Engineering Teacher Pedagogy: Using INSPIRES to Support Integration of Engineering Design in Science and Technology Classrooms

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Be one who INSPIRES

INTRODUCTION

The *Next Generation Science Standards* establish a shift toward integrating engineering into K-12 science education[1]. This shift presents significant challenges to school districts due to a lack of (1) teacher professional development that strengthens teachers' abilities to integrate engineering design concepts and practices with science learning; and (2) the concomitant instructional materials appropriate for classrooms. The **INSPIRES** (**IN**creasing **S**tudent **P**articipation **I**nterest & **R**ecruitment in **E**ngineering & **S**cience) research program supports the integration of engineering design into high school science and technology curricula and classroom practices, and strategically addresses these critical challenges (NSF #ESIE-0352504, awarded 2004; NSF #DRL-0822286, awarded 2008; NSF #DRL-1418183, awarded 2014).

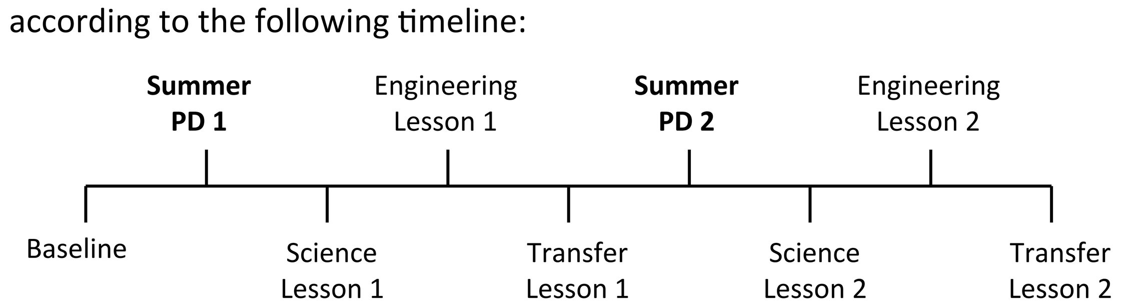
In the current research study, we implement the INSPIRES professional development (PD) model to investigate teacher pedagogical development over three years as a function of two distinct STEM learning environments: high school biology and technology education. **The broad goal is to characterize the benefits and limitations of utilizing an educative, curriculum-based PD model as a mechanism for strengthening teacher pedagogical skills for integrating engineering practices in high school STEM classrooms.** Here, we present findings from the first three years of the longitudinal study.

RESEARCH QUESTIONS

1. **Did teachers' classroom practice change as a function of the Project-based PD and curriculum enactment experience?**
2. **Did pedagogical skill development differ between biology and technology education teachers?**

