Policy translation in assemblage: networked actors mediating science teachers' policy play

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Abstract

Educational policies exist as part of complex systems of many policies, all of which science teachers must make sense before using in practice. Using Actor-Network Theory to view policy translation in assemblages, we examine how networked actors mediate teachers' policy play. Drawing on ethnographic methods and post-structural analytic tools, we identified four mediating actors: espoused practices, learning events, administrator relationships, and communities of practice. These actors interact in the assemblage to mediate teachers' policy dilemmas and policy responses, as they play with policies. Our findings indicate a need to look more closely at the interactions of policies with one another in teachers' policy play, policy dilemmas as learning opportunities, the importance of social relationships with administrators in teachers' policy play, and the dangers of lethal fidelity in adoption. We see these findings as tools to assist teacher educators in planning for future teacher learning around their role as translators and implementers of policy.

Keywords Educational policy, Assemblage, Dilemmas, Policy responses, Policy play

Introduction

The examination of educational policy within the teaching and learning of science is a critical area of current research, especially given the increasing emphasis internationally on national standards and curricula. However, the impact of policy has far reaching consequences and does not always meet the intended purpose. Policy is translated to fit the needs of local actors (Braun et al., 2011; McLaughlin, 1987; Spillane et al., 2002) interacting with a multitude of other humans and non-human actors in a school network. These include, but are not limited to, administrators (Jenkins, 2020; Stillman, 2011), teaching colleagues (Coburn, 2001), communities of teaching practice (Gallucci, 2003), tools (Cobb & Jackson, 2012) and curricular resources (Penuel & Gallagher, 2009).

Failure to account for the system in which translation is situated has critical consequences for implementation (Spillane et al., 2002).

In the last 25 years two major policy reforms have influenced science education practice in the United States: No Child Left Behind Act of 2001 (*NCLB*) and the *Next Generation Science Standards* (NGSS)*. NCLB* mandated implementation of rigorous academic standards, which would be assessed through state-designed standardized tests, as a means of minimizing educational inequity (Penfield & Lee, 2010). Initially focused only on math and reading, *NCLB* added science to accountability measures in 2008. The NGSS, a national informal policy, was created by a collective of states and other stakeholders to improve students' engagement with the processes of science, taking a three-dimensional approach that balances content and practices (NGSS Lead States, 2013). However, current standardized testing models were designed prior to the NGSS's inception and are not well aligned with the NGSS's learning theories (National Research Council, 2014).

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Locally translated, the misaligned policies of *NCLB* and the NGSS resulted in dilemmas for actors in educational networks—what science should be taught and how? Networked effects of these dilemmas reduced science instructional time and resources (Anderson, 2012; Au, 2011; Aydeniz & Southerland, 2012; Judson, 2013; Malen, 2011; Milner et al., 2012) and limited uptake of new science pedagogical practices (Aydeniz & Southerland, 2012; Southerland et al., 2007). Unbalanced attention to math and reading in the early *NCLB* era pushed math and reading test-preparation practices into science classrooms (Perlstein, 2007), negatively impacting science learning outcomes (Maltese & Hochbein, 2012). This is not solely a challenge in the US. International assessments like the Programme for International Student Assessment (PISA), the Trends in International Mathematics and Science Study (TIMSS), the Progress in Reading Literacy Study (PIRLS) and country-specific assessments mean standardized testing impacts science education around the world (i.e., Jeong et al., 2023; Lundqvist & Lidar, 2021; Ma, 2021; Neumann et al., 2010; Suprapto et al., 2021; Yan, 2015).

Science education research has looked to mediate the dilemmas teachers face in translating education policies into science classrooms. In studies focused on teachers the influence of teacher beliefs (Hayes et al., 2019; Roehrig & Kruse, 2005), professional learning design (Allen & Heredia, 2021; Allen and Penuel, 2015; Ryder et al., 2018), and teacher understanding of the policy (Maeng et al., 2020) all influenced teachers' policy translation. Administrators initially translated policies at both district (Haverly et al., 2022) and building levels (Cherbow et al., 2020; McNeill et al., 2018; Wenner & Settlage, 2015) shaped the policy messages moving through the school networks, influencing network translations.

With multiple policies and so many potential influences, there remains work to be done that accounts for this complexity in policy translation. In this paper, we present an ethnographically informed study of one school district and the way teachers translate multiple intertwining policies influencing middle school science teachers' practice. These policies produce dilemmas (Windschitl, 2002) as policies meet in the assemblage and through play, are translated into practice (Koyama & Varenne, 2012). How components of the policy assemblage mediate teachers' policy play are at the epicenter of this cultural study.

