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Pre-Service Teachers' Perceptions of Norms of Interaction for Fourth-Grade Students' Engineering Design Problem-Solving

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Abstract

This study examined elementary pre-service teachers' (PSTs) perceptions about norms of interaction to emphasize with fourth-grade students as they worked in teams to solve an engineering design challenge. From analysis of PSTs' lesson reflections and post-unit interviews, the findings revealed a range of PSTs' conceptions for seven social norms of interaction and indicated PSTs' emphases on norms promoting students' individual contributions versus norms encouraging collective efforts in solving the engineering problem. The results suggest focus areas for teacher educators in preparing PSTs to promote social norms for collaborative engineering design problem-solving.

Keywords: Pre-service teachers, perception, elementary school, engineering design

Introduction

With the introduction of the Next Generation Science Standards (NGSS), a new expectation for teachers of grades K-12 is that they integrate engineering design problem-solving with students' science learning (NGSS Lead States, 2013). Similar to engineers who collaborate in teams and negotiate design proposals (Jin & Geslin, 2009), the intent of the standards is that students come to see themselves as members of a community who interact together to generate design proposals, test and evaluate designs, optimize potential solutions, and negotiate the most effective design to a defined problem within a given set of constraints (NRC, 2012).

At the elementary grade level, researchers have found that some students who lack confidence in generating or sharing ideas feel empowered when working in collaborative groups to solve an engineering problem (Cunningham & LaChapelle, 2012). However, studies also have identified that students' perceptions of social codes and status in the class can inhibit their participation in collaborative design work as well as influence whether they offer design ideas or acquiesce to other's proposals (Wendell, Wright, & Paugh, 2015). Since most elementary pre-service teachers (PSTs) have no experience with engineering design and need preparation in how to foster social norms for students' interaction and collective efforts in engineering problem-solving, teacher educators face new challenges in preparing PSTs.

Social norms of interaction set the ground rules for collaborative discourse in a socially situated activity (Palinscar, Anderson, & David, 1993). Yet, promoting a classroom climate in which students engage in norms of interaction and are responsive to other's contributions can be difficult for teachers (Engle & Conant, 2002). From their long apprenticeship of observation during their own school experiences (Lortie, 1975), PSTs may be more familiar with Initiation-Response-Evaluation (IRE) discourse whereby the teacher initiates a question, the student responds, and the teacher evaluates the response (Cazden, 1988; Lemke, 1990). The IRE approach often elicits an unsophisticated response from students without encouraging them to listen to or build upon other's ideas. In addition, though PSTs may have experienced group learning in their own education, Kennedy (1999) argues that they may not be aware of scaffolds necessary to foster productive collaborative work or practices to elicit students' diverse perspectives and critical thinking. Thus, for this study, we sought to gain baseline information about PSTs: What are PSTs' perceptions about norms of interaction to emphasize with fourth-grade students in solving an engineering problem? The warrant for this inquiry is that teacher educators would benefit from awareness of PSTs' pre-existing schemas about group norms in order to develop PSTs' understanding of collaborative discourse for engineering design.

Core Ideas for Engineering Design Education

According to the National Academy of Engineering (NAE, 2010), one of the general principles for K-12 engineering education is to promote habits of mind as essential 21st century skills such as collaboration and communication. NAE (2010), described engineering as a "team sport" in which "collaboration leverages the perspectives, knowledge, and capabilities of team members to address a design challenge" while "communication is essential to effective collaboration" (p. 45). The intent of NGSS is that by the end of fifth grade, student teams would be able to collaborate to (a) define a problem, determine constraints of the problem, and establish criteria for a desired solution; (b) brainstorm for possible solutions and evaluate design proposals based on specified constraints and criteria; and (c) test possible solutions, identify failure points, and share ideas to improve a design (NGSS Lead States, 2013).