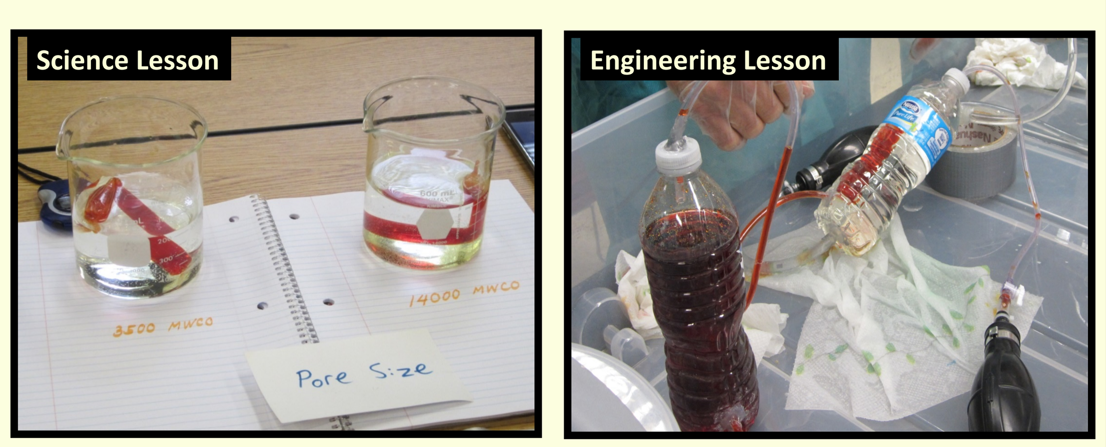
METHODS

The study followed a longitudinal triangulation mixed methods design. Biology (n=7) and technology education (n=12) teachers from a large suburban school district in the Mid-Atlantic region participated in the study. The PD program consisted of a 5-day summer institutes followed by after-school sessions through the academic years. Selected lessons were recorded according to the following timeline:



Science and ***Engineering*** lessons are from the INSPIRES Hemodialysis curriculum; they contain engineering design and reformed, student-centered pedagogies (**Fig. 1**). The ***Baseline*** and ***Transfer*** lessons are non-INSPIRES lessons selected by the teacher that incorporate the NGSS Engineering Design standard (HS-ETS1)[1].

Fig. 1. INSPIRES Hemodialysis Curriculum



The ***Science Lesson*** is an inquiry-based activity focused on diffusion. Dialysis membranes of different pore sizes containing artificial blood are shown.
The ***Engineering Lesson*** allows students to design, build, and test their own Hemodialysis systems; a sample final product is shown.

Lesson recordings were scored on the RTOP rubric[2] and inter-rater reliability indicated correlations in the good-to-excellent range[3]. Mean total scores were compared using repeated measures ANOVA (**Fig. 2, Table 1**) and mean scores comparing five RTOP item subcategories were determined (**Table 2, Fig. 3**).

Qualitative trends were examined for Year 1 lessons from a subsample of randomly-selected teachers (n = 6). Observers used an inductive content analysis approach to identify common themes and divergent cases[4].