Theoretical and conceptual framing

We draw on sociocultural theory in which individual change is rooted in and driven by social context and culture (Vygotsky, 1978). Sociocultural theory frames learning as the evolution and internalization of social practices (language, actions, norms) that occur within the affordances and constraints of the social structure in which an actor participates (Greeno, et al., 1996; Vygotsky, 1978). The translation of policies in schools is deeply contextual and situated (Braun et al., 2011), and capturing the small ways in which policies become part of the culture requires an examination of the culture itself. We use Actor-Network Theory to trace the micro-interactions of actors in an assemblage and how connections between actors, both human and non-human, are negotiated, renegotiated, shift and change, and come together to influence policy translations (Fenwick, 2010).

Actor-Network Theory (ANT) frames learning as a process of local struggle (Fox, 2000) inclusive of human and non-human actors, making it an excellent tool to trace how policy, a non-human actor, interacts with other actors in the networks of schools to produce effects on teachers' practice (Fenwick & Edwards, 2011). Fenwick (2010) elucidates the efficacy of ANT in the study of educational policy—centering artifacts and emphasizing socio-materialism dissolves global/local distinctions to see policies as effects of interactions and recognize the messiness of policy play.

Networks, in ANT, are "an assemblage of materials brought together and linked through processes of translation, that together perform particular function" (Fenwick & Edwards, 2011, p. 5). We use this definition to frame policy as an actor in school networks where policy is the attempt by one group to influence the actions of another (Stein & Coburn, 2008). These networks are mechanisms of power, in which "Societies, organizations, agents, and machines are all *effects* generated in patterned networks of diverse (not simply human) materials" (Law, 1992, emphasis original). Therefore, a policy's power and influence over the targeted community is an effect of the network in which the policy acts (Fenwick, 2010; Law, 1992). Likewise, teachers are networked effects of their past and present engaging with other actors, human and material to "get things done" (Fenwick & Edwards, 2011, p. 5).

Within science education, ANT studies often center single policies in the network. For example, Colston and Ivey (2015) used ANT in describing the sociohistorical entanglement of climate change in Oklahoma. At the center of this study was standards policy and the power relations which mediated the translation of new science standards. However, ANT opens opportunities to expand these findings and ask questions about policies that include the many negotiations, actors, and responses that influence school networks (Fenwick, 2010), bringing policy into play in networks among other policy actors.

The complex networks we aim to study are entangled with many other networks, inseparable except by our own choices of what and how to focus our work (Barad,

2007). Due to the complexity of the network, we chose to center teachers in the uncentered network to trace networked effects (Fenwick, 2010) of teachers' policy play. Conceptually, we focus on two key frames: policy dilemmas and policy assemblages. In this section, we first introduce the concept of dilemmas as a networked effect of interactions in assemblages. Next, we describe assemblage theory and its use in studying the complexity of policy translation through ANT.

Policy dilemmas

Policy making, such as the creation of standards, attempts to order practice from a distance (Fenwick, 2010), but during translation, negotiations occur at points of connection between actors in networks. One way to trace these negotiations in the assemblage is to identify how teachers express dilemmas related to translation of policies. Dilemmas are "aspects of teachers' intellectual and lived experiences that prevent theoretical ideals of [policy] from being realized in practice" (Windschitl, 2002, p. 132). Four categories of dilemmas describe different social aspects of networks which can challenge a teachers' philosophical, psychological, and epistemological understandings:

Conceptual dilemmas are rooted in teachers' attempts to understand the philosophical, psychological, and epistemological underpinnings of [the policy]. Pedagogical dilemmas for teachers arise from the more complex approaches to designing curriculum and fashioning learning experiences that [the policy] demands. Cultural dilemmas emerge between teachers and students during the radical reorientation of classroom roles and expectations necessary to accommodate the [the policy]. As various stakeholders in school communities question institutional norms and routines of privilege and authority are disturbed they often experience political dilemmas (Windschitl, 2002, p. 132).

Framing teachers work in terms of dilemmas has shown promise in describing the challenges teachers' experience in policy translation that employs a level of professional thinking (Tillema & Kremer-Hayon, 2005) to reconcile connections between actors, including new policies (Saroyan & Trigwell, 2015).

Dilemmas have been employed analytically to examine many different topics including equitable teaching (Braaten & Sheth, 2017), student-centered teaching (Harvey et al., 2015), curricula development and implementation (Luehmann, 2007; Nash et al., 2021) and new assessment practices (Caspari-Gnann & Sevian, 2022; Suurtamm & Koch, 2014), identity development (Luehmann & Tinelli, 2008), and technology implementation (Anthony & Clark, 2011). Though dilemmas exist as interconnected problems of practice (Braaten & Sheth, 2017; Windschitl, 2002), research about K-12 teachers' dilemmas often generalized across the four types of dilemmas or focused on one policy, practice, or source of change in teachers' practice. The messy, interconnected nature of policy requires further study of how dilemmas act in assemblages to influence policy translations.