However, evaluative discourse is not an innate skill for young children; it requires that teachers scaffold students' development for reasoned dialogue, promote explicit social norms for collaborative problem-solving, and offer opportunities for practice with peers (Kuhn, 1991; Mercer, Dawes, Wegerif, & Sams, 2004). Given the limited research on discourse in elementary engineering design (Watkins, Spencer, & Hammer, 2014; Wendell et al., 2015), we examined literature from the sociocultural perspective on social norms of interaction for indications of how elementary teachers could foster collaborative discourse for problem-solving with students.

Social Norms of Interaction for Students' Problem-Solving Discourse

Research has shown that a teacher's promotion of social norms of interaction can support problem-solving among students working in groups (Herrenkohl, Palinscar, DeWater, & Kawasaki, 1999; Mercer et al., 2004; Palinscar et al., 1993). Since engineering problem-solving is a socially situated activity requiring collaborative negotiation of design ideas, we adopted a conceptual framework of social norms of interaction from the work of Palinscar et al. (1993) and Mercer et al. (2004) in science learning. Palinscar et al. (1993) identified four norms of interaction for students in small group problem-solving: "contribute to the group's efforts and help others contribute….; support one's ideas by giving reasons….; work to understand other's ideas….; and build on one another's ideas" (p. 647). Their research suggested that students' science learning involves construction of conceptual understanding through social interactions.

By establishing social conditions for talk, Mercer et al. (2004) argue that a more equitable learning environment is created in which quieter students feel their contributions are valued and students receive access to a broader range of ideas. Mercer and colleagues (2004) suggested a set of norms or ground rules for group-based discursive interaction:

> All relevant information is shared; all members of the group are invited to contribute to the discussion; opinions and ideas are respected and considered; everyone is asked to make their reasons clear; challenges and alternatives are made explicit and are negotiated; and the group seeks to reach agreement before making a decision or acting. (p. 362)

Studies with elementary teachers who promoted these norms indicated that students adopted a shared purpose of collaboration for group activities (Mercer et al., 2004).

From the field of elementary science, Carlone, Haun-Frank, and Webb (2011) examined normative practices promoted in two fourth-grade classes for student dialogue about their scientific thinking. The results from one class showed that when the norm of turn-taking was emphasized, students shared their individual ideas, but some group members' ideas were ignored and students did not build upon each other's ideas. In contrast, students felt more affiliated with science learning when students were expected not only to share their ideas, but also explain each other's thinking, question and build on other's ideas, and collaborate to have a collective purpose of "we solve problems together" (p. 471).

Strategies to Promote Students' Modes of Discourse

In addition to norms, students need specialized language or modes of discourse to communicate ideas to others (Palinscar et al., 1993). Matsumura, Slater, and Crosson (2008) found that when teachers set clear expectations not only for the manner of student interactions with peers (i.e., respect and validate other's contributions, bring others into the conversation), but also for the substance and language of student contributions (i.e., cite evidence for ideas), there was greater student participation in discussions. For discourse in the science classroom, Zembal-Saul, McNeill, and Hershberger (2013) outlined explanation-driven language for elementary students based on Toulmin's (1958) basic argumentation components: claim, evidence, and reasoning. Zembal-Saul et al. suggested that elementary teachers model and expect students to use "talk moves" (Michaels, Shouse, & Schweingruber, 2008, p. 91), such as explaining their reasoning and evidence for an idea, restating someone else's thinking, or explaining reasons for agreeing or disagreeing with another's idea. Though this language was intended for students' construction of scientific explanations, it is also applicable to discourse for engineering design.

Pre-Service Teachers' Perceptions of Norms and Experiences with Modes of Discourse

Relevant to this study are findings reporting PSTs' preconceptions and experiences with group-based learning or engineering problem-solving. For example, deJong, Cullity, Haig, Sharp, and Spiers (2011) found that the PSTs in their study had limited knowledge and experience with norms for consensus building or conflict resolution. They reported that PSTs felt frustrated with interpersonal conflicts within a group and favored assigning students to groups. The PSTs also perceived that group work resulted in inequitable participation by group members; thus, they preferred to designate student roles in order to ensure equitable effort by each person. In science education, research has indicated that PSTs' belief in the need to control students' social behavior and learning underlies their concerns about students working in groups (Bryan, 2003).