RESULTS

Fig. 2. Mean RTOP Scores Across All Categories

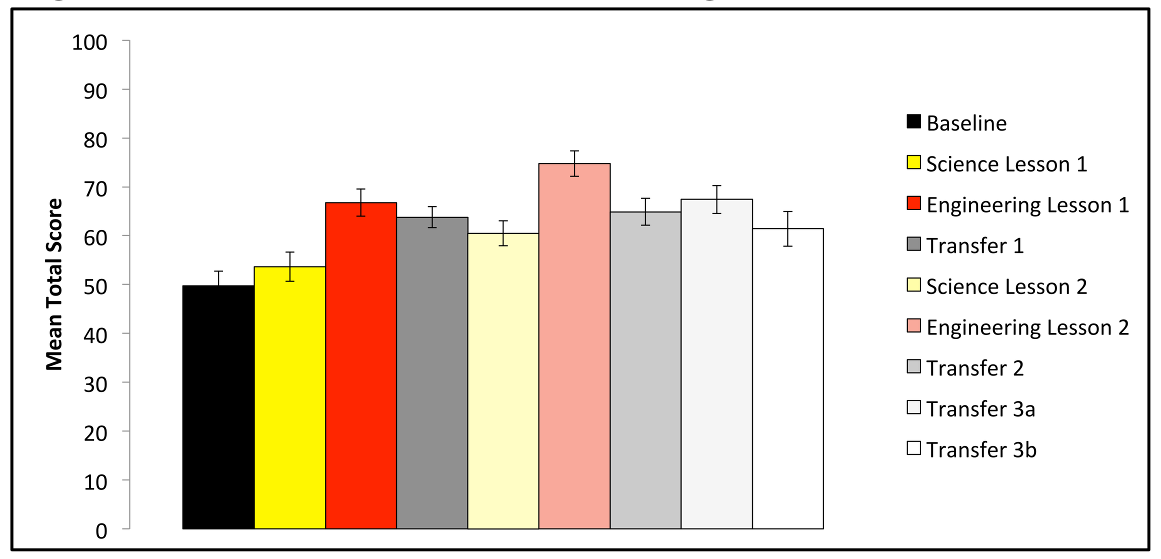
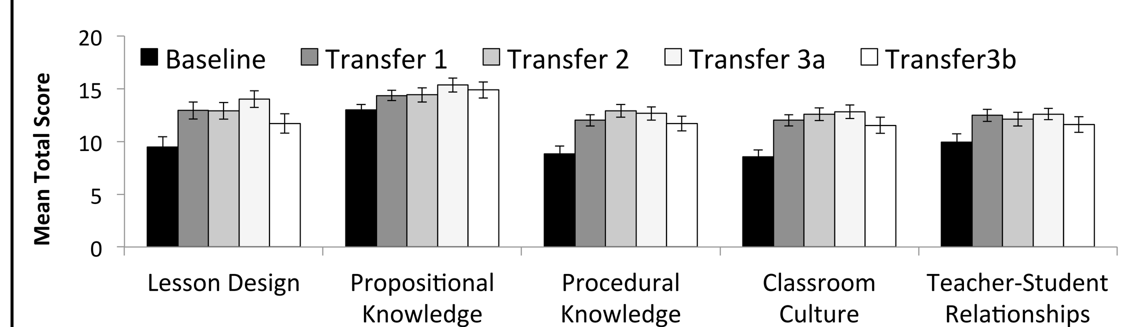
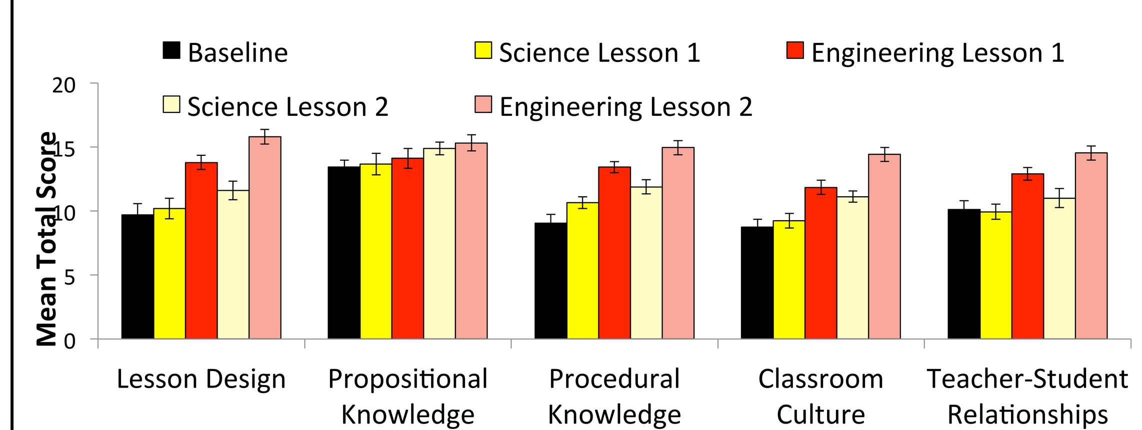


Fig. 3. Mean Scores Across RTOP Subcategories (n = 17)

