Board 163: Examining teachers' enactment of engineering-focused design principles using action, speech, and gestures in elementary settings (Work in Progress)

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Abstract
This work-in-progress presents a qualitative analysis of video recordings of engineering education in elementary classrooms. The study aims to examine how teachers enact the program's design principles in action, speech, and hand gestures within an elementary education program developed in the USA. The videos were transcribed verbatim, with the transcriptions serving as the basis for detailed coding and categorization of the data. Recurring themes related to the program's design principles utilized within the videos were identified. Teachers' gestures were coded into categories of representational, deictic, or beat gestures. The preliminary findings suggest that teachers use a range of verbal and nonverbal strategies to engage students in engineering concepts. Teachers' speeches often focus on setting learning in a real-world context, scaffolding student work, and demonstrating inclusivity. Teachers' actions, such as writing, drawing, and holding up objects, provide visual support for their instruction. We also found that teachers used different hand gestures during the lessons. By employing some of these gestures, teachers help students establish connections between physical actions and engineering principles. The preliminary findings offer insights into using speech, actions, and gestures to support engineering instruction. Future steps for this work-in-progress will be to code the remaining videos of elementary classrooms.

Keywords: Precollege engineering education, psychology, socio-emotional learning, gestures, professional development

Introduction

In recent years, integrating engineering principles into elementary education has garnered significant attention, resulting in developing engineering education programs for elementary classrooms (Cunningham & Lachapelle, 2016) and even for early childhood education (Davis, Cunningham, & Lachapelle, 2017). Echoing the current advocacy for engineering integration in K-12 education, teachers' interdisciplinary-related skills have become increasingly imperative (Radloff et al., 2023). This work-in-progress research undertakes a qualitative analysis of engineering education within elementary classrooms in the United States of America (USA), focusing on the enactment of specific categories of design principles by teachers through actions, speech, and gestures. By examining how teachers implement these design principles, this research aims to shed light on engineering education practices in elementary classrooms.

Engineering education in elementary classrooms

The integration of engineering in K-12 education has gained recognition among educators as a way to enhance students' understanding of science concepts and foster critical thinking and problem-solving skills (Cunningham & Lachapelle, 2016). Engineering education for elementary students involves authentic engineering problems that have been adapted for young children, and years of evaluative research on the impact of an elementary engineering program has found not only better learning in children but also increased engagement in students from various profiles, including those from disadvantaged backgrounds and students with disabilities (Cunningham et al., 2020; Lachapelle et al., 2011; Robinson et al., 2017; Weis & Banilower, 2010). Engineering education programs for elementary classrooms contain design components such as diverse role models (i.e., inclusion), open-ended challenges, embracing failure, and collaboration (Cunningham & Lachapelle, 2016). These are socio-emotional components of Transformative Competencies endorsed by the Organization for Economic Cooperation and Development (OECD) for developing citizens in the new global economy (OECD, 2019). Considering the recognized benefits of engineering education in elementary classrooms, addressing the potential shortcomings of teachers' limited grasp of engineering knowledge's nature, scope, or validity is essential (Radloff et al., 2023). Thus, we aimed to explore how teachers enacted the principles of an engineering education program in their own classrooms. By understanding actual practices, we develop a starting point to determine how certain pedagogical approaches or instructional strategies influence student engagement, understanding, and achievement (Hammack et al., 2024; Yeter, 2021).

Teachers' enactment of engineering-focused design principles

Teachers do not rely solely on speech during classroom instruction. They also use actions, such as writing or drawing, and *gestures*. Here, we will use a definition of *gestures* widely adopted within the educational and developmental psychology literature: movements of the hands/arms that sometimes co-occur with speech but could also occur alone, revealing the mental representations of the speaker (Mcneill, 1992). Gestures not only reflect the thoughts of the speaker (Hostetter & Alibali, 2008) but also have an impact on the listener's comprehension of the speaker's message (Hostetter, 2011). In STEM education, instructors' gestures have been found to help students learn in science and math (Alibali & Nathan, 2007, 2012; Hostetter, 2011).

What kinds of gestures might a teacher produce in elementary classrooms for engineering education? This question has yet to be explored in the literature due to limited research on engineering design instruction in elementary programs (Moonga et al., 2023). Drawing from the findings of past research in K-12 math (Alibali & Nathan, 2007, 2012; Hostetter, 2011), we expect teachers' gestures to play an important role in the elementary engineering classroom. There are four categories of gestures: iconic, metaphoric, beat, and deictic (i.e., pointing) (Mcneill, 1992). These gestures could play a role in elementary education by supporting the communication of engineering design principles. Iconic gestures represent objects or actions through physical movements, which could be useful in explaining engineering concepts visually. Metaphoric gestures use hand movements to convey abstract ideas or relationships, allowing students to make connections between abstract concepts and real-world examples. Beat gestures accompany speech rhythmically and could help emphasize key points or concepts during discussions.

