What Professional Development Program Features Increase Teacher Knowledge?

PDMOST (Professional Development Models and Outcomes for Science Teachers)

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Background and Introduction

- Teachers have single largest effect on student academic gains
  - Specifically, the teacher *knowledge*
  - Need both SMK and PCK to be effective
  - KOSM is an essential component of PCK
- Teachers undergo PD to become more effective than before
  - Hundreds of millions of dollars spent towards goal
  - Does it achieve the desired goal?
- Very few *large-scale* studies of PD program effectiveness
  - Tend toward small-N sizes, local effects
  - Outcome measures are tailored to specific programs, limiting generalizability

Abbr.	Explanation
PD	Professional development
SMK	Subject matter knowledge
PCK	Pedagogical content knowledge
KOSM	Knowledge of student misconceptions

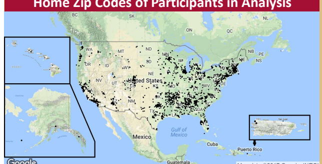
- PDMOST study
  - Large-scale and distributed for increased power and generalizability
  - Outcome measures based on national standards across fields
  - Studies effectiveness of PD at increasing SMK and KOSM, the essential components of teacher knowledge required to be effective
  - Connect contents of the PD to changes in outcome measures (teacher knowledge), rather than introspective self-reports.

Data Collection Methods

Surveys was administered during the summers of 2015 and 2016 to participants of PD programs aimed at K-12 science teachers.

1858 geographically distributed participants responded to the pre- and post-survey. representing 227 different PD sessions from a total of 53 different providers

Home Zip Codes of Participants in Analysis



Dots indicate that at least one participant provided a home ZIP code in that location. Map is scaled independently for each inset (Hawaii, Alaska, and Puerto Rico) for clarity. All 50 states + Puerto Rico have at least 2 unique zip codes provided, with a median of 18.5 and a maximum of 210.

Measured participant SMK and KOSM with a series of multiple choice questions covering the subject- and grade-relevant K-12 NRC science standards:

- Received credit for their SMK for correctly answering the question.
- Received credit for their KOSM for correctly answering the question (as above) and also correctly identifying the most common student misconception (defined as the single incorrect answer chosen by more than 50% of students who got it wrong).

The pre-survey also asked about the participants' educational history and teaching experience. The post-survey included questions about how the PD program was conducted, with a large focus on the frequency of various common features.

Mean Gains of Participants

Does attending a PD program help participants increase their SMK and/or KOSM, on average?
SMK: Yes, but only a small amount, particularly compared to average possible gain (28% incorrect)
KOSM: No, which might explain why the mean KOSM score was much lower than SMK.

T-test of Mean Gains

		Mean	C.I.	t-score	Signif.	Cohen d
SMK	raw gain (0-1 scores)	0.0186	(0.0135, 0.0238)	7.0941	p < 0.001	0.0624
	in terms of s.d.	0.1163	(0.0841, 0.1484)			
KOSM	raw gain (0-1 scores)	0.0047	(-0.0025, 0.0118)	1.2745	n.s.	n.s.
	in terms of s.d.	0.0275	(-0.0148, 0.0698)			

Linear Model of Gains

Constructing the model: Regression models for SMK and KOSM gains were constructed in parallel, constrained to use the same predictors. Starting with the participant-level variables, non-significant predictors were iteratively removed until all remaining predictors were significant for at least one of SMK and/or KOSM. This process was then repeated with the provider-controlled variables added, and the overall model was pared down to the final form, below.

Participant-level vs Provider-controlled: The top half of the model describes variables which describe the participant, their background, and other factors that a prospective PD provider cannot easily control. The bottom half (below the dashed line) describe variables which the provider can directly and easily adjust, such as the content of the PD and how it is delivered.

Things that were not found to be significant:

Participant-level: whether participant degree or certification was in a related field to the subject of the PD program; the highest level of achieved degree (i.e., Bachelors vs. Masters, etc.).

Provider-controlled: whether the program was conducted as an online, overnight, or day program; who was involved in presenting the PD program; and whether the perceived goal of the program was to increase participant knowledge of SMK, PCK, or curricula knowledge. **Notably, program duration (in days, from 1-20) was not found to have any significant association with either SMK or KOSM gains.**

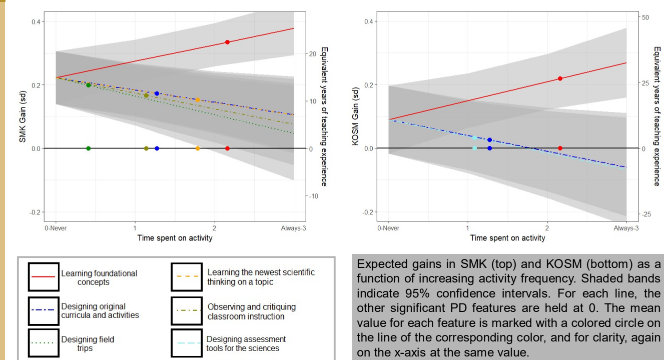
PD features: including learning reformed pedagogies like Inquiry-Based Learning techniques, Active Learning activities, or Modeling Method of Instruction activities; learning strategies for incorporating science content, cross cutting concepts, or science and engineering practices into the science curriculum; participating in lectures or workshops led by either research scientists or science educations; learning strategies for using simulations, collecting and/or analyzing data, or collecting information from the internet with students in the classroom; conducting scientific research; or collaborating with colleagues in the same domain, grade, or geographic area.