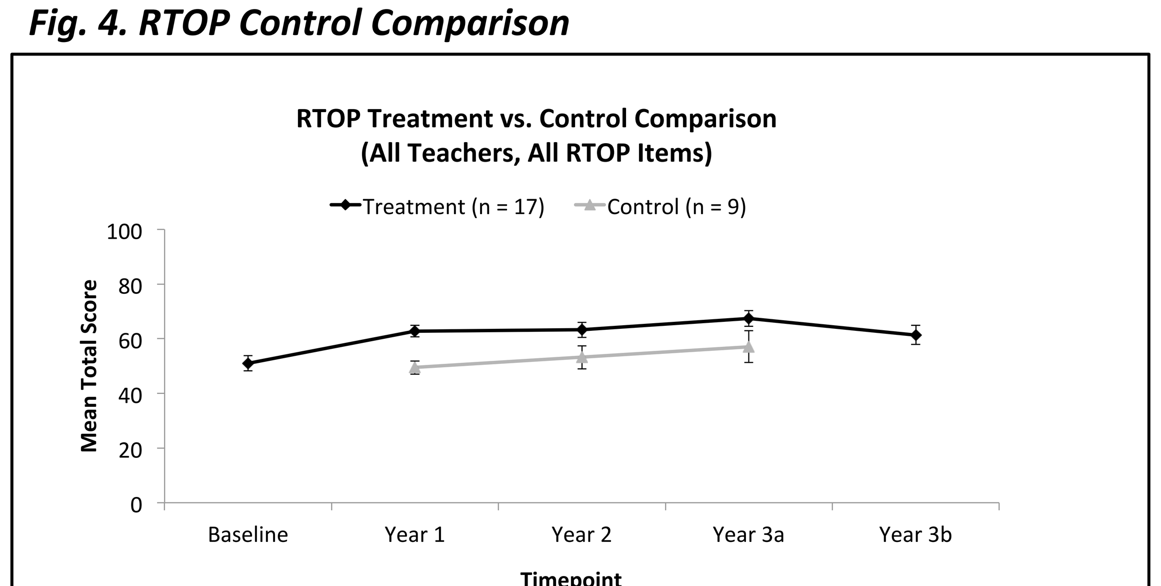


Comparison	Sig. (Lesson Design)	Sig. (Propositional Knowledge)	Sig. (Procedural Knowledge)	Sig. (Classroom Culture)	Sig. (Teacher-Student Relationships)
Baseline : Transfer 1	.266	1.000	.161	**.029***	.521
Baseline : Transfer 2	1.000	1.000	**.001***	**.016***	1.000
Baseline : Transfer 3a	.093	.073	**.003***	**.029***	.177
Baseline : Transfer 3b	1.000	1.000	**.014***	**.039***	1.000



Comparison	Sig. (Lesson Design)	Sig. (Propositional Knowledge)	Sig. (Procedural Knowledge)	Sig. (Classroom Culture)	Sig. (Teacher - Student Relationships)
Baseline : INSPIRES ENG 1	**.009***	1.000	**<.001***	**.005***	**.006***
Baseline : INSPIRES ENG 2	**.001***	.085	**<.001***	**<.001***	.002*
INSPIRES SCI 1 : INSPIRES ENG 1	**.011***	1.000	**.023***	**.010***	**.007***
INSPIRES SCI 1 : INSPIRES ENG 2	**.002***	1.000	**<.001***	**<.001***	**<.001***
INSPIRES SCI 2 : INSPIRES ENG 2	**.010***	1.000	.123	**.019***	.055

Fig. 4. RTOP Control Comparison



All whiskers in Figures 2, 3, 4 and 5 represent standard error.

