

uncertainty management

*p < .05, ** p < .01, *** p < .001

Thrill Seeking

National Science Foundation

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Research Questions

RQ 1: How does sustained engagement with professional development in uncertainty management affects teachers' capacity to recognize and utilize student epistemic uncertainty as a **pedagogical resource** for engaging students in productive struggle to develop scient knowledge?

RQ 2: How do teachers' instructional practice in managing epistemic uncertainty change over time when they utilize epistemic uncertainty as a pedagogical resource for engaging students in productive struggle?

RQ 3: How do teachers' approach to managing uncertainty influence students' perceptions, practice, and management of epistemic uncertainty?

Students from twelve middle-school teacher classroom

1	nder Grade		Tota	
	6th 7th		8th	
Male	45	165	242	252
Female	45	124	215	384
Non-binary	1	15	24	40
Total	91	304	481	876
Confirmatory Factor Analysis		OU2 Scientific U	gement	modeling I Epistemic Curiosity (Litman, 2008; Post-survey)
.759* (.041) .759* (.041) .713* (.045) .750* (.059) .585* (.059) .585* (.059) .585* (.070) .6	toward uncertainty in knowledge development 500* (041) 631* (035) 634* (035) 654* (036) 635* (043) 25* (647* (044) 49) 9 Positive reactions to uncertainty 570* (044) 166 592* (051) 095) Negative reactions to uncertainty 166 573* (053) 095) Self-efficacy in uncertainty 529* 057) Self-efficacy in uncertainty 529* 057) Strategy for uncertainty 529* 057) Strategy for uncertainty 529* 057) Strategy for uncertainty	OU5 Orient tow uncerta know develo OU6 Rnow develo OU8 PR1 PR2 PR3 PR3 PR4 PR4 NR1 NR2 NR2 NR3 Self-ef in uncerta manage SE1 Self-ef in uncerta manage SE2 SU1 SU1 Strateguncerta manage	ard ainty in ledge opment itive ons to tainty ative ons to tainty efficacy ertainty gy for tainty ative tainty	0.097 (ns)
Structural Equa	ation modeling II	Negative		*p < .05, ** p < .01 tainty and Overt Soc
Management (Pre-survey) Orientation toward uncertainty in knowledge development Positive reactions to uncertainty 1	Six-Dimensional Curiosity (Kashdan et al., 2020; Post-survey) 20* -0.169* -0.169* Deprivation Sensitivity 189* 0.399*** 0.399*** Overt Social	- Overall, r	Significant	• сентерности • сентерности
Self-efficacy in uncertainty	\backslash	Reference	ces	

r subscales while separating overt and covert social curiosity ality and Individual Differences, 157, 109836. Litman, J. A. (2008). Interest and deprivation factors of epist riosity. Personality and individual differences, 44(7), 1585-

Managing Uncertainty for Productive Struggle: Exploring Teacher Development for Managing Students' Epistemic Uncertainty as a **Arizona State** University **Pedagogical Resource in Project-Based Learning**

Ying-Chih Chen & Michelle Jordan Mary Lou Fulton Teachers College, Arizona State University Ying-Chih.Chen@asu.edu; Michelle.E.Jordan@asu.edu