Linear Model of SMK and KOSM Gains

		SMK gains Est.	SMK gains SE	SMK gains Sig	KOSM gains Est.	KOSM gains SE	KOSM gains Sig
(Intercept)		0.041	0.079		0.128	0.102	
Pretest SMK Score (standard deviation)		-0.382	0.020	***	0.183	0.025	***
Pretest KOSM Score (standard deviation)		0.037	0.019		-0.565	0.026	***
Gender (ref: Female)	Male	0.141	0.037	***	0.056	0.047	
	Other	0.240	0.201		-0.373	0.229	
Field (ref: Life Science)	Chemistry	-0.122	0.061	*	-0.057	0.079	
	Earth Science	-0.163	0.067	*	-0.416	0.087	***
	Physics	-0.323	0.059	***	-0.259	0.076	***
	Physical Science	-0.176	0.057	**	-0.291	0.073	***
	Space Science	-0.212	0.056	***	-0.272	0.073	***
Grade Band (ref: 5-8)	"Elementary" (K-4)	0.047	0.046		0.011	0.060	
	"High School (9-12)	0.075	0.064		-0.111	0.083	
Closest related past class subject (ref: Matched)	Other non-science	-0.263	0.048	**	-0.153	0.063	
	General science	-0.051	0.089		0.003	0.110	
	Other science	-0.012	0.050		0.017	0.062	
Per Year of Teaching Experience		0.006	0.002	***	0.000	0.002	
Previously attended a PD program		-0.064	0.015	*	0.030	0.019	
Only taught a different grade band		-0.096	0.044	*	-0.043	0.056	
Goal of program to increase participants' knowledge of "Other" (i.e., not SMK, PCK, or curricula knowledge)		-0.038	0.032		-0.182	0.041	**
Attended because program	…provided an opportunity to learn new or innovative methods of teaching science	0.124	0.031	**	0.118	0.040	*
	…looked fun, challenging, or personally rewarding.	0.079	0.044	*	0.108	0.058	**
How often was time spent…	…designing student field trips	-0.044	0.041	**	-0.006	0.051	
	…learning the newest scientific thinking on a topic	-0.038	0.017	*	-0.032	0.022	
	…learning foundational concepts in the sciences	0.046	0.015	**	0.053	0.020	*
	…developing original curricula / activities	-0.040	0.018	*	-0.051	0.024	*
	…observing and critiquing classroom instruction	-0.054	0.019	**	-0.007	0.024	
	…designing assessment tools for the sciences	-0.010	0.020		-0.053	0.026	*
Variance Explained ‖ Adjusted R^2		0.259 ‖ 0.248			0.272 ‖ 0.261		

Significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Marginal Effects of PD Features



Expected gains in SMK (top) and KOSM (bottom) as a function of increasing activity frequency. Shaded bands indicate 95% confidence intervals. For each line, the other significant PD features are held at 0. The mean value for each feature is marked with a colored circle on the line of the corresponding color, and for clarity, again on the x-axis at the same value.

Interpreting the Results

Largest effect sizes are for things that are outside of the control of a PD provider, but are worth paying attention to when designing policy and strategy:

- Higher incoming SMK makes it easing to learn KOSM; easier to learn student misconceptions when you're not struggling with your own?
- Some subjects are harder to improve in than others; do those subjects need new approaches to PD?
- Teachers who repeatedly attend PD learn less new subject knowledge than first timers, even after controlling for their prior teaching experience and incoming knowledge; are these teachers being failed by the system?
- Teachers testing in subjects or grade bands where they had no prior teaching experience showed significantly lower gains: PD is much less effective at helping bridge a teacher between subjects.

Small effect sizes (d << 0.3) for things that are within the control of a PD provider:

- Knowledge gains associated with teaching fundamental concepts over any other activity.
- Effect of attending a PD still much larger than average gains accumulated over a year of teaching; mean SMK gains for attending a PD become equivalent to over 7 years of experience teaching, while the standardized effect of a particular PD feature is of the same magnitude as 2-4 years per standard deviation change.

Average SMK and KOSM gain (in s.d.) per year of prior teaching experience

	Mean	95% conf. int.
SMK/year	0.0149	(0.0090, 0.0208)
KOSM/year	0.0083	(0.0027, 0.0139)

Key Findings

- Focus on teaching foundational concepts in the sciences
  Improve teacher SMK and KOSM through PD by maintaining a focus on foundational concepts throughout the program. Strong focus on creating new content takes time away and tends to result in no SMK/KOSM gains.
- Make the program intellectually and/or personally engaging
  Teachers who come to PDs they find interesting or engaging tended to have significantly higher knowledge gains, among the largest effects seen.
- Learning science content without prior teaching experience is hard
  PD is less effective at rapidly bringing teachers up to speed in a brand new subject, though it works for transfer between subjects. Certain subjects apparently harder to learn than others.
- PD can serve as a catch-up tool for experienced teachers who have gaps in their SMK

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