Fig. 5. Innovation Configuration Mapping (IC Maps) of Engineering Lessons

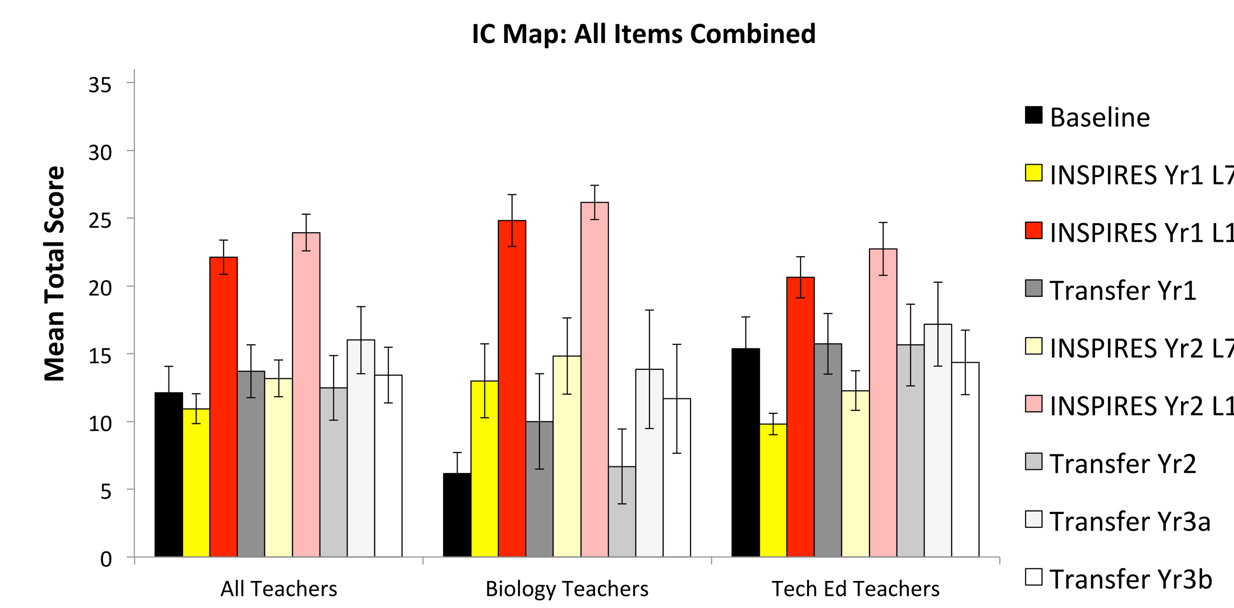


Table 1. Pairwise Comparisons for IC Maps

Comparison	Sig. (All Teachers N = 17)	Sig. (Bio Teachers N = 6)	Sig. (Tech Teachers N = 11)
Baseline : INSPIRES ENG 1	**.004***	.089	1.000
Baseline : INSPIRES ENG 2	**<.001***	**.009***	.518
INSPIRES SCI 1 : INSPIRES ENG 1	**<.001***	.177	**.001***
INSPIRES SCI 1 : INSPIRES ENG 2	**<.001***	.120	**.003***
Transfer 1 : INSPIRES ENG 1	**.027***	.679	1.000
INSPIRES SCI 2 : INSPIRES ENG 1	**.008***	1.000	**.027***
Transfer 2 : INSPIRES ENG 1	**.009***	.101	1.000
Transfer 3b : INSPIRES ENG 1	**.010***	.353	1.000
Transfer 1 : INSPIRES ENG 2	**.002***	.508	.206
INSPIRES SCI 2 : INSPIRES ENG 2	**.002***	.404	**.022***
Transfer 2 : INSPIRES ENG 2	**.001***	.147	.639
Transfer 3b : INSPIRES ENG 2	**.002***	.464	.107