Policy assemblages

Viewing policy translation through the lens of assemblages (Deleuze & Guattari, 1987), a concept associated with ANT (Koyama, 2015) allows space to encapsulate the complexity and multiplicity of policies in a network as a joint production of practice (Gorur, 2011; Strom, 2015). Drawing on Deleuze and Guattari (1987) and Delanda (2004), Strom defined assemblages as "a heterogenous collective of elements, both material and non-material, that come into composition in different ways at different times to produce a particular activity" (Strom, 2015, p. 322). These assemblages are always shifting and changing but become temporarily stable, a traceable "thing" (Koyama, 2014; Koyama & Varenne, 2012) enabling researchers to examine network power relations continually influencing policy translation (Fenwick & Edwards, 2011).

To move policies from object-like to material actors in assemblages of human, material, and discursive actors, we view the process of policy translation as "play" (Koyama & Varenne, 2012). Policy play is the selective maneuvering or appropriation of policy as it moves through the network (Koyama & Varenne, 2012). Drawing from an ethnographic study of New York City schools translating *NCLB,* Koyama and Varenne (2012) illustrated productive policy play as actors assembled educational reform. One principal described how a material actor in the network, a policy related tool for student data management, was simply an obstacle actors will work around, carrying on with their work relatively unchanged (Koyama & Varenne, 2012). This example demonstrates that policy always has room for actors to negotiate, interpret, and selectively translate, or play (Koyama, 2017, p. 66). The gap in literature we aim to fill is to better characterize how teachers engage in policy play, negotiating dilemmas to translate policies into practice.

School networks are messy assemblages of people, materials, policies, ideas, discourses, practice—all actors who, in relation, have the power to influence networks. We embrace this messiness and ask the following research questions:

- In what ways do actors in assemblages mediate teachers' dilemmas around policies as they respond to policies?
- In what ways do networked effects of teachers' assemblages influence their productive policy play?

Methodological design

We frame this work as an ethnographically informed study that uses traditional tools of educational ethnography in science education (Sherman et al., 2019; Green & Bloome, 2004; Hammond & Brandt, 2004). Ethnography in science education pushes on what science is (Brandt & Carlone, 2012) and in our case, what science education is and how policy contributes to its creation and application in a set of United States middle schools. Ethnographic methods capture the cultural implications of policies and how they are lived by the members of the system, examining policy as part of the infrastructure of schools embedded in multiple layers, actors, and spaces.

Ethnographic methods have previously supported cultural and ANT examinations of school policy. For example, Nespor (2002), using ANT, traced a parent's role in defining policy within a school district, describing how she moved and interacted with principals, teachers, other parents, children, and board members. Nespor highlighted ways this parent framed the policy of new standards as she interacted with the various infrastructure pieces. Muncey and McQuillan (1996), in another ethnographic study of educational policy, examined how teachers interacted with one another in ways to translate and respond to school policies. Ethnographic methods worked to decipher the who, how, for what of policy actors within the educational assemblages (Koyama, 2015). The assemblage relationships revealed ways policy has been understood and transfigured as it moved through assemblage. This study goes beyond explaining policy outcomes or networks of actors to describe networked effects.

Positionality

In line with ANT, socio-materialism, and ethnography, we recognize the ways we are entangled in the work and present our positionality within it. Katie designed the study as part of her PhD program and completed all data collection and analysis with support from Scott (her PhD advisor). Katie is a middle class, white female. She grew up and taught middle school science nearby the district in this study which had similar demographics. Katie entered the teaching field from a career in the earth sciences about the same time as *No Child Left Behind* policies required testing of science education required in US public schools. Katie took opportunities to engage with the writing and revision of the middle school science state test (see Bateman et al., 2022). This experience, combined with her involvement in local and state science education organizations and her school community created paradoxes and challenged her views of science education. Her history and background helped Katie connect with teachers in the study from an insider's perspective—she could commiserate with their frustrations, understand the nuances of local politics influencing the school, and speak as a local. She had existing relationships with some teachers through the local and state science education organizations, teacher education workshops, and community organizations who helped broker entry to the culture of the middle schools. However, her ethnographic training supported her in making the familiar strange, using both participants and outsiders to member check and validate findings.

Study context

This study takes place in two middle schools in Brighton School District (all names are pseudonyms) located just outside a metropolitan city in the northeastern United States. Two district middle schools served 990 predominantly white (62%) students experiencing poverty (62.8%) in grades 7–8 (ages 12–14). In 2017, at the end of data collection, under 20% of Brighton's middle school students scored proficient or advanced on state-wide mathematics tests while 34.7% of students scored proficient or advanced on the science test. (See Additional file 1 for greater demographic detail.)

