Professional Development for STEM Integration:
Analyzing Bioinformatics Teaching by Examining Teachers' Qualities of Adaptive Expertise

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INTRODUCTION

OBJECTIVES

To investigate challenges teachers experienced in implementing a PBL bioinformatics unit after participating in PD activities that were constructed using research-based effective PD practices.

BIOINFORMATICS

An interdisciplinary field that combines informatics methods (e.g., use of large scale aggregate data) with biological applications to address environmental and medical issues such as how to mitigate asthma in urban centers due to low air quality.

ADAPTIVE EXPERTISE (AE)

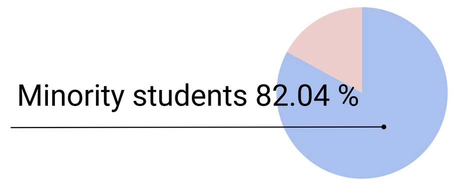
We examined teaching practices through the lens of AE:

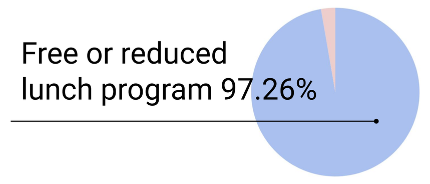
1) ***Flexibility,*** the ability to apply their knowledge to new situations, and spontaneously changing enactments.
2) ***Deep-level understanding,*** sufficient understanding of the content in order to recognize meaningful patterns quickly.
3) ***Deliberate practice,*** engaging in reflection, conscious deliberation, and regulation processes.

METHODS

PARTICIPANTS

- 5 high school science teachers (Females: 3; Males: 2)
- Teaching experiences: 2 – 17 years (Mean: 10.8). Nominated as the best biology and environmental science teachers in the district
- 122 students





DATA SOURCES

- 30 observation notes across five teachers' classrooms (range: 5 – 8 observations; 50 – 90 mins for each period)
- Informal debrief interviews (range: 5 – 20 mins)
- 5 semi structured interviews (range: 26 – 108 mins)
- Student Likert-scale pre- and post-survey (39 items, 5 constructs; n=122)

DATA ANALYSIS

- Coded for adaptive expertise category (High, Medium, Low).
- Total of 251 enactments, with 16 double codes.
- Cronbach's IRR score = 0.73, from 20% of the data (n=51).
- Exploratory factor analysis

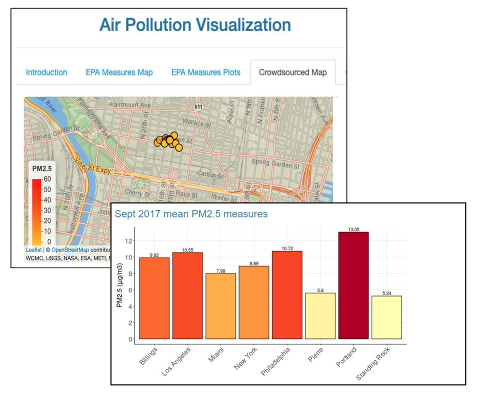
STEM-INTEGRATED CURRICULUM: K-12 BIOINFORMATICS