Finally, deictic gestures, such as pointing, could be used to direct attention to specific objects or locations, directing students to design elements within the program.
To investigate how elementary teachers enact engineering-focused design principles, we examined their speech, actions, and gestures in the classroom. We expected to find the use of hand gestures in the classroom to augment engineering design principles in addition to the use of speech and action (i.e., writing, drawing, opening books for display, etc.).

Method

Data source

The data source for this study consists of classroom videos obtained from an elementary engineering education program's YouTube channel. The videos are in the public domain and are recordings of engineering education in elementary classrooms across the USA. In each video, a teacher was shown delivering parts of an engineering lesson to a class of students. The videos contained direct instruction by the teacher, moments of interaction between the teacher and the students, and moments of student activity. The teacher in these videos had received prior training in delivering the program. The materials used in class consisted of a storybook narrating the background of a real-world problem that students had to work together in groups to solve using commonly available objects. The lesson centered on the hands-on construction of a solution using a 5-step framework of "questioning, planning, implementing, concluding, and reporting" adapted for younger children from the engineering design process (Cunningham & Lachapelle, 2016).

In total, videos on 12 different lesson topics were available for analysis. For each of the 12 topics, there were videos from two different classrooms. Each classroom featured a different teacher. For this work in progress, we selected three lesson topics for coding and analysis. The topics were sound waves, circuits, and air resistance. In total, 24 videos were coded (i.e., 3 lesson topics; each lesson topic had four separate videos showing different sessions of the same lesson, with two different classrooms per lesson topic). Thus, we coded the speech, action, and gestures of six individual teachers. The selected lesson topics were conducted in diverse classrooms from public schools across the USA (Midwest, New England, and Southeast).

We initially selected these three lesson topics because they were the topics most similar to the science syllabus in Singapore classrooms. The wider application of this work, which is outside the scope of this paper, is to potentially translate aspects of elementary engineering education into the Singapore classroom.

Data coding and analysis

The videos were transcribed verbatim, with the transcriptions serving as the basis for detailed coding and categorization of the data. The teachers' hand movements were identified for the presence of gestures, and these gestures were coded into categories of representational, metaphorical, deictic, or beat gestures (Mcneill, 1992). We also coded moments in the video when the teacher did an action, such as (but not limited to) writing, drawing, or holding up an item.

Once the coding process was completed, the coded data were analyzed to match moments of the teacher's speech, action, and gesture to each of the three categories of design principles of the program. These categories were (1) setting learning in a real-world context, (2) scaffolding student work, and (3) demonstrating inclusivity, which is a category originating from the literature on an inclusive engineering curriculum for elementary school students (Cunningham & Lachapelle, 2016).

Preliminary results

Speech and action

Based on the preliminary findings, the teachers' speech addressed the engineering education design principles of setting learning in the real world, presenting authentic challenges, scaffolding, and inclusivity (Cunningham & Lachapelle, 2016) . Across all the lesson topics, every teacher spent at least 10 minutes of the entire lesson talking about storybook elements to provide real-world context. Furthermore, they also related the lesson topic to the immediate environment that the students were in. For example, during the lesson on Sound Waves, one of the teachers told her students, "*I want you to write down different sounds of things that you hear throughout the day when you are here at school*."

In all lessons, we found evidence of scaffolding in the teachers' speeches. This quote from a teacher on sound waves (i.e., building a spectrogram) demonstrates scaffolding across sessions:

> *"Today… We are going to be listening to real bird calls. Yesterday, we heard ones that were just modeled bird calls… Today we're actually going to be hearing real bird calls, and you're going to be doing the same sort of thing that you did yesterday but in a little bit different way. Listening to the real bird calls might be a little bit more of a challenge; who's up for a challenge?"*

Teachers also talked about the diversity of individuals involved in solving engineering problems. In the lesson on circuits, the protagonist of the story problem was a girl named Emily who lived in Australia. An example of how the teacher engaged students with this point on diversity can be seen in this quote:

> "*Let's talk about where she's from. First of all, can anyone point to me where Australia is... I want you to label where Australia is, and I also want you to label where the United States is… and maybe you can find the country that your family's from; for example, if your family's from Morocco, try to find Morocco on the map*."

We found that teachers produced actions in relation to the program's materials. For example, their actions involved mostly holding up lesson materials to show the class and drawing diagrams related to the lesson topic, which can be interpreted as scaffolding.