Though data collection captured the influence of more policies, we focus on three policies influencing Brighton's middle schools that can represent different types of policies. The focal policies were generated nationally and locally and acted formally and informally to influence science teaching in the network. The first policy *NCLB*,[1] was a formal national policy in the United States implemented by bureaucrats at the state level. This policy required middle level students be tested annually in math and English and in science in 8th grade (13–14-year-olds). The networked effects of *NCLB*, particularly misinterpretations of results as "failing" were far reaching (Koyama, 2012). Local newspapers published annual test scores for schools and districts in their readership. Accountability was for test scores not pedagogical practices (Cobb & Jackson, 2012), limiting the uptake of reform-based practices (Anderson, 2012) to focus on perceived deficits (Desimone, 2013). As a result, local effects of *NCLB* in Brighton manifested as a focus on standardized test

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[1] Although NLCB has been replaced by a new policy, *Every Student Succeeds Act*, standardized tests and pedagogical practices to prepare for them continue to influence classrooms nationwide.

preparation (i.e., practice tests, math and reading focus, use of student test scores for decision making).

The second policy, the Next Generation Science Standards (NGSS; NGSS Lead States, 2013), contain a set of three-dimensional performance expectations designed to foster K-12 science literacy through integrated, hands-on, student-centered learning (NGSS Lead States, 2013). For middle school science teachers, this can be a drastic pedagogical shift, requiring renegotiation of roles and what counts as science (Stroupe, 2014). The NGSS were not federally mandated but some states and school districts across the United States had already adopted them. Science teacher organizations at national and state levels also highly recommended the NGSS. State science education newsletters frequently included NGSS-aligned professional learning opportunities and resources. Studies have shown that material actors, like science frameworks and international tests, influence translations in networks (Gorur, 2011), thus exerting influence over a group, making them policy (Stein & Coburn, 2008).

The third policy, Project-Based Learning (PBL) positioned local administrators in the role of policymakers. Brighton administration decided to make PBL (Krajcik et al., 1994) a pedagogical tool for which they would provide professional learning and look for implementation of during formal and informal observations. PBL fosters student-driven instruction through driving questions, focusing on learning goals, collaboration, and engagement in scientific practices to create an artifact to demonstrate their learning (Krajcik & Shin, 2014). Much as the NGSS disrupted teacher-as-knowledge authority, PBL can be a challenging transition as it draws on constructivist teaching theory (Blumenfeld et al., 1991; Windschitl, 2002). Though we acknowledge the rich history of PBL in science education (see Krajcik & Shin, 2014 for a review) this was more locally defined and reified through the district and subsequently, teachers' views of implementation of PBL were not always in alignment with research-based views of the practice.

Participants

We situate the adult participants in the study as part of three distinct groups: administrators, science teachers, and non-science teachers. We intentionally included non-science teachers to capture the broader education policies, not specific to science education within the larger school context. Administration ($N=7$) included those at the school (principals, coaches), district (superintendent, curriculum coordinator), and state level who had influence over teachers in the study both formally and informally. We selected these participants because of their roles in shaping the policy assemblage at each middle school.

Four science teachers serve as the focal teachers here. Two 7th grade (12–13 year olds) science teachers were veteran teachers (Maggie and Talia, 10+years of experience) and held science education degrees. Two 8th grade (13–14 year old's) science teachers were novices (Kasey and Rory, less than 3 years of experience) and had not specialized in science education during teacher preparation. Four veteran non-science teachers from math ($N=1$), history ($N=2$), and English ($N=1$) further informed analysis. all of whom were veteran teachers (see Table 1). We do not present the evidence of non-science teachers in this manuscript to focus on the science teachers' experience, however, data from non-science teachers' observations, interviews, and artifacts were instrumental in analysis and describing the network.

Data collection

Data collection for this study endeavored to trace the assemblage of two middle schools and how the actors within it played with policies. To meet this goal, the first author interviewed school personnel; engaged in participant observations of school-based activity; and collected artifacts from the school during an eighteen-month period from January 2016 to June 2017. Participant observation occurred during classroom instruction, teacher professional learning, and school-wide events

Table 1 Description of case study science teachers teaching position and experience during the study. Rory joined the study in 2016-2017 after transferring from a district elementary school. His elementary teaching was not included in observations but mentioned in interviews

Teacher pseudonym	Grade	School	Experience level
Kasey	7th and 8th math and science (2015-2016)	Wilson MS	Novice
	8th grade science (2016-2017)		
Maggie	7th grade science	Wilson MS	Veteran
Rory	3rd grade (2015-2016 – not part of study)	Elementary School	Novice
	8th grade science (2016-2017)	Wilson MS	
Talia	8th grade science (2015-2016)	Wilson MS (2015-2016)	Veteran
	7th grade science (2016-2017)	Aldrin MS (2016-2017)	

or meetings (e.g., assemblies, orientation, teacher leader meetings) as demonstration of action (Latour, 2007). We video recorded events and wrote field notes which guided the creation of daily memos (Emerson et al., 2011). Observations of classroom practice helped to determine what practices teachers employed in their classroom and categorize their responses to policies. Observations of professional learning and other school-based events helped the authors situate the teaching practices and responses in the larger network and identify the network actors that mediated policy translation.

