Geoscience for justice: A pedagogical model of transformative science learning

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Research Series Virtual Brown Bag

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Presentation Outline

- Motivation for the work
- Theoretical framework
- Research design
  - Lines of inquiry (RQs)
  - Data collection and analysis
  - Results and implications
- Questions and discussion

Motivation

Educational opportunity gap

- Lack of access to curricula that combines relevant science content and investigative practices (Basu & Barton, 2007)
- Outcome of lack of access: undermines student interest, perceived relevance, and perceived value of science (Buxton, 2010; Brkich, 2014)

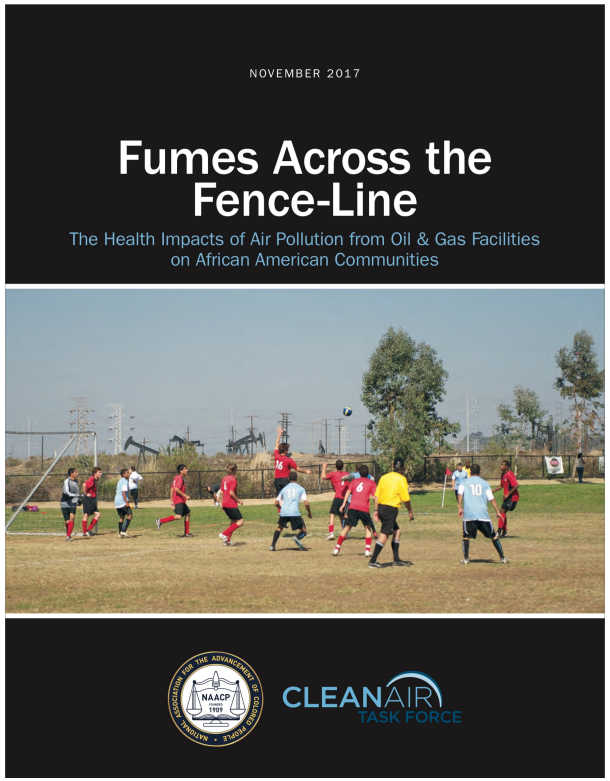
Environmental injustice in impoverished and historically marginalized communities

- Poor indoor and outdoor air quality (Mantaay, 2007; Miranda, Edwards, Keeting, & Paul, 2011; Pastor, Morello-Frosch & Sadd, 2006; Wodtke et al, 2022)
- Poor quality drinking water and sewage systems (Balazs, Morello-Frosch, Hubbard, & Ray, 2011; Balazs & Ray, 2014; Heaney, Wilson, Wilson, Cooper, Bumper & Snipes, 2011, 2013)
- Students attend schools located near or on brown fields (areas of high exposure to environmental hazards) (Pastor, Sadd & Morello-Frosch, 2004)
- Residents in poor and segregated communities are projected to be the most vulnerable to the adverse impacts of climate change (Shonkoff, Morello-Frosch, Pastor & Sadd, 2011; EPA, 2021)
- Disproportionate exposure and magnitude of exposure to environmental toxins [Risk Screening Environmental Indicators (RSEI; Sicotte & Swanson, 2007)]

Environmental Injustice

Villarosa, L. (2020). Pollution is killing Black Americans. This Community Fought Back. *The New York Times Magazine*.

Fleischman, L. & Marcus, F. (2017). *Fumes across the fence-line: The health impacts of air pollution from oil & gas facilities on African American communities*. NAACP and Clean Air Task Force.



Environmental Injustice

Socially vulnerable communities will be disproportionately impacted by climate change

EPA (2021). Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003. www.epa.gov/cira/social-vulnerability-report

