IMPROVING SOCIAL AND CONCEPTUAL CONNECTIONS DURING REMOTE STATISTICS CLASSES

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Remote instruction lacks shared physical space and physical social presence. This can make it difficult to incorporate embodied learning techniques, which have been shown to strengthen learning outcomes, into our lessons, and can make it difficult to feel socially connected to peers. We propose that incorporating embodiment into a synchronous lesson by engaging students in a physical task using a shared set of materials can help strengthen social and conceptual connections. We outline a high school statistics lesson on measurement error that involves building a popsicle stick catapult and measuring gummy bear launch distances. We distributed a set of all the necessary materials to the students at the start of the course. The activity simulated a sense of shared space and brought about multimodal learning and shared physical experiences. We witnessed enhanced joint attention, the development of physically grounded understanding, and increased engagement.

INTRODUCTION

Globally, millions of students have been affected by school closures because of the COVID-19 pandemic (UNESCO, 2021), thrusting many of them into remote instruction. Although there are advantages to remote classrooms, one major drawback is that they lack shared physical space and physical social presence, and, as a result, it can be more challenging to incorporate lesson activities that activate physical embodiment and multiple learning modalities. Embodied learning techniques, such as those that involve physical movement, manipulation of concrete materials, and the use of gesture, have been shown to enrich learning in a wide range of domains, including complex topics such as math and science (Alibali & Nathan, 2012; Glenberg, 2008; Macedonia, 2019; Stolz, 2015; Weisberg & Newcombe, 2017).

For instance, in the cognitive and learning sciences, there is a rich literature documenting the correspondence between the gestures made by students and teachers during math lessons and the development of students' understanding of mathematical concepts (Goldin-Meadow et al., 2009; Zhang et al., 2021). Studies have also shown how other types of physical movement (Thomas & Lleras, 2009) or manipulation of physical materials (Carbonneau et al., 2013) can improve learning and transfer by driving insights during problem-solving and concretely grounding comprehension. For example, physics students who held a spinning bike wheel in a demonstration of angular momentum improved their understanding of the concept more so than students who simply observed the demonstration (Kontra et al., 2012). And yet, the common routine during remote learning is typically limited to passive, screen-based activities such as reading text and watching videos, and interactions mainly revolve around typing and mouse-clicking.

Not only can the lack of shared physical space in a remote classroom impose challenges on making use of embodied learning techniques, but the inherent lack of physical social presence can also make it difficult for students to feel connected to their peers and teachers. Thus, as a consequence of the disembodied remote learning environment, there are two potential connections valuable to learning that may be weakened: social connections (as a result of the lack of physical social presence), and conceptual connections (as a result of the limitations imposed on the use of embodied learning techniques).

Social Disconnection

Social disconnection is the form of disconnection that is typically most salient for instructors, as it is typically impossible to ignore when students become less engaged, or when they are feeling socially isolated from their peers. While many teachers will likely agree with this anecdotally, there is recent literature documenting how the remote classroom is linked to significant decreases in engagement and

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increased burnout (Chen et al., 2020). In particular, students who opt to remain muted or with their video cameras off during synchronous class time, do not get the benefit of social and physical cues to help them feel connected. This is quite concerning since feeling socially connected can support collaborative learning, which is considered a valuable component in student success (Panadero & Järvelä, 2015; Rannastu-Avalos & Siiman, 2020). For instance, when students feel connected to their peers and teachers, there are benefits to their mental health and to their academic achievement (MacLeod et al., 2019), and peer-to-peer learning has been shown to improve learning, increase students' confidence, and reduce anxieties in the classroom (Fagen et al., 2002; Zhang et al., 2017).

Conceptual Disconnection

Conceptual disconnection is more subtle but still consequential: in the remote learning environment, there are fewer opportunities to strengthen conceptual connections through physically grounded, multimodal learning experiences. As summarized by the Practicing Connections hypothesis (Fries et al, 2020), making connections across concepts is important for robust, generalizable learning, and is something that can be achieved through varied and deliberate practice, including practice that varies across modalities. For example, learning statistics requires students to make many connections across various representations of mathematical concepts, and contexts surrounding data. Instructors in a face-to-face classroom can use embodied techniques, physical space, and social interactions to expose students to multiple representations experienced via multiple modalities (e.g., rolling dice or flipping coins, drawing graphs, sharing manipulatives, physically demonstrating phenomena), and deliberately connect them together. These connections help ground students' understanding of abstract material across concrete representations and experiences. Without that physical space to support making these more widely varied connections, it can be much more challenging for instructors to develop an effective statistics lesson that harnesses the full power of social and embodied learning.

How can we bring some embodiment back to the remote learning experience?

We propose that bringing some embodiment back into the remote statistics classroom will help alleviate some of the social and conceptual disconnect. More specifically, we theorize that a lesson that involves *a group task using shared manipulatives during synchronous instructional time* will help bring about the desired connections. In the remainder of this paper, we will describe the lesson that we designed applying principles of embodied learning, and discuss observations from our implementation.