We conducted interviews to understand the reasoning behind teachers' practice, their policy dilemmas, and the ways in which they translated policies in the network. Semi-structured interviews expanded on the observations and provided insight to the thinking of the members of the school community, including their impressions of the success of policies (Latour, 2007). The author audio recorded formal interviews. Informal interviews and unsolicited oral accounts (Hammersley & Atkinson, 2007) also occurred as teachers and administrators spoke about the school community and its members, which were not audio recorded but documented in field notes. These short, informal oral accounts provided in-the-moment responses to action in the network such as administrator visits, student learning, or lesson challenges.

Finally, artifacts triangulated observation and interviews and provided a look at non-human actors in the system. Artifacts collected included copies of curricula; sample grade reports; student handouts used during observation; photographs of student work samples; and the physical classroom environment. District level artifacts included the teacher handbook, student standardized testing scores and demographic information, professional development schedules, standards and curricular documents, and science curriculum team meeting notes. Centering artifact analysis builds on ANT's affordance for education policy study to trace the consequences of policy through the assemblage (Fenwick, 2010).

Data analysis
We utilize post-structural theory in data analysis through assemblages as analytic tools (Koyama & Varenne, 2012; MacLure, 2013) to capture the fleeting tracings of policy assemblages, organized following the loose guidelines found in the works of Koyama and Varenne (2012), MacLure (2013), and Augustine (2014), rooted in Deleuze and Guattari's robust post-structuralist body of work. As the researcher and event are intertwined (Maclure, 2013),

our reading and writing became a method of analysis itself (Augustine, 2014), creating an accumulation of field notes, memos, jottings, narratives, and notes on readings to further trace the assemblage and identify relevant actors in the network.

We next wrote narratives summarizing teachers' practice from the amalgamation of observations, interviews, and artifacts to center each teacher separately in assemblage, highlighting relationships and temporarily created patterns related to the focal policies. These patterns "glimmered" (Maclure, 2013) allowing a return to the data to first label each teacher's policy response (adopt, adapt, combine, reject; Coburn, 2001) and any policy dilemmas (conceptual, pedagogical, cultural, or political; Windschitl 2002). We then highlighted relationships and networked effects across teachers, policies, and schools from which we identified four network actors who mediated policy dilemmas and responses. We returned to the data to generate assemblage tracings focused on these actors. Throughout the process, we shared emerging findings with two members of the Brighton community, one teacher who participated in the study, and one who had not participated. When they disagreed with a finding presented to them, we discussed at length to ensure we represented their experiences with authenticity.

As writing tracings of assemblages can be challenging, we describe two case study teachers' assemblages as "exemplifications", providing rich detail. This allows these two cases to stand in for more than these two individual teachers (Maclure, 2010). In the findings, we will provide details of the networked effects of policies on teachers' assemblages with evidence across all data types, represented parenthetically with the data type (observation, interview, field note, artifact) and date (year-month-day).

Results
Teachers' navigation of policy dilemmas resulted in four kinds of responses which were mediated by four actors in the policy assemblage. These actors work in concert with one another over time to influence teachers' level of productive policy play. We illustrate these ideas in three sections: a) what responses teachers developed from policies, b) the mediating actors which influenced teachers' responses to dilemmas, and c) how the interaction of policies, dilemmas, responses, and network actors influenced the level of policy play with which teachers engaged over time. We focus here on science teachers (veterans Maggie and Talia, novices Rory and Kasey) to illustrate the findings through the lens of three focal policies (*NCLB*, NGSS, PBL).

Teacher responses to policies

Using our holistic approach to view teachers' actions over the 18 months of the study, we identified four policy responses by teachers in this network. Table 2 details each science teachers' responses to the three focal policies. The identified responses were not fully emergent but expanded upon from an a priori set identified by Coburn (2001). In her work, Coburn describes how teachers co-constructed meaning of policies which resulted in responses which she names throughout as adopt, adapt, combine, or reject/ignore. However, definitions and delineation of these responses was not central to the findings regarding sensemaking, but notes on this reading during informed the authors in development of the coding schema. We define each of these responses based on our coding of all eight participating teachers below. In the set of four science teachers central to this manuscript, one teacher adopted one policy, three teachers adapted policies, one teacher combined policies, and three teachers rejected policies. We disentangle responses from the network temporarily to describe each response type with examples of teachers' responses to a single policy.

Adopt

When teachers' policy response closely resembled the policymakers' intention, we labeled this as *adopting* a policy. This response was seen with only one science teacher in the study, Talia, around the policy of PBL. After Talia tested this practice with one unit in 2015–2016 (Interview 20160310) she centered her practice around PBL in 2016–2017. Though other science teachers facilitated PBL-based instruction, Talia's practice closely aligned with the tenets of PBL. Her students worked collaboratively to produce artifacts related to real world problems (Krajcik et al., 1994), grounded in state science standards and the NGSS.