Furthermore, PSTs' comfort with using talk moves in their own engineering design conversations could influence the degree to which they support elementary students' discourse. From exploring PSTs' conversational moves for an engineering challenge in their science and engineering methods course, Wendell (2014) found that the PSTs generated and affirmed design ideas with each other to arrive at a design decision; yet, infrequently questioned or expressed disagreement with another's design ideas—norms needed to evaluate engineering proposals.

Method

Participants and Study Context

The participants for this study included 24 of 27 third-year undergraduates enrolled in two sections (n = 14 and n = 10) of a science teaching methods course in an elementary education program at a private university in the Northeast. None of the PSTs had prior experience or knowledge of the engineering design process.

The goals for the science teaching methods course, taught by the first author, were to develop PSTs' ability to promote elementary students' science/engineering practices, create a collaborative classroom climate, and facilitate students' discourse for scientific meaning-making and engineering problem-solving. To increase the PSTs' awareness of normative classroom practices for students' expression of their engineering design ideas, they examined findings from Carlone et al.'s research (2011) for approaches of how to promote group members' solving problems together. The PSTs also worked through engineering problems in teams during the methods course in order to identify gaps in their own content knowledge, engage in collaborative decision-making about proposed designs, experience the engineering design process for themselves, and reflect on the norms they used to negotiate design ideas.

The PSTs applied their learning in practicum teaching at a local urban elementary school that serves a diverse student population. Each PST taught four two-hour weekly sessions of an integrated science and engineering unit on electricity to a small group of two to four fourth-grade students. The rationale for PSTs working with a small group of students was to enable them to focus attention on student thinking and interaction.

In lesson one, PSTs introduced students to the engineering problem: the field near the school needed lights so students could play soccer at night. Each team of students would design a model of a lighting scheme for the field that met budgetary limits and lighting requirements. To prepare students to solve the engineering problem collaboratively, PSTs co-created norms of interaction with their students. During the second lesson, students engaged in series and parallel circuitry investigations to identify features of each type of circuit that could be helpful when designing a solution. In the third session, students generated ideas for possible designs and constructed one agreed-upon design. Finally, in the fourth session, students evaluated the first design, proposed design revisions, and built and tested a second design before making presentations of their design choice to the class. Through this unit, fourth-graders applied their growing knowledge about series and parallel circuits to solve the engineering problem.

Data Sources and Analyses

To gain insight into the PSTs' perceptions about norms of interaction for engineering problem-solving, the data sources included (a) PSTs' written responses to specific prompts from their four post-lesson reflections about norms they emphasized to promote student discourse in solving the engineering problem and (b) transcriptions from post-unit interviews with the PSTs. PSTs' meta-cognitive reflections, typically used in teacher preparation programs to develop PSTs' skill in analyzing their growing teaching practice, provide a means for teacher educators to gain insight into PSTs' thinking and decision-making (Davis, 2006). PSTs completed a reflection within 48 hours of each lesson to capture their perceptions of norms of interaction for engineering design as soon as possible. From research in fields of socially constructed learning and social interaction for discourse (Mercer et al., 2004; Palinscar et al., 1993), we selected seven norms of interaction as our conceptual framework to examine PST written reflections:

- Contribute to the discussion and group efforts;
- Help others contribute to the discussion and group efforts;
- Listen to and understand other's ideas (i.e., restating another's reasoning);
- Support ideas with evidence and reasons;
- Make alternative ideas explicit and evaluate these ideas;
- Build on other's ideas; and
- Seek to reach group agreement before making a decision or acting.