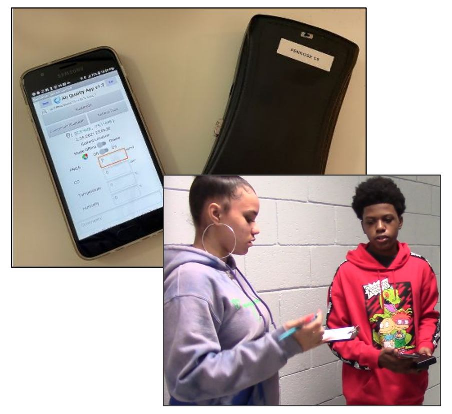
- 16 lessons

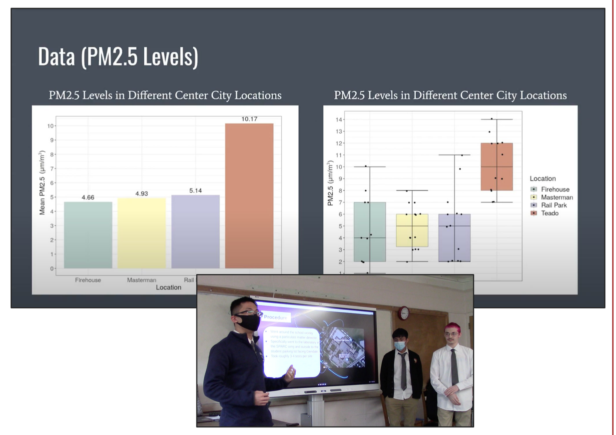
Problem-based learning | Outdoor data collection | Data analysis and visualization

Issue of asthma rates in urban environments

Air quality data collection through sensors and app







TEACHER PD

- July 2019, 75 hours
- Areas of Core Teacher Knowledge: Bioinformatics; Data Science; Problem-Based Learning; Socioscientific issues; Mobile Learning; Culturally Relevant Pedagogy

WEEK 1	WEEK 2	WEEK 3
Focusing on areas of teacher knowledge, teaching context, and population, collaboration	Tailoring and adopting the curriculum for local classroom teaching in small teams	Piloting revised core lessons to a small set of high school students

- Emphasis on real-world application

FINDINGS: TEACHERS

ADAPTIVE EXPERTISE SCORES BY CATEGORY

Teacher	Flexibility	Deep-Level Understanding	Deliberate Practice	Overall Expertise
Teacher 1	2.24	2.40	2.33	6.97
Teacher 2	1.97	1.20	2.16	5.33
Teacher 3	1.93	1.70	2.17	5.80
Teacher 4	2.19	1.91	2.33	6.44
Teacher 5	1.56	1.32	2.10	4.97
Average	1.98	1.70	2.22	5.90

- AE combined score range: 4.97 – 6.97 (out of 9)

CHALLENGES IN IMPLEMENTING PROJECT ACTIVITIES

- **Implementation complexity** (51%, 60 comments)

  "And so having gone through it in actuality, there was a couple things that I found tricky. I found tricky the keeping track of all the devices and the technology. [It was like] "Okay. Here. I'll give you this device. Wait a minute. I didn't…mark who actually had that device."

- **Content preparedness** (32%, 38 comments)

  "We were good in terms of the other science concepts that were there, like asthma and air quality particles. But as far as the statistics and relating that real research to our … and teaching our students that, I think I was a little bit under prepared."

- **Alignment with familiar pedagogical supports** (9%, 11 comments)

  "I feel like if I just would have planned this out more, you would've had kind of more things to use in our toolbox like handouts, notes, things like that. More substantial things that we can implement."

- **Resource navigation and access issue for just-in-time instruction** (8%, 9 comments)

  "But I think by the time that I was teaching that myself, it required some more review. When I was [in the PD workshop], I was kind of getting it, but I think [only] because [the bioinformatics instructor] was right there."

ACKNOWLEDGEMENT: This work is funded by the U.S. National Science Foundation DRK12 program, grant DRL #1812738

FINDINGS: STUDENTS

Student Classroom Experiences

Factor	Pre-Survey Average (SD)	Post-Survey Average (SD)	Paired *t*-test results
Interest in real-world data	3.74 (.92)	3.79 (.95)	t = -.82, p = .413
Bioinformatics	3.31 (1.15)	3.71 (.94)	t = -4.07, p <.001
Data literacy	4.32 (.78)	4.28 (.78)	t = -.57, p = .564
Computational tools	3.00 (1.12)	3.79 (.92)	t = -.95, p < .001
Local community	2.27 (1.16)	3.18 (.98)	t = -8.31, p < .001