Adapt

Teachers who *adapted* policies made minimal to moderate adjustments that changed the intent of the policy but met their classroom's needs. This response to policy was the most frequently seen response from teachers

in the study across all three key policies. Rory strongly opposed *NCLB*-based testing policies because they "don't tell you much about how you can make changes to the instruction and increase student understanding" (Interview 20161118). Yet, he assessed students through tests and quizzes that mimicked standardized tests asking for students to select the correct formula for work, select the correct examples of simple machines, and calculate work and power in a test in November 2016 (Artifact 20161122). Rory also adapted the NGSS after being introduced to them mid-way through the year. At the end of the school year, Rory was using the NGSS in his planning. He found them much clearer than the state standards and they guided his decisions on what he needed to complete over the year (Interview 20170601). Though not fully aligned to the NGSS, Rory used the NGSS to guide his curricular decision making in the latter half of the year, thus adapting the policy.

Combine

Teachers who *combine* as a means of implementation created bricolages of policies and practices. By piecing together policies and practices that often have different theoretical underpinnings, teachers who combine make moderate to significant changes to the intent of multiple policies. This response was observed with Kasey across two policies, *NCLB* and PBL. In her practice, Kasey tried to serve many policies simultaneously, combining PBL, *NCLB*-based testing policies, and other local policies. She implemented PBL with only one section of her eighth grade where they created a lesson to teach younger students about density by using technology, a local policy, to research the topic. In other class sections, students searched for answers in a textbook to review for an upcoming chapter test which was comprised of mostly multiple-choice questions similar to the state standardized test. In all sections, students copied notes from slides in "Cornell Notes" format, a local policy (Observation 20170113). Kasey took multiple pieces of many policies in an amalgamation. She did not reject them, but they were they not used in line with the intent of the policy makers.

Table 2 Policy responses by teacher for three focal policies. One teacher was unfamiliar with the NGSS, and thus did not have a response during the study

Teacher Pseudonym	Policy		
	NCLB testing policy	NGSS	PBL
Kasey	Combine	[unknown to teacher]	Combine
Maggie	Adapt	Reject	Reject
Rory	Adapt	Adapt	Adapt
Talia	Reject	Adapt	Adopt

Reject

Teachers who *reject* a policy do not implement the policy, or in some cases make a token implementation, such as using the name of a practice without the true underpinnings and theories. Teachers pretended these policies did not exist or outwardly objected to policies. Two science teachers rejected focal policies. Maggie rejected both the NGSS and PBL as fads that would be phased out with new administrations. Asked about the NGSS, she shrugged her shoulders and stated, "circles instead of squares." (Interview 20161118). She had looked at them and found them not to be that different from other standards with which she was familiar. She expressed similar feelings about PBL—she already did labs and projects, now she referred to them as a PBL (Interview 20170112). This name shift was to satisfy the policy, but Maggie's instructional practice was unchanged. For example, Maggie called a project in which students created a campaign for "best organelle" a PBL (Interview 20170112). She provided criteria and choice of a product format but assessed presentation skills not science content or practices used during the process (Artifacts 20170113). We therefore labeled this as a token implementation, given there was no change of practice to meet the policy.

In another rejection response, Talia chose to ignore the school community's focus on *NCLB*-driven test preparation. She stated that she just does not think about the state test and the low scores of her school when planning her science instruction (Interview 20160310). Artifacts of the classroom throughout the study eschewed traditional assessments, rather, assessments evaluated students' development of driving questions, reflections, explanations in write ups of their investigations, and outputs of projects using a rubric. Therefore, Talia rejected policy with a refusal to take up practices that would promote test-taking skills for *NCLB*-based state standardized tests.

Influential network actors on policy dilemmas

How teachers responded to policies was influenced by the relationship between the dilemmas teachers experienced in translating the policy and the network actors interacting with that policy dilemma. The teachers' responses to policy dilemmas were not tied to any one trait of the teacher or the network, but a collective of interacting actors which influenced both the policy dilemmas they experienced and the responses to those policy dilemmas. We identified four influential actors of this network (Table 3) that were sustained across policies, teachers, and the network: 1) availability of learning events; 2) diversity and availability of communities of practice (COPs); 3) teachers' relationships with administration, and 4) teachers' espoused practices. In this section we describe each of these actors and the ways in which they mediated teachers' policy dilemmas and responses through examples from the four science teachers' policy assemblages.