Environmental Injustice

SCIENCE ADVANCES | RESEARCH ARTICLE

COGNITIVE NEUROSCIENCE

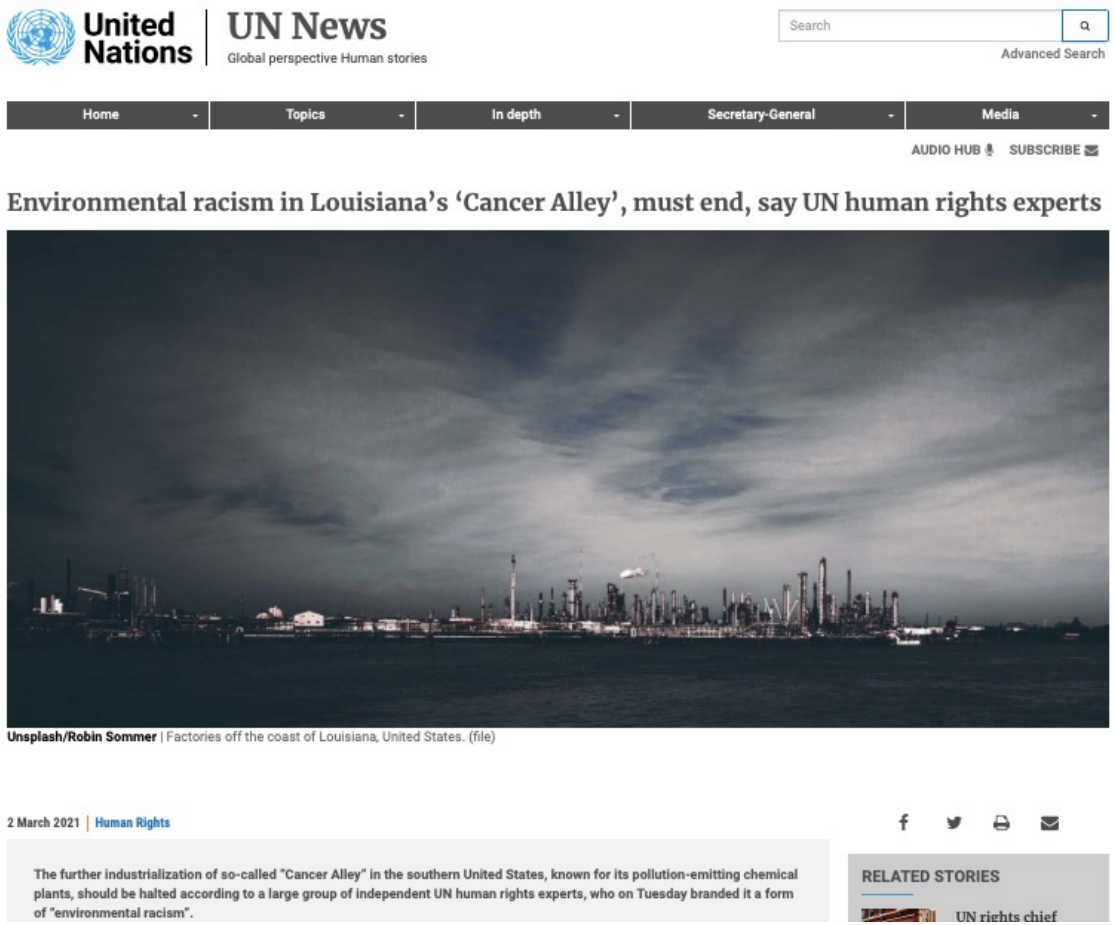
Concentrated poverty, ambient air pollution, and child cognitive development

Geoffrey T. Wodtke[1]*, Kerry Ard[2], Clair Bullock[2], Kailey White[1], Betsy Priem[1]

Why does growing up in a poor neighborhood impede cognitive development? Although a large volume of evidence indicates that neighborhood poverty negatively affects child outcomes, little is known about the mechanisms that might explain these effects. In this study, we outline and test a theoretical model of neighborhood effects on cognitive development that highlights the mediating role of early life exposure to neurotoxic air pollution. To evaluate this model, we analyze data from a national sample of American infants matched with information on their exposure to more than 50 different pollutants known or suspected to harm the central nervous system. Integrating methods of causal inference with supervised machine learning, we find that living in a high-poverty neighborhood increases exposure to many different air toxics during infancy, that it reduces cognitive abilities measured later at age 4 by about one-tenth of a standard deviation, and that about one-third of this effect can be attributed to disparities in air quality.

Wodtke, G. T., Ard, K., Bullock, C., White, K., & Priem, B. (2022). Concentrated poverty, ambient air pollution, and child cognitive development. *Science Advances*, *8*(48), eadd0285.

Environmental Injustice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Environmental racism in Louisiana's 'Cancer Alley', must end, say UN human rights experts

Unsplash/Robin Sommer | Factories off the coast of Louisiana, United States. (file)

2 March 2021 | Human Rights

The further industrialization of so-called "Cancer Alley" in the southern United States, known for its pollution-emitting chemical plants, should be halted according to a large group of independent UN human rights experts, who on Tuesday branded it a form of "environmental racism".

