to intervene. For example, the teacher may choose to pause an activity in one CUBE or send a message to the screen of the least engaged student in another CUBE.

## **Conclusions**

The functionalities and robustness of the CUBE have to be evaluated in research activities. Its design is based on three main pillars: embodied learning, balanced engagement, and classroom orchestration. However, additional uses and theoretical underpinnings may be identified by the reader. This paper serves as a first introduction of the CUBE to the CSCL audience, in search of constructive feedback and future collaborations.

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