Learning events

A lack of availability of learning events around a policy was connected with teachers' conceptual and pedagogical dilemmas. Participating in learning events around policies supported teachers in navigating these policy dilemmas, however, opportunities to participate in policy-related learning events were not equally available at the two middle schools in the 2016–2017 school year (Fig. 1). Wilson MS offered far less formal, structured professional learning time (35 h) compared to Aldrin MS (64 h). Wilson devoted the majority of professional learning (30%) to technology, while Aldrin MS devoted the same amount of time to math and technology. In learning events related to *NCLB*-based testing policies, teachers discussed analysis and use of student data (14.3% at Wilson MS, 10.2% at Aldrin MS). Only Wilson MS held PBL

Table 3 Description of mediating actors

| Actor categories	Actor variations	Description
Learning events	Available	Teachers have access to introductory and supportive learning events around a policy.
	Not available	Learning events are not accessible by teachers or do not provide foundational information.
Communities of practice	Diverse	Teachers engage with multiple communities of practice in and out of the school network.
	Homogenous/ small	Teachers engage with mostly local communities of practice with often overlapping membership.
Administrative relationship	Collegial	Teachers view administrators as collaborators, colleagues, and/or supportive.
	Managerial	Teachers view administrators as authorities, managers of practices and policies.
Espoused practices	Emergent	The ways in which teachers speak of their teaching practice has not yet become clear, is still developing and growing.
	Strong	Teachers talk of practice is consistent and firm in what constitutes good teacher practice for them.
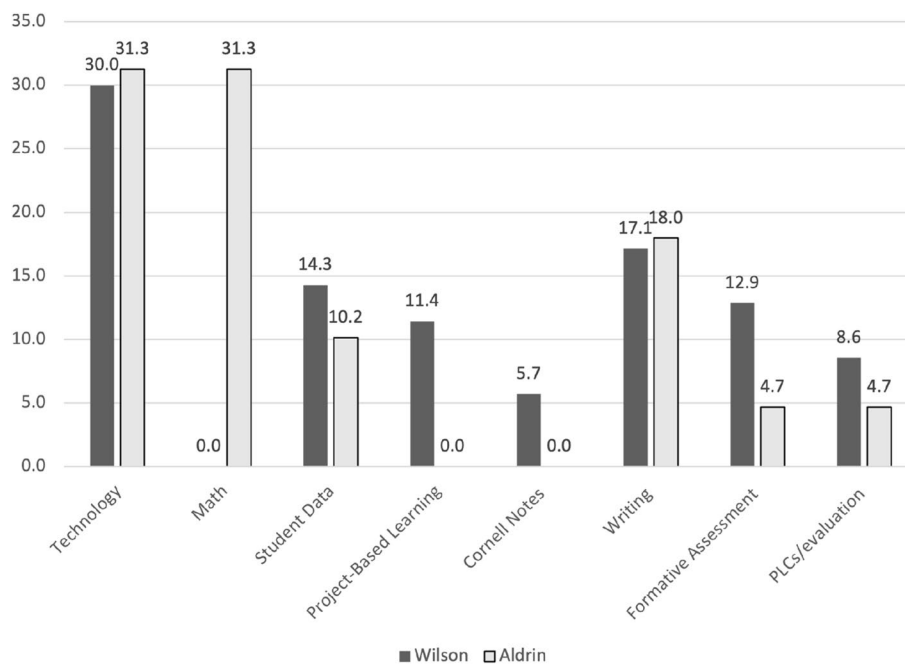
Fig. 1 Percentage of professional learning time devoted to different topics in the 2016–2017 school year in Brighton School District

learning events specific (11.4%). No NGSS or science-specific learning events occurred at either school. Consequently, some teachers sought learning events outside the district to supplement their understanding of PBL and the NGSS through workshops and graduate courses.

Lack of learning events

Absence of learning events coincided with teachers expressing conceptual and pedagogical dilemmas as teachers lacked fundamental understanding of the policy or misunderstood the epistemic nature of the policy. This happened frequently as teachers at Wilson MS attempted to implement PBL. Though heavily supported by administrators and the presence of a growing COP there was not a formal introductory learning event about PBL in 2016–2017. Veteran teachers had been sent to a large convention with formal learning events around PBL in 2015 (Interview 20160310), but teachers new to PBL in 2016–2017 lacked access to these learning events.

Adaptation of policies occurred as teachers navigated the conceptual dilemmas and translated policy without formal learning events. Rory employed PBL in this classroom after piecing together the policy meaning from informal colleague interactions and internet searches (Field Notes 20161121). His conceptual understanding misaligned with research based PBL models, such that his designed project assessed students' content knowledge rather than engaging them in a learning

process. Reflecting on his first try at implementation Rory described his current understanding:

> *It's a skill or concept that you want the students to learn, and then you do some front-loading of the information, and they demonstrate mastery of that information through the project. So, it can be an alternative assessment, I mean you can certainly do tests and quizzes within a project-based unit of learning, but instead of a test, you could do a project as the demonstration of mastery. I mean, it could be an individual project, I use it as a group project, but I could see someone flexibly doing it with one person, each doing their own project-based learning assignment. (Interview 20170113)*