				Project Year	Summer		Fall	Spring
t Its'	Manage Scientific Uncertainty for Productive	explore for inducing struggle "Why do with uncertainties do students struggle with?" Conceptual Epistemic	fy sources of struggle students struggle ertainty? Where is nty coming from?" Cy Ambiguity	2021-2023 (Baseline data collected 2021-2023; 2021 for the first 12 teachers; 2022 for another 12 teacher)	Summer Professional Development	Pretest (Achievement Test & Uncertainty Survey) Sustaine	Observation, Interview, Teacher Reflection Journal	Post-test (Achievement Test & Uncertainty
tific	Struggle	uncertainty Uncertainty Incoheren	ce Conflict Core Sequence Task concepts Core	2022-2024		Observa	l Comparison of ational Data tial Analysis)	Longitudinal, design Experimental Comparison
			Meaningful/ Just-in-time Perceived Authentic Just-in-time complexity			(Sequen	liai Analysis)	
						ays to manage uncertaint Theory-driven combined with da		2)
ing			$\widehat{\mathbf{v}}$	Storylines (Reiser et al., 2021)	There is no lesson plan or pathway observed	Teacher designed a lesson plan involving mostly lectures and/or direct instruction with little time	Teacher intentionally designed a lesson integrating prior	a Teacher positions students as co-authors in knowledge building by intentionally
	Evaluate pathways		ognize and wrestle with scientific uncertainties to develop their scientific knowledge of help students explore and resolve scientific uncertainties derived from different			built in for student discovery or exploration		designed a lesson trajectory that helps students organize learning goals and integrate prior
	for sensemaking		cognitive sources	Raising				knowledge, practices, and explore uncertainties
У	✤ Stu		ective by pedagogically designing for relevance, timing, and complexity of scientific uncertainties	(Beghetto, 2020; Chen et al. 2019; Jordan, 2015; McDaniel et al., 2003)	, This was not observed	Teacher problematized a phenomena only in the beginning of a topic to elicit interest and foster engagement with the topic (surface level / shallow problematization) ; teacher did not provide opportunity to dig into it for further exploration	Teacher intentionally problematized a phenomenon and provided time and opportunity for exploration of the same or continued topic ; Raised related uncertainty after an instance of reduction - purpose is to practice higher level thinking and	Teacher intentionally problematized content to extend the phenomenon in a new way, direction, or application to practice higher level thinking and problem-solving skills/practices
			Questions to Guide Students	Maintaining			problem-solving skills	
			atize a Phenomenon	(Babrow et al., 1998; Chen et al., 2019; Jordan, 2015; Michaels & O'Connor, 2015	This was not observed	Teacher invited students to ask new questions but did not allow space/time to develop the ideas or critique other arguments	Teacher compared conflicting ideas either from literature or student ideas without additional time to develop new arguments	Teacher challenged students to clarify and critique arguments/claims made and strategically compared
oms		enomenon and identify students' aps and curiosities.	Knowledge: What am I certain about? What am I not certain about? What do I need to know?					conflicting claims to stimulate alternative ideas; rephrased questions to facilitate students' exploration of ideas
		certainty and develop a plan to address it.	<i>Question:</i> What are my questions about the phenomenon? m Products	Reducing (Babrow & Matthias, 2009; Brashers, 2001; Jordan, 2015)	This was not observed	Teacher gave answers promptly at the first sign of struggle - does not give details of why/how	uncertainties in groups and/or provided an answer key or resources if they got stuck. If th	Teacher scaffolds the information to support students to seek information needed, guides students to correct answers without telling them, uses familiar phenomena-based
	4 0						answer, they explain the concept or reasoning. Rephrasing a question or prompt in order to	
		ts to explore explore (e.g., dependent, independent) e and testable/ solvable problems		Postponing (Anderson, 2003; Brashers, 2001; Jordan, 2015)	This was not observed	Teacher does not answer student questions or uncertainties/walks away from students or groups that are verbally not		Teacher re-addresses students prior uncertainties and questions that were initiated throughout the class
			terial Practice			understanding the content		
	analyzing dat	to address the uncertainty, collecting and ta	Design: What investigation can I design to address my questions? Data: What data can I collect? How can I organize my	Teachers dem	onstrated a po	Teacher B sitive but limited awa		-
			data?	 pedagogical re Teachers perce 		nty as a way to induce	curiosity and persist	through struggle.
	1. Investigation/	/ design procedures/ prototype	m Products	 Teachers perceived uncertainty as a way to induce curiosity and persist through struggle. Teachers quickly reduced uncertainty, providing few opportunities for productive struggle during lesson enactment 				
	-		procedures/ prototype / different modalities (e.g., tables, figures, graphs, diagrams, pictures) • Uncertainty reduction strategies resulted in fractured uncertainty navigation pathy		ation pathways in			
	1 lateraret dete		nentative Practice	teacher const				
	testing/experi incoherent, or	a and meaning of the results of iments, including ambiguous, unexpected, or conflict results Iltiple perspectives, seek convergent Igs	 Solution (individual): What evidence do I have to support my claim? How consistent are my results (with my expectations and across the dataset)? Comparison (group): How do my results and my ideas compare with others? What should I change about my ideas or my science practices? What can I suggest to peers to help improve their investigation/analysis/prototype? 	Teaching Strategy ■ Supporting ↓ Conceptual Uncertainty	explain a pl ct and compare d to explain a p de unnecessary of students to focus Retrieve co ay knowledge (la	everyday language to henomenon liverse prior knowledge phenomenon onceptual uncertainties on target knowledge mtent and anguage & experience)	Phase 2. Identifica	<image/> <image/>
		Classroo	m Products	Epistemic Uncertainty			entify the gap in Idea ting understanding info	
		erpretation/ consensus of the phenomenon aims, understandings, processes that need		Navigation A Supporting			the phenomenon be pport deep reasoning (e.	etween variables .g., analogical) to
		v .	ication, and Transformation	Strategy and what a core conce		and what knowledge	ap in existing understanding knowledge to pursue amplify specific aspects of	
Р. Е.	generalizing k	ew questions and uncertainties linked to	Reflection: How have my ideas changed on a continuum between uncertainty and certainty? Relevance: What can I do with the new knowledge? How do I situate it relative to other things I care about or know? New uncertainty: What new questions or uncertainties does this knowledge raise for me? Transformation: How do I explain my ideas to different audiences using multiple modes of representation?	Teaching Strategy Supporting Conceptual Uncertainty Navigation	that can be comp connect to studer to further devi- entify conceptual ertainties that can in initial ideas	and knowledge resources rehensible to students its' everyday examples elop understanding	a core concept and the w	
): Briefe v. <i>Person</i>			m Products	Epistemic Uncertainty Navigation			Connect scientific knowledge to	Compare new understandings and apply the "best"
emic cu -1595.		he developed knowledge to theory (concep f the developed knowledge to make a pred		Supporting			observations	understanding to the phenomenon