A PHYSICAL GROUP TASK USING SHARED MANIPULATIVES: THE CATAPULT LESSON

The lesson was implemented with fully remote high school students in a newly developed Statistics and Data Science course (CourseKata; Son and Stigler, 2021) in the San Mateo Unified High School District. The main learning objective for this lesson was to help students understand *measurement error*, including how to identify sources of it, and how to distinguish it from *mistakes*, but the lesson also covered topics such as *experimental design*, and *explaining variation*.

For the core activity of the lesson, students built popsicle stick catapults (see Figure 1) to launch gummy bears and measured the distance they traveled. Students were tasked with answering the question: What affects how far the gummy bear launches? At the beginning of the school year, we supplied each student with a packet of all the necessary physical materials (popsicle sticks, rubber bands, gummy bears, measuring tape) that they picked up from their campus.

During synchronous instruction time, students worked in groups (in Zoom breakout rooms) to build their catapults, launch the gummy bears, and take measurements. They also spent some whole-class time both experimenting and discussing the best way to uniformly execute the launches and measure the launch distances (e.g., using different tools such as rigid rulers or measuring tapes). Additionally, they experimented with variations in catapult design (by adding more "lift" sticks, as indicated in Figure 1). They recorded their data, then cleaned and analyzed it using R and Jupyter notebooks (open-source programming tools commonly used by data scientists) in the subsequent lesson. All lesson materials can be found at this link: http://bit.ly/catapult-lesson-materials.

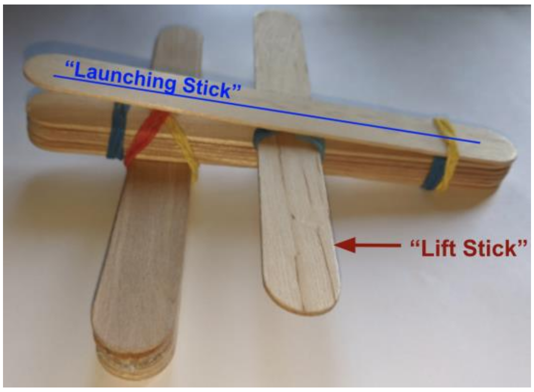

Figure 1. Catapult for launching gummy bears. Arrow indicates where "lift sticks" can be added or removed to adjust the height of the lift for the launching stick.

WHAT DID EMBODIMENT BRING TO THE LESSON?

By doing this physical group task, and with each student having their own set of materials, there were three noticeable features of embodiment brought into this remote lesson. First, engaging simultaneously as a group in the same physical task, simulated a sense of shared space. Second, students were able to have shared embodied experiences by observing and replicating the actions of others (e.g., "I saw the way you launch a bear and tried the same thing and observed a similar effect"). Third, the lesson recruited multiple modalities in the learning process because the students could explore the ideas through manual manipulation and other direct experiences and observations. These three features are not limited to the building of a catapult or measuring gummy bear launches, but can be implemented in a variety of other group activities with shared physical manipulatives, conducted during a synchronous remote lesson.

According to our reading of the embodied cognition and education literature, there may be three types of social and conceptual connections that were enhanced during this lesson: joint attention, grounded understanding, and engagement (see Figure 2). Next, we will describe these in more detail, and will also discuss relevant class observations during lesson implementation.

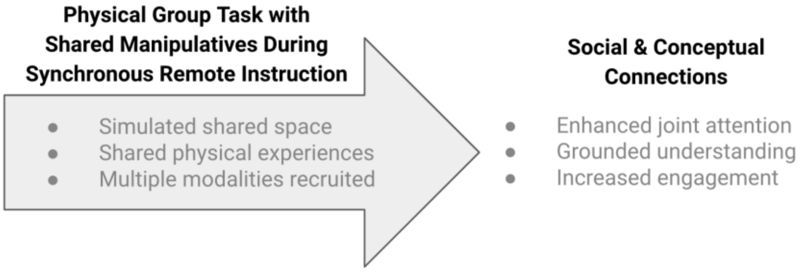

Figure 2. Features of the physical task during remote learning that lead to enhanced connections (both social and conceptual). Note although we posit three features of the physical task (inside the arrow) and three enhanced connections, we do not mean to imply that each feature and connection is aligned one to one. The features *together* may lead to the enhanced connections.

Joint Attention

Classically, joint attention has been defined as looking at (a behavioral proxy for *attending to*) an object that someone else is looking at, and is often studied in relation to infant language learning or imitation (Carpenter et al., 1998; Moore et al., 2014). Much of this literature suggests that more joint attention is associated with better learning. Note that joint attention is an example of both a social *and* a conceptual connection -- there is a social component because joint attention occurs between people but also a conceptual one because the social connection is implicated in the processes of learning. We extend the basic notion of joint attention to education by defining it as when students attend to the actions of others and use that information during learning.

During implementation, students were more inclined to have their video on during the building, launching, and measuring activity. Students' eye gaze suggested that they were closely watching how others launched and measured in order to discuss various outcomes. As students discussed particular ideas about statistics (e.g., measurement error, where to measure from), they gestured to particular places on the objects in front of them and angled their cameras to show their group mates what they were looking at and talking about.