Teachers' AE Predicts Student Classroom Experiences

Student Construct Being Modeled	Predictors	Estimates (SE[a])	Pr(>|t|)
Overall Experience	Teacher AE	5.09 (1.73)	.0045
	Pre-score	.15 (.08)	.054
Interest in real-world data	Teacher AE	.45 (.82)	.583
	Pre-score	.39 (.11)	.0075
Bioinformatics	Teacher AE	1.58 (.65)	.0164
	Pre-score	.06 (.07)	.4315
Data literacy	Teacher AE	.97 (.24)	<.001
	Pre-score	.12 (.08)	.1161
Computational tools	Teacher AE	1.27 (.38)	<.001
	Pre-score	.06 (.07)	.369
Local community	Teacher AE	.59 (.33)	.0764
	Pre-score	.17 (.09)	.0728

IMPLICATIONS

- The interdisciplinary nature required for STEM-integration, where teachers necessarily must become expert and understand how to authentically integrate STEM content, adds further complexity in terms of how best to support teachers.
- The study analyzed teachers' AE in teaching STEM-integrated instruction, revealing significant differences in their AE due to variations in flexibility (pedagogical content knowledge) and deep-level understanding (content knowledge).
- Lower AE scores of teachers were linked to a lack of content preparedness, emphasizing a critical feature of success for STEM-integrated instruction, which is the ability to fully integrate different knowledge domains.
- Teachers did not feel competent or confident in data literacy aspects of the curriculum, which could explain why there was no significant growth in the factors related to student interests in working with real-world data.
- Understanding of teacher content knowledge can impact what and how students learn in STEM-integrated curricular experiences.
- There is a need for more training of teachers in content areas that they are less familiar with in the STEM topics being integrated (e.g., Brand, 2020).
- PD activities must provide specific examples, annotated resources, and more detailed rationales for how integrating core topics supports real-world problem solving.
- Understanding the nature of teacher challenges with respect to teaching emerging science content and methods is critical to consider when building PD experiences.

REFERENCE: Yoon et al. (major revisions). Making the case to improve teachers' STEM-Integrated content knowledge: An analysis of teachers' adaptive expertise and impacts on student classroom experiences. *Journal of Research in Science Teaching.*

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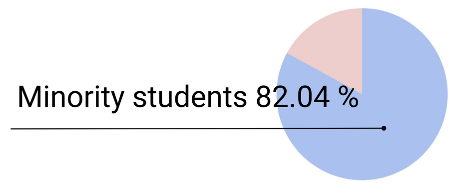

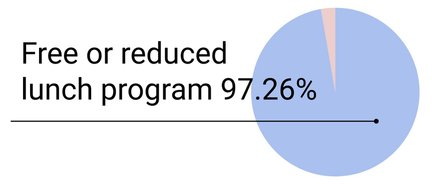

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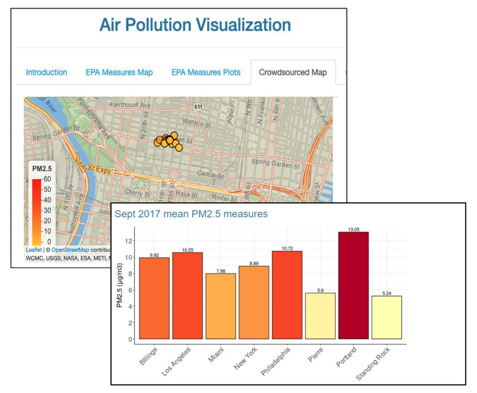