To generate a data corpus (Erickson, 1986), we identified 316 comments that addressed norms of interaction from the 96 PST reflections for the four lessons from both methods course sections. We randomly selected the reflections of six PSTs and independently coded the comments for norms of interaction, achieving 80% inter-rater reliability (Stevens, 2002). After resolving all discrepancies through discussion, we coded individually the remaining PST reflections.

To gain more insight into the PSTs' perceptions, the second author conducted post-unit interviews to avoid the possibility that the first author's presence, as methods instructor, could bias the PSTs' responses (Creswell, 2009). PSTs participated in 30-minute audio-recorded interviews

Table 1
Frequency, percentage, and sub-categories of PSTs' perceptions of norms of interaction coded from reflection comments

Norm of Interaction	Frequency	Percentage	Sub-categories of PSTs'perceptions of norms with frequency of comments
Contribute to the discussion and group efforts	124/316	39%	• Students provide own ideas and participate in the problem-solving (104/124) • Students assign roles to problem-solve (13/124) • Students take turns in sharing ideas (7/104)
Help others contribute to the discussion and group efforts	20/316	6%	• Students encourage peers to share ideas or contribute to group efforts (12/20) • Students rotate in assigned role of encouraging peer's contributions (8/20)
Listen to and understand other's ideas	16/316	5%	• Students listen to other's ideas (8/16) • Students listen to and are able to explain a peer's ideas (8/16)
Support ideas with evidence and reasons	75/316	24%	• Students support ideas with reasoning (42/75) • Students support ideas with evidence (22/75) • Students support ideas with both evidence and reasoning (11/75)
Make alternative ideas explicit and evaluate these ideas	43/316	14%	• Students offer alternative ideas to proposals and evaluate the ideas (29/43) • Students offer alternative ideas and evaluate ideas using visual supports (3/43) • Students offer alternative ideas to proposals without evaluating ideas (11/43)
Build on other's ideas	19/316	6%	• Students expand thinking by building on other's ideas (19/19)
Seek agreement before making a decision or acting	19/316	6%	• Students seek agreement by evaluating proposals to make a decision (16/19) • Students seek agreement by voting (2/19) • Students seek agreement by combining elements from each proposal (1/19)

n = 24 pre-service teachers

individually, in pairs, or in a small focus group using a semi-structured format. The researchers coded the interview transcriptions for statements that addressed any of the norms of interaction to triangulate reports from PSTs' reflections about each of the norms (Denzin, 1978).

From these analyses, we identified patterns in the reflections and interview data of PSTs' perceptions of norms of interaction to emphasize in engineering lessons. Using Miles and Huberman's (1994) constant comparative methodology, further analysis of the reflection data revealed sub-categories of PSTs' conceptions about the norms of interaction. Table 1 displays the frequency and percentage of PST reflection comments for the seven norms of interaction and the respective sub-categories (Gravetter & Wallnau, 2008). Table 2 provides examples of PSTs' reflection comments and interview statements for each sub-category of norms of interaction. Initials were used to denote fourth-grade student names.

Results

PSTs' Perception of Norms of Interaction for Engineering Problem-Solving

Three broad categories emerged of PSTs' perceptions of norms of interaction for small groups of fourth-grade students as they solved an engineering problem: (a) emphasis on individual contributions for design ideas, (b) evaluation of alternative ideas, and (c) under-emphasis on attending to other's contributions.

Emphasis on individual contributions for design ideas. From PSTs' reflection comments addressing norms of interaction for students' engineering problem-solving, the PSTs most often commented on two norms: (a) *contribute to the discussion and group efforts*, and (b) *support ideas with evidence and reasons*. Both norms encourage individual students to contribute their own ideas and efforts to solve the engineering problem. In combination, 62% of all PSTs' reflection comments addressed norms focused on students' individual contributions.