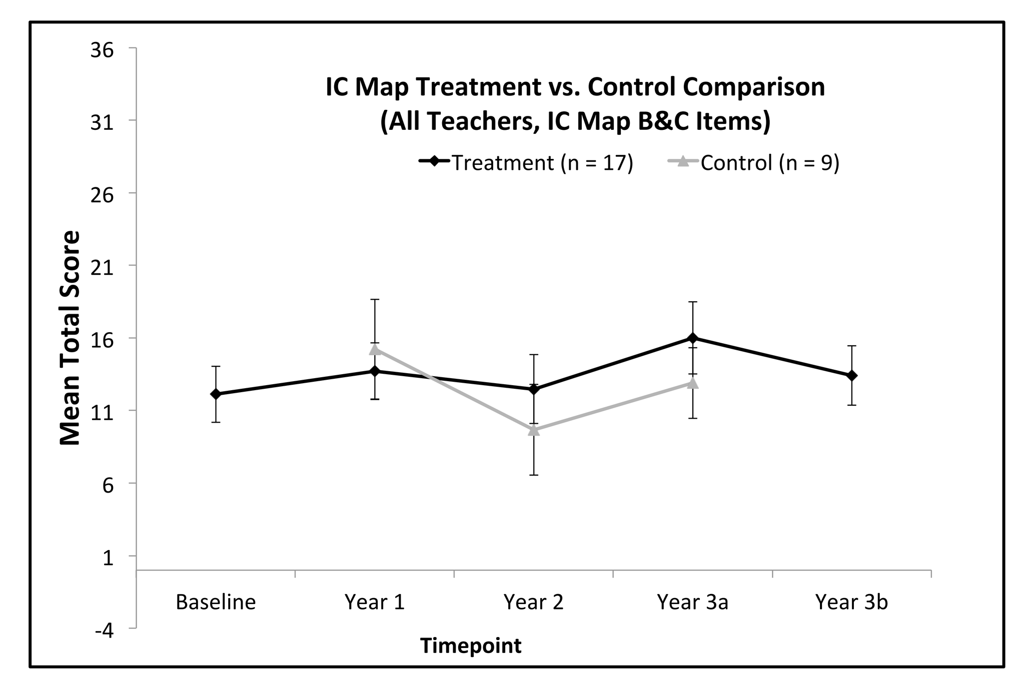
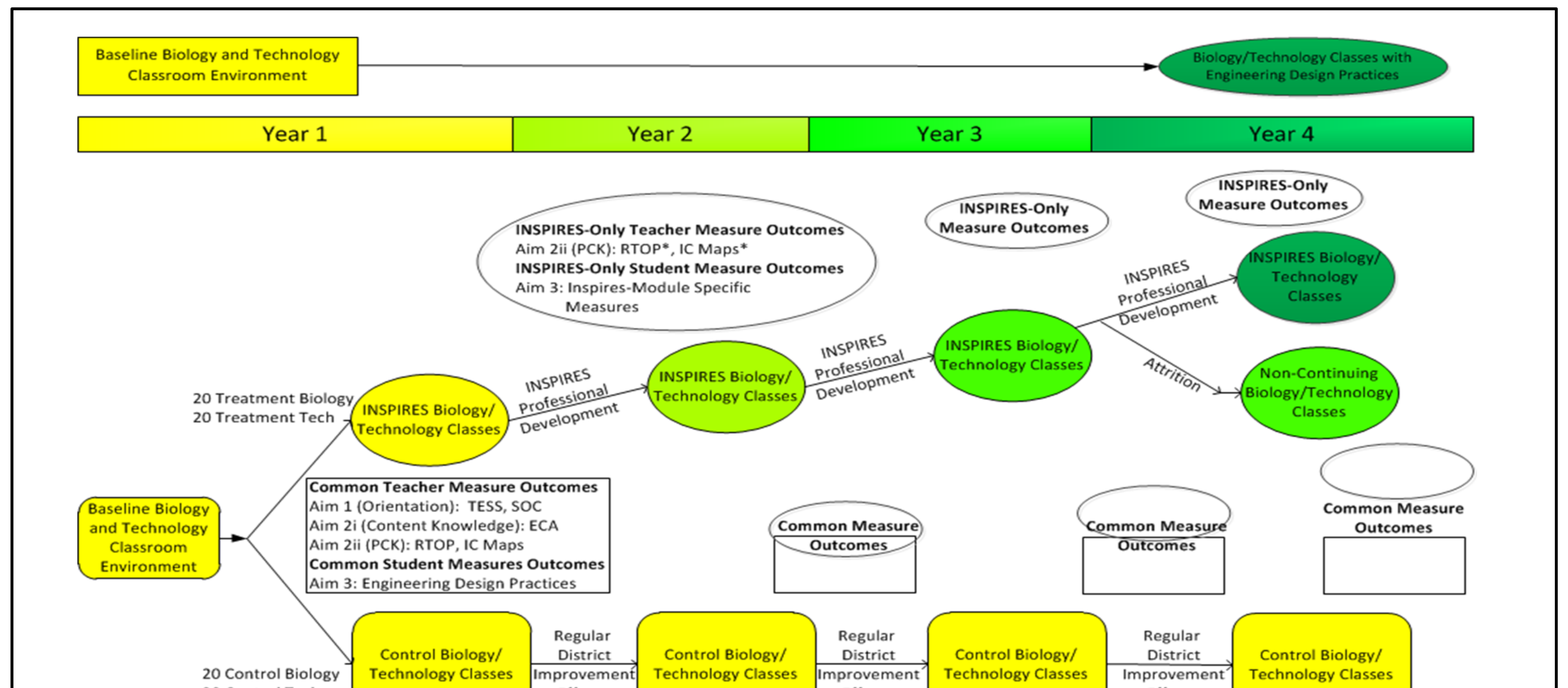