RELATED STORIES

UN rights chief

- Former site of forced labor/enslavement of African Americans
- Site of 4 African American ancestral burial grounds
- Current site of 150 oil refineries, plastics plants, and chemical facilities
- Cancer, respiratory illness
- Cancer risk 104-105 cases per million for African American communities compared to 60-75 cases per million for predominantly White communities

United Nations News (2021, March 02). Environmental racism in Louisiana's "Cancer Alley", must end, say UN Human rights experts. https://news.un.org/en/story/2021/03/1086172

Environmental Injustice

EPA (2021). Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003. www.epa.gov/cira/social-vulnerability-report

Fleischman, L. & Marcus, F. (2017). *Fumes across the fence-line: The health impacts of air pollution from oil & gas facilities on African American communities*. NAACP and Clean Air Task Force.

Taylor, D. (2014). Toxic communities. In *Toxic Communities*. New York University Press.

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Theoretical Framework:
Transformative learning experience (TE)

Operationalization of Transformative Experience

Transformative learning experience (TE): cognitive, affective, and behavioral (Pugh, 2002; Pugh, 2020)

- Perceived relevance
- Perceived value
- Application

Learning outcomes of Transformative Experiences

- increased engagement with academic content, positive affect (enjoyment), and improved conceptual change (Heddy & Sinatra, 2013)
- increased interest (Heddy & Sinatra, 2017)
- knowledge transfer (Pugh, Linnenbrink-Garcia, Koskey, Stewart & Manzey, 2010)

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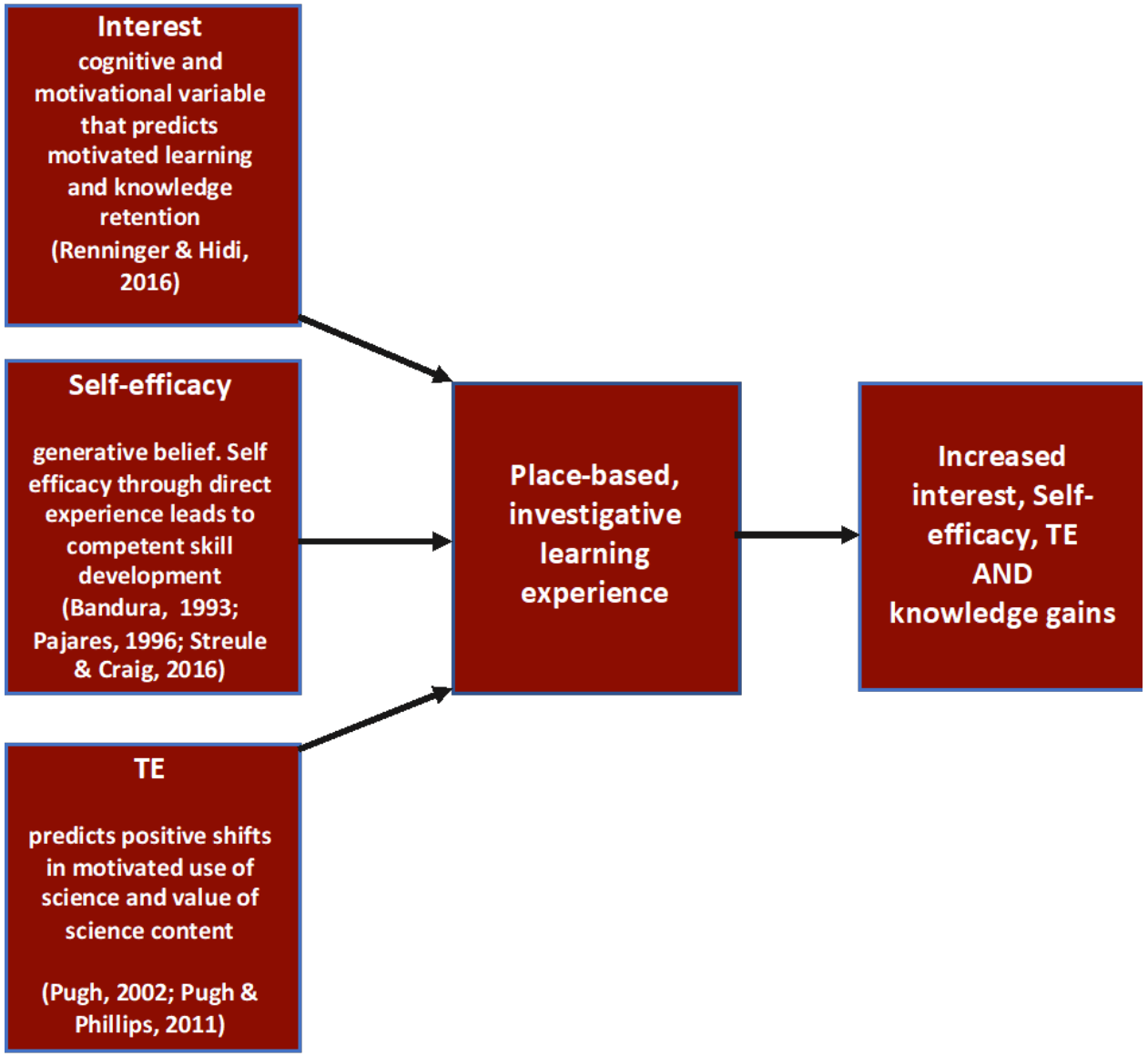
The Pedagogical Model