Gesture

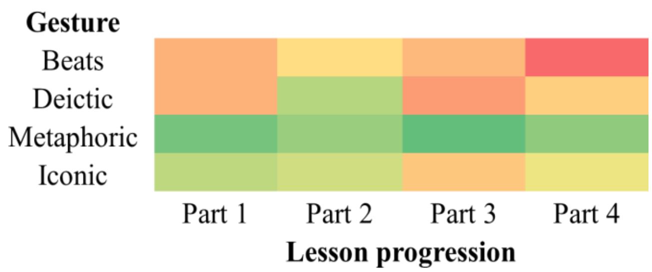
In the coded videos, we identified four distinct types of gestures: beat, metaphoric, iconic, and deictic gestures. Table 1 below presents an example of each type of gesture used. We observed that iconic gestures were used to connect physical movements with specific engineering concepts, which could deepen students' understanding and aid knowledge retention. Teachers used metaphoric gestures to express drag force, texture, high/low pitch and volume, and closed circuits. These gestures provide physical analogies to abstract concepts, which could enable students to grasp complex or intangible ideas more easily. Deictic gestures are used to point, indicate, or direct attention. Teachers used deictic gestures to point at students, the radius of a parachute, the board, a student's notebook, or materials related to engineering design tasks. This observation aligns with established research on pointing gestures as visual cues, guiding students' attention, and highlighting relevant objects or locations (Hostetter & Alibali, 2008). Beat gestures involve rhythmic movements that emphasize or highlight aspects of speech. Using beat gestures aligns with the theory that rhythmic movements enhance engagement, capture attention, and aid in information processing (Hostetter & Alibali, 2008). Next, we constructed a heatmap of the total number of each gesture type for all the coded lessons across all the teachers as the lesson progressed.

Table 1. *Examples of gestures produced in the engineering lessons as a function of gesture type*.

Gesture type	**Example**
Iconic	Lifting the right hand with the palm facing upwards to illustrate to students the height achieved by a parachute against air resistance.
Metaphoric	Spreading out the arms horizontally to demonstrate volume and stretching the arms out vertically to demonstrate pitch to represent sound waves.
Deictic	Pointing to a diagram on the board.
Beat	Moving their hands with palms facing upwards in a rhythmic manner with speech.

The heatmap shows the count of each gesture type distributed across the whole lesson, with green representing smaller numbers and red representing larger numbers. There were relatively high numbers of beat gestures compared to other gestures, especially at the end of the lesson. This observation suggests that teachers might use beat gestures to maintain student engagement and attention toward the lesson's end.

Figure 1. *Heatmap of each gesture type across lesson progression for all six lessons*



We also constructed separate heatmaps for the three topics (Figures 2, 3, and 4). It appears that teachers used more iconic gestures for sound waves and air resistance than circuits. This pattern of gesture production could have been due to sound waves and air resistance affording more representation of action using the hands.

Figure 2. *Heatmap of each gesture type across lesson progression for the topic on circuits*

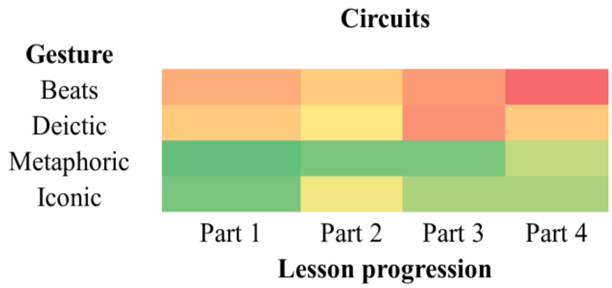


Figure 3. *Heatmap of each gesture type across the progression of the lesson on the topic of sound waves*

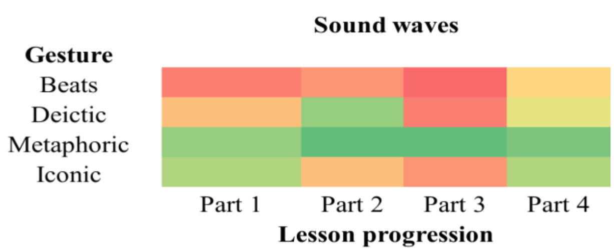
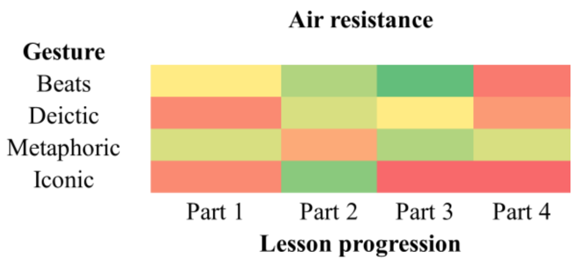


Figure 4. *Heatmap of each gesture type across lesson progression for the topic on air resistance*



Implications and Future Directions

These preliminary results highlight the crucial role of speech, action, and gestures in supporting the teachers' explanations and improving the clarity of their instruction. Teachers delivered the principles of the program multimodally, with gestures used mostly to scaffold students' learning and speech expectedly used in the more narrative aspects of the program, such as setting learning in the real world and inclusivity. Our findings suggest that gestures could augment young students' understanding of engineering concepts, given their ubiquitous use by teachers in elementary engineering education. However, more work needs to be done to investigate the impact of teachers' gestures on students' end. Our preliminary results also suggest that teachers' gestures help students understand elements of the engineering process, and teachers in elementary engineering might consider using gestures more for this reason. In addition, there are limitations to using YouTube videos for data, such as a lack of control over the classrooms and teachers represented. This work in progress continues with the coding of the remaining videos in the public domain and may eventually lead to a catalog of teaching practices in elementary engineering education.

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