Fig. 6. INSPIRES Experimental Plan



INSPIRES project progression with measurement outcomes. SOC=Stages of Concern. TESS=Teaching Engineering Self-Efficacy Scale. RTOP=Reformed Teaching Observation Protocol. PCK=Pedagogical Content Knowledge. IC Maps=Innovation Configuration Maps. LOU=Levels of Use. ECA=Engineering Content Assessment. RTOP* and IC Maps* represent an additional data collection point only for INSPIRES teachers.

DISCUSSION

The results suggest that reformed pedagogy improved significantly during this longitudinal study. Gains in reformed practice (RTOP scores) as well as the integration of Engineering practices (IC Map scores) were evident in lessons associated with the INSPIRES curriculum, particularly the "Engineering Lesson" (Lesson 11). This finding implies that providing teachers with lesson exemplars can serve as effective scaffolding.

One reason why Lesson 11 may be more reform-oriented than the other lessons is because the design-based lesson may have pushed teachers from their comfort zones and encouraged them to follow the lesson plan more closely. Evidence for this speculation is presented when teachers enact specific pedagogical strategies in the Lesson 11, but not Lesson 7 (Science Lesson), even though the lesson plan guide prompts the use of these strategies in both lessons. For example, using student artifacts from prior lessons are explicitly encouraged in the guides for both Lessons 7 and 11, although we observed teachers enacting student artifact-sharing more in Lesson 11 than in Lesson 7. Similarly, both lesson plan guides encourage teachers to prompt students in sketching their experimental systems. Within our qualitative subsample, we found that only technology education teachers followed this strategy during Lesson 7, while both biology and technology education teachers prompted design sketches in Lesson 11. In the latter example, technology education teachers may have followed the science-based lesson plan more closely than the biology teachers, perhaps because the non-science teachers require more support while enacting a lesson with a science focus. Then, perhaps all teachers sought extra support from the lesson plan guides when enacting a novel, engineering design-based lesson. Therefore, while there were no quantitative significant differences identified between technology education and biology teacher RTOP scores, the qualitative analysis suggests that technology education teachers may have been following the lesson plan more closely than biology teachers during Lesson 7.

Teachers ability to "transfer" these practices into their own lessons were mixed. RTOP comparisons between Baseline and Transfer lessons did demonstrate significant gains in sub-categories associated with Procedural Knowledge and Classroom Culture. A similar pattern of growth, however, was not demonstrated with explicit Engineering Design Practices as measured by the IC Maps instrument.

Additionally, there is not a significant difference between biology and technology education teachers' pedagogical growth at this time. However, analyses of subsequent Year 3 Transfer lessons may reveal differences between teachers of different content areas. The final year of this longitudinal study is expected to yield further reform in pedagogical skills and the integration of engineering practices into STEM classrooms (**Fig. 5**). To date, these findings provide insights for rethinking the structure of PD, particularly in the integrated use of an educative curriculum aligned with intended PD goals.

NEXT STEPS

The next step of the study is two fold. One track is to analyze data at the individual teacher level. Extensive longitudinal classroom observation data (RTOP and IC maps) as well as teacher efficacy measures and qualitative interview data has provided several interesting cases for further analysis.

The second track is to explore relationships and patterns among the different measures.

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