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Research Questions

Research Question 1:

(a) Is this pedagogical model of Earth science effective with respect to leading to desired learning outcomes?

(b) For students who experience transformative learning (intervention), what are the pre to post and delayed post differences in TE (perceived value and relevance of Earth science), application of Earth science concepts, and knowledge?

Research Question 2:

Does TE as a learning outcome differ for students who express more as opposed to less awareness of environmental issues in their local communities?

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Methods: Participants

Methods:

- purposeful criterion sampling
- quasi-experimental between and within subjects comparison
- mixed methods
- convergent parallel design within a pragmatic paradigm

Participants:

- high school science students

Intervention:

- Four academic tasks
- Flint, MI as a case study
- Written reflective prompts

Comparison:

- Four academic tasks
- Online exploration of geoscience careers
- Written summary responses

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Instrumentation

TE

TE measure

- 7-items
- 5-point Likert-type scale, with some open-response follow up questions
- Cronbach's α = .855 [acceptable; (Tavakol & Dennick, 2011)]

Knowledge

Knowledge instrument

- 10 items from validated instruments
- 5-point Likert-type scale questions
- Earth science and water quality content

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Methods:
Statistical Procedures

- Repeated Measures ANOVA (RQ1)
- Sequential (Hierarchical) Linear Regression (RQ2)
- Structural Equation Modeling (SEM) and Path Analysis (RQ 1)

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Results:
Repeated Measures ANOVA

Statistically significant and meaningful pre to post increases in TE by Grade:

$F(2, 155) = 7.13$ $p = .001$ $\eta 2 = 0.84$

Statistically significant and meaningful pre to post gains in knowledge for the intervention group:

$F(1, 159) = 7.34$ $p = .007$ $\eta 2 = .044$ (Intervention)

$F(1, 159) = 1.30$ $p = .255$ (Comparison Group)

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Results:
Repeated Measures ANOVA (3 time points)

Statistically significant and meaningful pre to post and delayed post gains in knowledge by subject—Biology

F(2, 128) = 3.56, *p* = .031, η2 = .053 (Intervention Group)

Statistically significant and meaningful pre to post and delayed post increases in TE by subject—Earth and Space Science

F(2, 127) = 5.53, *p* = .005, η2 = .08

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Results: Sequential Linear Regression

Predictors of Learning Outcomes

Model	ΔR^2	*p*-value
1	.045	.009
2	.574	< .001
3	.047	< .001

Model 1 predictor: School
Model 2 predictors: School, Intervention, General Science Interest (pre), Knowledge (pre), TE (pre), Grade Level, Course
Model 3 predictors: School, Intervention, General Science Interest (pre), Knowledge (pre), TE (pre), Grade Level, Course, **Environmental Awareness**

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Scholarly Contribution

Evidence of the efficacy of a pedagogical model leading to:

- positive attitudinal shifts in student perception of Earth science content as relevant, valuable, and applicable
- knowledge gains retained pre, post, and delayed post
- Engagement of students in critiquing persistent patterns of environmental injustice
- curricular access to investigative practices
- actionable knowledge for both geoscience/Earth science educators and education researchers with respect to designing effective learning experiences

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Questions and Discussion

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Thank You!