2. Application of the developed knowledge to make a prediction in a new situation (practically)

Teaching Strategy

Research Assistants Emily Starrett (Mathematics Education) Jongchan Park (Learning Sciences) Carlos Meza-Torres (Science Education)

	F	Fall	Spring
al	Pretest (Achievement Test & Uncertainty Survey)	Observation, Interview, Teacher Reflection Journal	Post-test (Achievement Test & Uncertainty
	Sustaine	d Professional Learning Co	ommunities
	Observa	Comparison of tional Data ial Analysis)	Longitudinal, design Experimental Comparison
-	ays to manage uncertaintie Theory-driven combined with da		
	1	2	3
lesson hway	Teacher designed a lesson plan involving mostly lectures and/or direct instruction with little time built in for student discovery or exploration	Teacher intentionally designed a lesson integrating prior knowledge but does not dig deeper into the content to identify unanswered questions	Teacher positions students as co-authors in knowledge building by intentionally designed a lesson trajectory that helps students organize learning goals and integrate prior knowledge, practices, and explore uncertainties
ot	Teacher problematized a phenomena only in the beginning of a topic to elicit interest and foster engagement with the topic (surface level / shallow problematization) ; teacher did not provide opportunity to dig into it for further exploration	Teacher intentionally problematized a phenomenon and provided time and opportunity for exploration of the same or continued topic ; Raised related uncertainty after an instance of reduction - purpose is to practice higher level thinking and problem-solving skills	Teacher intentionally problematized content to extend the phenomenon in a new way, direction, or application to practice higher level thinking and problem-solving skills/practices
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			alternative ideas; rephrased questions to facilitate students' exploration of ideas
ot	Teacher gave answers promptly at the first sign of struggle - does not give details of why/how	Teacher asked students to discuss questions or uncertainties in groups and/or provided an answer key or resources if they got stuck. If the teacher immediately provides an answer, they explain the concept or reasoning. Rephrasing a question or prompt in order to get to the correct answer	Teacher scaffolds the information to support students to seek information needed, guides students to correct answers without telling them, uses familiar phenomena-based evidence to explain target concepts
ot	Teacher does not answer student questions or uncertainties/walks away from students or groups that are verbally not understanding the content	Teacher asks students to hold onto their predictions, questions or uncertainties but does not re-address them later	Teacher re-addresses students prior uncertainties and questions that were initiated throughout the class

Synthesize, evaluate, and apply the "best' new understanding to explain the phenomenon