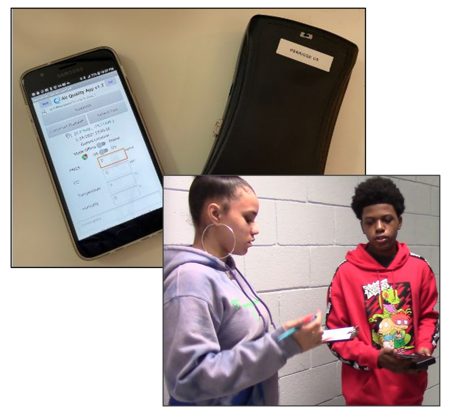

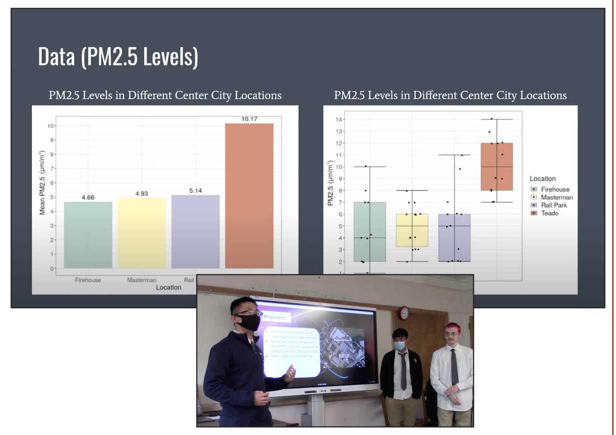

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Student Classroom Experiences

Factor	Pre-Survey Average (SD)	Post-Survey Average (SD)	Paired *t*-test results	Effect Size (Cohen's *d**)
Factor 1	3.74 (.92)	3.79 (.95)	$t(121) = -.82, p = .413$	
Factor 2	3.31 (1.15)	3.71 (.94)	$t(121) = -.4.07, p < .001$	.25
Factor 3	4.32 (.78)	4.28 (.78)	$t(121) = -.57, p = .564$	
Factor 4	3.00 (1.12)	3.79 (.92)	$t(121) = -.95, p < .001$	.51
Factor 5	2.27 (1.16)	3.18 (.98)	$t(121) = -8.31, p < .001$	.45

*Cohen's *d* value of .2, .5, and .8 represent small, medium, and large effects (Cohen, 1998)

- Factor 1: Interest in real-world data
- Factor 2: Bioinformatics
- Factor 3: Data literacy
- Factor 4: Computational tools
- Factor 5: Local community

Teachers' AE Predicts Student Classroom Experiences

Student Construct Being Modeled	Predictors	Estimates	Std. Error[a]	*t*-value	Pr(>|*t*|)	Cohen f^{2b}
Overall Experience	Intercept	64.58	15.7	4.12	<.001	
	Teacher AE	5.09	1.73	2.93	.0045	.034
	Pre-score	.15	.08	1.95	.054	
Factor 1	Intercept	24.99	7.78	3.21	.0017	
	Teacher AE	.45	.82	.55	.583	-
	Pre-score	.39	.11	3.46	.0075	
Factor 2	Intercept	14.81	4.91	3.02	.0031	.005
	Teacher AE	1.58	.65	2.43	.0164	
	Pre-score	.06	.07	.79	.4315	
Factor 3	Intercept	5.50	1.69	3.28	.0014	.02
	Teacher AE	.97	.24	3.82	<.001	
	Pre-score	.12	.08	1.58	.1161	
Factor 4	Intercept	10.04	2.87	4.01	<.001	.004
	Teacher AE	1.27	.38	3.39	<.001	
	Pre-score	.06	.07	.90	.369	
Factor 5	Intercept	4.72	2.44	1.93	.0555	.03
	Teacher AE	.59	.33	1.79	.0764*	
	Pre-score	.17	.09	1.81	.0728*	

*Denotes instances where Teacher AE or Pre-score was a marginally significant predictor of student outcome being measure.
[a]Robust standard errors to correct for dependence of test scores (students nested within teachers' classrooms).
f^2 values of .02, .15, and .35 represent small, medium, and large effects (Cohen, 1988).

IMPLICATIONS

- There is a need for more training of teachers in content areas that they are less familiar with in the STEM topics being integrated (e.g., Brand, 2020).
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