Contribute to the discussion and group efforts. PSTs reported this norm most frequently (39%) in the reflection comments. Three sub-categories emerged for PSTs' perceptions of this norm: (a) students provide their own ideas and participate in the problem-solving, (b) students take turns in sharing their ideas, (c) students take on different roles to problem-solve. The majority of PSTs' reflections interpreted this norm to involve encouraging students to provide their own design ideas and participate in building a prototype for the ballfield lighting design (104 of 124 reflection comments). However, some PSTs held the conception that this norm involved assigning roles or "jobs" to students in order for all to engage in the lesson (13/124 reflection comments). Other PSTs interpreted this norm to mean that students either "take turns" in sharing their ideas or take on different roles when building a prototype in order to ensure equity of student participation (7/124 reflection comments).

Support ideas with evidence and reasons. This norm, the second most frequently addressed (24%), included three sub-categories of PSTs perceptions: (a) support ideas with reasoning, (b) support ideas with evidence, (c) support ideas with evidence and reasoning. More than half of the PSTs' comments (42/75 reflection comments) focused on students' supporting ideas with reasoning. Some PSTs perceived this norm involved students supporting ideas with evidence (22/75 reflection comments). However, interviews revealed that some PSTs felt their students did not understand what constituted evidence when comparing prototypes in the engineering challenge. Fewer PSTs perceived this norm through the lens of using both evidence and reasoning (11/75 reflection comments). Consistent across each of the three sub-categories is the focus on each student providing support for his or her individual engineering ideas.

Encouragement of evaluation of alternative ideas. One norm of interaction involved not only promoting individual contributions by asking students to make their alternative engineering ideas explicit, but also inviting team members to consider and evaluate these ideas—a norm that encouraged thinking beyond one's own ideas.

Table 2

Examples of PSTs' reflection comments and interview statements for sub-categories of norms of interaction

Norms of interaction and sub-categories of PSTs' perceptions of norms	Examples of PSTs' reflection comments and interview statements
Contribute to the discussion and group efforts	
• Students provide own ideas and participate in the problem-solving	• "When a student would give an idea, I would probe them to give me more, 'What do you mean when you say…' That was done individually."
• Students assign roles to problem-solve	• "Sometimes I assign roles so that everyone is involved." "One of the norms that I really had to emphasize was to include everyone--make sure they each have a job--because I had two students that would sit out."
• Students take turns in sharing ideas	• "One norm that was very important was making sure there is only one speaker at a time, that they would take turns and not speak over one another.
Help others contribute to the discussion and group efforts	
• Students encourage peers to share ideas or contribute to group efforts	• "I asked Student T to explain if he agreed or disagree. He replied with 'Yes, I do.' Student N and Student A asked him to tell us why he agreed."
• Students rotate in assigned role of encouraging peer's contributions	• "If one student was being quieter that everybody else, the Participation Leader would say, 'What do you think?' 'What is your opinion on this?' or 'What is your idea?' It would allow all the students to participate."
Listen to and understand other's ideas	
• Students listen to other's ideas	• "It is so important to make sure students are listening to other students' ideas because it may change their thinking."
• Students listen to and are able to explain a peer's ideas	• "I always had them restate what the other student said in their own words to understand others' ideas, learn something else, or you have the same question."
Support ideas with evidence and reasons	
• Students support ideas with reasoning	• "When a student shared an idea on using a simple circuit, I said, 'Why would that work best?' Students then came up with reasoning."
• Students support ideas with evidence	• "I asked them to explain what they thought worked best and give evidence about brightness levels. I wanted them to actually look at their data."
• Students support ideas with both evidence and reasoning	• "I made sure to ask questions such as, 'Why do you think that?' or 'What is your evidence for that?' to encourage discourse."