Grounded Understanding

Even though the lesson involved concrete activities such as building the catapult, launching candy, and measuring distances, the goal was to explore abstract concepts such as measurement error versus mistakes and engage in operationalizing ideas such as the "best" way to measure distance. In many domains of science and mathematics, the goal of learning is understanding at an abstract and structural level rather than a concrete and superficial level. This abstract learning underlies our capacity to transfer our learning across superficially different situations. We would like for our students to learn about measurement error with catapults and candy launches but recognize that same principle in a different context (e.g., measurement error when it comes to estimating COVID-19 cases).

In the context of our catapult lesson, one benefit of the simultaneous physical activity was that these abstract ideas were grounded in concrete, observable, repeatable, physical experiences. Research in cognitive sciences suggests that examples of concepts grounded in rich physical and social interactions facilitate abstract reasoning (e.g., Wason & Shapiro, 1971; Nisbett & Ross, 1980; Reyes, Thompson, & Bower, 1980). Throughout the lesson, students were able to engage in manual manipulation and multimodal learning as they talked about measurement error; thus, a highly abstract concept was linked to concrete decisions and experiences. There were observable consequences of deciding whether to measure from one point or another, because students were able to try different ideas out and observe the effects (e.g., different methods of launching the gummy bears). This physical tinkering experience may provide fodder for future mental simulations which can serve as the basis for increased conceptual flexibility and generalizable problem-solving (Goldstone et al., 2010; Goldstone et al., 2017).

We observed this during implementation, as students experimented with several different methods of launching without being prompted by the instructor, and organically raised a wide array of questions to fellow group members (e.g., How long do we hold down the launching stick before releasing? Which way do we orient the gummy bear? At which end of the catapult do we begin our measurements? Which part of the bear do we measure? Do we measure where it lands or where it first bounces? Do we measure straight or diagonally if it launches sideways?).

Engagement

Finally, embodied activities in an academic context may also help provide a common starting place for learning, such that variation in students' prior knowledge plays less of a role. During the catapult lesson, because there was a physical and more exploratory means of developing knowledge, a student who might know less about the definition of specific statistical terms can still share with confidence about a technique they discovered while trying to launch gummy bears. Students who might have otherwise felt academically less competent compared to their peers could feel as though their contributions were valid and interesting enough to share. Even though there are always a few students who are willing to offer responses to the teacher, in this lesson, there was a noticeable increase in the variety of students who offered suggestions and responses. We also witnessed an increase in peer-to-peer interactions, in which students made reference to what their peers had said. Such interactions have been linked to increases in critical thinking (American Association for the Advancement of Science, 1993; Council of Chief State School Officers, 2010; National Research Council, 1996).

The increased engagement was particularly notable during the breakout room sessions where students were more actively engaged in discussions with their groups (in some cases even laughing and seeming to have fun) while working with their catapults. This is in comparison to previous classes in which students often kept their cameras off and were minimally engaged in breakout rooms. There were more organic, casual conversations, such as comments on unusual things that happened (e.g., "The gummy bear landed on its feet!"; "Mine went crazy far!"; "Did you eat your gummy bears?") rather than terse moments of conversation strictly aimed at completing the task the instructor had set out for them. Although it should be noted that even with noticeable increases in engagement, there were still a few students who were not engaged, and kept their cameras off, or stayed muted.

LIMITATIONS

While we observed many benefits from employing this method, there are also a few limitations to keep in mind, the first being that this was not a controlled experiment. We did compare this lesson to previous lessons but not in a systematic way. However, three different teachers in the same school district implemented this lesson and they provided similar anecdotal reports. We have plans to more rigorously study these phenomena to supplement our observations.

Another consideration is that simultaneous physical activities (e.g., passing out physical materials, building the catapults) may take up valuable time and resources. This lesson required more logistics than other lessons so it is also important to examine whether the benefits outweigh the costs. Any lesson that builds up students' social and cognitive connections requires time -- and time is a scarce and precious resource in the remote learning landscape. For example, it took extra class time to have students build the catapults together. One alternative is to ask students to build the catapults before class, but would reduce the time spent fostering peer connections. The lesson also takes more time than a direct instruction lecture because student-guided discussion and exploration generally takes more time.

CONCLUSION

For many of us instructors, we were unexpectedly 'catapulted' into this remote learning environment, forced to rapidly adapt, and along the way we experimented with ways to make remote learning "work." Many of us long for a return to in-person instruction, however remote instruction, in some form, will be more prevalent and accepted post-pandemic; thus, we should look to research in the learning sciences to help improve its effectiveness.

Although there are always differences between remote and face-to-face instruction, identifying the affordances that are beneficial to students and mimicking them in a way that makes sense in that modality can be useful. As we attempted to include elements of embodied experiences in our remote lessons, we were able to more clearly articulate why those features work in a face-to-face setting. Our approach is a modest, initial effort but shows the promise of drawing upon the combined creativity of teachers, designers, and researchers to make remote instruction more effective and engaging.

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