Make alternative ideas explicit and evaluate these ideas	
• Students offer alternative ideas to proposals and evaluate the ideas	• When I posed the question, "How can we increase the brightness?" Student M thought, "We could take bulbs away or add batteries." Students A and B took over the calculations and quickly realized adding more batteries to the current series design would put them over budget.
• Students offer alternative ideas and evaluate ideas using visual supports	• "Mini-posters of sentence starters" were helpful for student discourse: "'I like your idea, but I think…,' 'I agree/disagree because…,' and 'I think…because…'" "I engaged students in a comparison of the two designs. We had made posters with a diagram and explanation for each design."
• Students offer alternative ideas to proposals without evaluating ideas	• "One student was adamant about her design being the best design." Peer evaluation of design ideas is "challenging… especially when students didn't agree." "Student E would usually agree with whatever Student C said."
Build on other's ideas • Students expand thinking by building on other's ideas	• "I asked students to each tell something they liked about the other designs that their peers came up with. This allowed them to really look at the other designs instead of just assuming their design was the best. By looking at each other's ideas, they were able to expand upon their own thinking and even make adjustments to their own proposed design." "A student would be very set on their idea. But then they would hear another student's idea and…pull their ideas together."
Seek agreement before making a decision or acting • Students seek agreement by evaluating proposals to make a decision	• "I know that our first design didn't work, but we would've never known that if we didn't try it. And we would of never built this one without the first one." (PST report of a student comment).
• Students seek agreement by voting	• "to decide on the first design, I asked students to vote and explain why they were voting for a particular design and why they believed it was the better choice."
• Students seek agreement by combining elements from each proposal	• After coming up with one design as a group of three, I had both groups come together to better the design. The students were able to all work together and come up with ideas for the best design that they would then create.

Make alternative ideas explicit and evaluate these ideas. PST comments on this norm (14%) involved three sub-categories: (a) students offer alternative ideas to proposals and evaluate the ideas, (b) students offer alternative ideas and evaluate ideas using visual supports, and (c) students offer alternative ideas without evaluating the ideas. The data indicated that most PSTs who addressed this norm in their reflections (29/43 reflection comments) perceived it involved two aspects—students offer alternative ideas to their peer's proposals, and then the group members evaluate the ideas. A few PSTs viewed that visual supports (i.e., sentence starters for student discourse or diagrams of the suggested designs) facilitated students in generating and evaluating alternative proposals (3/43 reflection comments). However, some reflection reports (11/43 reflection comments) depicted this norm as challenging or suggested an unawareness of the need for students to evaluate ideas. PST descriptions of challenges involved both student disagreements or acquiescence to the stronger voice in the group. Other PSTs' reports noted adoption of an idea from one student by all group members without mention of vetting the design proposal. Though PSTs reported encouraging students to present alternative ideas, some PSTs did not perceive the need to emphasize evaluation of proposals.

Under-emphasis on attending to others' contributions. Most PSTs gave limited attention to four norms of interaction in their engineering reflections: (a) *help others contribute to the discussion and group efforts*, (b) *listen to and understand other's ideas*, (c) *build on other's ideas*, and (d) *seek agreement before making a decision or acting on an engineering design.* These norms all required students to focus on others' ideas and share responsibility for the group's engineering design work.

Help others to contribute to the discussion and group efforts. From 6% of the reflection comments, two sub-categories emerged of some PSTs' perceptions about this norm: (a) students encourage their peers to share ideas or contribute to group efforts and (b) students rotate in their assigned role of encouraging peer's contributions. Some PSTs who addressed this norm viewed that students should take a pro-active role in encouraging their peers to contribute to solving the engineering problem (12/20 reflection comments). Other PSTs viewed that this norm involved a rotating monitor role each week of "Participation Leader" whose job was to ensure that each team member contributed an idea (8/20 reflection comments). Yet, one PST noted that she viewed this norm as challenging for elementary students since she perceived that they did not have enough experience in helping others to contribute to the discussion and group efforts.

Listen to and understand others' ideas. This norm, addressed in 5% of the PST reflection comments, involved two components of not only listening to the design ideas of others, but also demonstrating understanding by explaining a peer's ideas. Half of the PSTs who wrote about this norm (8 of 16 reflection comments) viewed it solely with a focus on the action of listening--"look, lean, and listen" without commenting on students' being able to explain a peer's idea. In contrast, half of the PSTs (8 of 16 reflection comments) perceived that it involved not only students' listening to each other, but also explaining each other's ideas.

Build on other's ideas. PSTs in 6% of the comments described this norm as encouraging students to expand their thinking by attending to and building on other's ideas (19/19 reflection comments). The few PSTs who addressed this norm held the view that by promoting this norm, students who were fixed on their own idea could consider other possibilities. The PSTs perceived that this norm could help students broaden their thinking about possible design ideas as solutions to the engineering problem.

Seek agreement before making a decision or acting. From 6% of the reflection comments, the few PSTs who addressed this norm held varied perspectives on how students sought agreement: (a) students collaborate as a team to evaluate proposals and make a design decision, (b) students vote on one design from the proposals, or (c) students select parts of different proposals to combine into "one big design." The majority of PST reflection comments for this norm (16/19 reflection comments) revealed that PSTs who addressed this norm viewed prototype evaluation as necessary for students to come to agreement on a design decision and determine improvements as a team. Two PSTs wrote about how they perceived students could seek agreement on design ideas by voting (2/19 reflection comments). In contrast, one PST (1/9 reflection comments) described her view of how students could reach agreement by combining elements from different proposals. Overall, however, most PSTs either did not address this norm in their reflections or indicated that students struggled to reach agreement on a design.

In summary, the results indicated that PSTs most frequently perceived social norms of interaction for group problem-solving through the lens of each student's individual contributions to discussions and efforts. The findings showed that PSTs less frequently considered norms that focus on students' collaborative interactions with shared group responsibility. One PST provided some insight during her interview into this difference in emphasis. She explained her exposure to norms from her own schooling:

> Not new to me were norms of active listening, respecting people, not talking when others are talking, and being able to really understand what a peer is saying. The norms that were new to me all fell under helping everyone participate and building on others' ideas to get a collective idea because in my experience, there was a lot of ownership on one's idea.

The PST's comment provided evidence of her own perspective and suggested an unfamiliarity that PSTs may have had with the full range of social norms of interaction.

Discussion and Conclusion

Elementary teachers are now expected to integrate engineering design with students' science learning (NRC, 2012). One key indicator of quality K-12 engineering education is students' participation as contributing, productive team members when solving design problems (Moore et al., 2014). This expectation for collaborative problem-solving has implications for the preparation of prospective elementary teachers in terms of their understanding of group norms of interaction.

From analyzing data using an adaptation of Palinscar et al.'s (1993) and Mercer et al.'s (2004) frameworks for social norms of interaction, we examined PSTs' perceptions of norms of interaction for fourth-graders as they engaged in solving an engineering design problem. Overall, the PSTs perceived group problem-solving to involve norms that encouraged each student to contribute individually to the discussion and design efforts more than social norms that encouraged students to invite team members to express their thinking, consider and evaluate the ideas of others, build upon other's ideas, or negotiate solutions as a group for shared responsibility in solving the engineering problem. This distinction in norms of interaction is consistent with Ford, Wentzel, Wood, Stevens, and Siesfeld's (1989) differentiation of domains for interpersonal social behavior: self-assertion, which privileges individuality and promotion of self in social groups versus integration, which focuses on social responsibility and promotion of other people or the social group. The norms that encourage students' integrative social responsibility to *help others contribute to the discussion and group efforts, listen to and understand other's ideas,* and *build on other's ideas* involve students' soliciting and responding to each other's thinking, a role typically assumed by the teacher when prompting discussion in the traditional science classroom (Lemke, 1990). Considering the type of discourse that most PSTs experience in their own education that emphasizes individual students' interactions with a teacher (Cazden, 1988), it is plausible that, for most of the PSTs, their perspective on social norms for interaction would focus on students' self-assertive contributions to discourse.

From analysis of the PSTs' perceptions, the data revealed a range of PSTs' conceptions about each norm that varied from belief in student-to-student interactions to reliance on teacher-created structures as aids for interaction. For example, for the most frequently cited norm in the reflections and interviews, *contribute to discussions* and *group efforts*, most PSTs discussed this norm in terms of encouraging each student to brainstorm for design ideas and contribute to the group efforts in building a design prototype. However, some PSTs viewed that they could operationalize this norm by providing a controlled group structure in which students take turns in sharing their design ideas and assume roles in building the prototype. Research in equitable science education has shown that an outcome of turn-taking in the elementary science classroom is that students advocate for their own ideas without considering ideas of others (Carlone et al., 2011). In addition, elementary PSTs' commonly held belief that they need to have controls in place to minimize conflict or dominance by more vocal students (Bryan, 2003) may explain the perception of some PSTs that teachers need to manage the student interactions.

This pattern of variation in PSTs' perceptions also emerged with the norms that the PSTs addressed less frequently. For example, while some PSTs perceived that the norm, *help others to contribute to the discussion* and *group efforts*, involved students encouraging peers to share the group responsibility of problem-solving, other PSTs envisioned that the teacher would assign a student to monitor and prompt group members' participation. Similarly, for the norm, *seek agreement before making a decision or acting*, some PSTs envisioned students working together to evaluate proposals before making design decisions. Other PSTs perceived that students could agree by voting or selecting parts of each student's proposal—actions that may not include evaluation of proposals, an essential element of the engineering design process (NRC, 2012).

Research in the field of transfer of educational theory to practice can shed light on the PSTs' perceptions of norms of interaction for group problem-solving. Fundamental in understanding PSTs' transfer of new learning from a teacher education program to practice is that PSTs actively make sense of theoretical and practice-based knowledge through the lens of their existing understandings and prior experiences (deJong, Cullity, Sharp, Spiers, & Wren, 2010). Therefore, identification of PSTs' pre-existing conceptions about group work and the norms of student interaction (deJong et al., 2010) can inform teacher educators of areas in need of focus when preparing PSTs for implementing engineering problem-solving.

To shift PSTs' traditional view of classroom interactions beyond the dialog of the teacher-student dyad to a student-student shared responsibility would require PSTs to reconceptualize their view of teacher and student roles (Herrenkohl et al., 1999). Analysis of videos depicting elementary students engaged collaboratively in engineering problem-solving would offer PSTs a visual depiction of how teachers can promote a classroom community in which students interact and value each other's contributions to solve the engineering problem. In addition, while solving engineering challenges within a methods course, PSTs' can have direct experience asking other group members to share design ideas, listening to other's ideas, seeking clarification of another's thinking, evaluating proposed solutions, building on other's ideas, and negotiating agreement among group members. PSTs would benefit from enacting norms of interaction themselves first to become comfortable with the full range of norms before encouraging elementary students to use norms to generate design solutions together. Finally, teacher educators can provide PSTs with opportunities to self-assess and discuss norms they use themselves when engaging with peers in the methods course to solve an engineering problem. From this preparation, PSTs can apply the same metacognitive approach in the elementary classroom by inviting students to self-evaluate their interactions with team members and identify steps for improvement (Solomon, Watson, Schaps, Battistich, & Solomon, 1990).

With the focus for this study on PSTs' attending to students' thinking in small groups, this research design provided an opportunity to obtain an in-depth understanding of the possible PSTs' conceptions about normative practices for student interaction with group problem-solving. Since engineering design is a collaborative endeavor, norms of interaction that emphasize individual contributions have a place in the engineering classroom by prompting students to share ideas; yet, norms that encourage students to attend to other's thinking also are needed for students to share responsibility of evaluating and optimizing engineering designs. With baseline information of PSTs' possible perspectives about norms, teacher educators can craft opportunities for PSTs' to experience and understand the norms of interaction that typically are underemphasized as well as expand their perceptions of how to promote student interactions for collaborative engineering design problem-solving. ■

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