This statement correlated with Rory's observed practice. The students in Rory's science classes worked on a wide variety of topics related to energy – making slime, putting an egg in a bottle, inflating balloons with baking soda and vinegar (Observation 20170111). Rory's understanding of PBL misaligned with the constructivist norms of research based PBL, a conceptual dilemma stemming from a lack of learning events. Although enthusiastic about the ideas he heard from colleagues, Rory misunderstood PBL and retained a transmission of information model of instruction. Rather than constructing explanations through a project, students received information via lectures and worksheets before they demonstrated

their learning with a collaborative product. The absence of PBL learning events available to Rory resulted in a conceptual dilemma, which led him to adapt the PBL policy to be a project assessment, rather than project as knowledge construction. We illustrate this as a policy translation diagram (Fig. 2), which shows how the policy (PBL) interacted with the network actors which influenced teachers' experienced dilemma (conceptual). These dilemmas in turn interacted with more actors before a teacher arrived at a policy response (adapt).

Teachers who had more access to formal learning events faced pedagogical dilemmas as they adopted policies. Talia had attended outside workshops around PBL sponsored by Brighton. Select teachers and administrators attended a large meeting focused in part on introducing tenets of PBL (Interview 20160310). After trying one PBL unit in 2015–2016, Talia adopted PBL for all her science instruction in the 2016–2017 school year. However, Talia expressed pedagogical dilemmas in her policy translation. Most prominently was the tension between the student-driven, socially relevant issues of PBL and the scientific practices of the NGSS and state standards in science (Fig. 3a).

In one PBL-based unit in 2017, students developed a question, "how does global warming impact animals?" to guide their construction of a product (Observation 20170201). In Talia's understanding of PBL, students should choose how to solve the problem. She interpreted this to mean she should not tell them how to do it (Interview 20170201). Students generated the question and built out their tasks using science standards (Observation 20170206) and Talia attempted to scaffold their inclusion of science practices by providing students with a scientific checklist (Fig. 4) students but did not choose any of

these science features in their projects. This illustrated tension between PBL's student-led pedagogy and the science and engineering practices from the NGSS. In reflection at the end of the year, Talia stated that PBL helped students develop in critical thinking, communication, and other domain general skills, but not their science skills, which distressed her (Interview 20170531). Her understanding of PBL as being fully student-driven thus created a pedagogical dilemma as she chose to adopt PBL with fidelity.

Communities of Practice (COPs)

COPs provided teachers with resources to learn about policies, however diversity and the breadth of communities with which the teachers engaged influenced their experienced dilemmas and responses. Teachers who engaged with only school-based COPs, had limited sensemaking resources and experienced conceptual and pedagogical dilemmas. Teachers who engaged with a heterogenous set of COPs navigated political dilemmas. External COPs such as national and local science teacher organizations, and internal groups committed to learning about PBL or educational technology, brought new ideas and opportunities to discuss the place of policies in their practice. Yet, COPs ideologies did not always align with one another. With increased understanding of policies, teachers faced political rather than conceptual and pedagogical dilemmas due to ideological tensions in policies and policy translations by different COPs.

Small and homogenous communities of practice

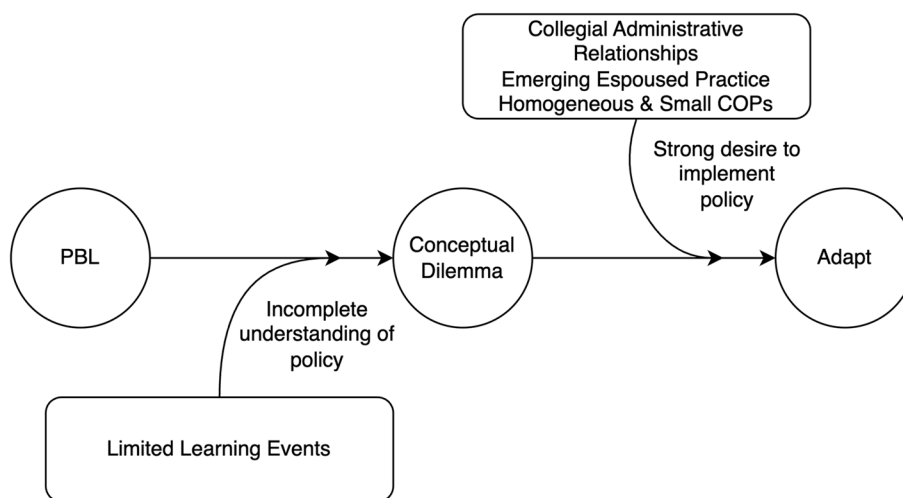Homogeneity and a limited number of COPs resulted in teachers facing conceptual dilemmas and rejecting

Fig. 2 Rory's policy translation of PBL policy influenced by incomplete understanding of policy and strong desire to implement PBL
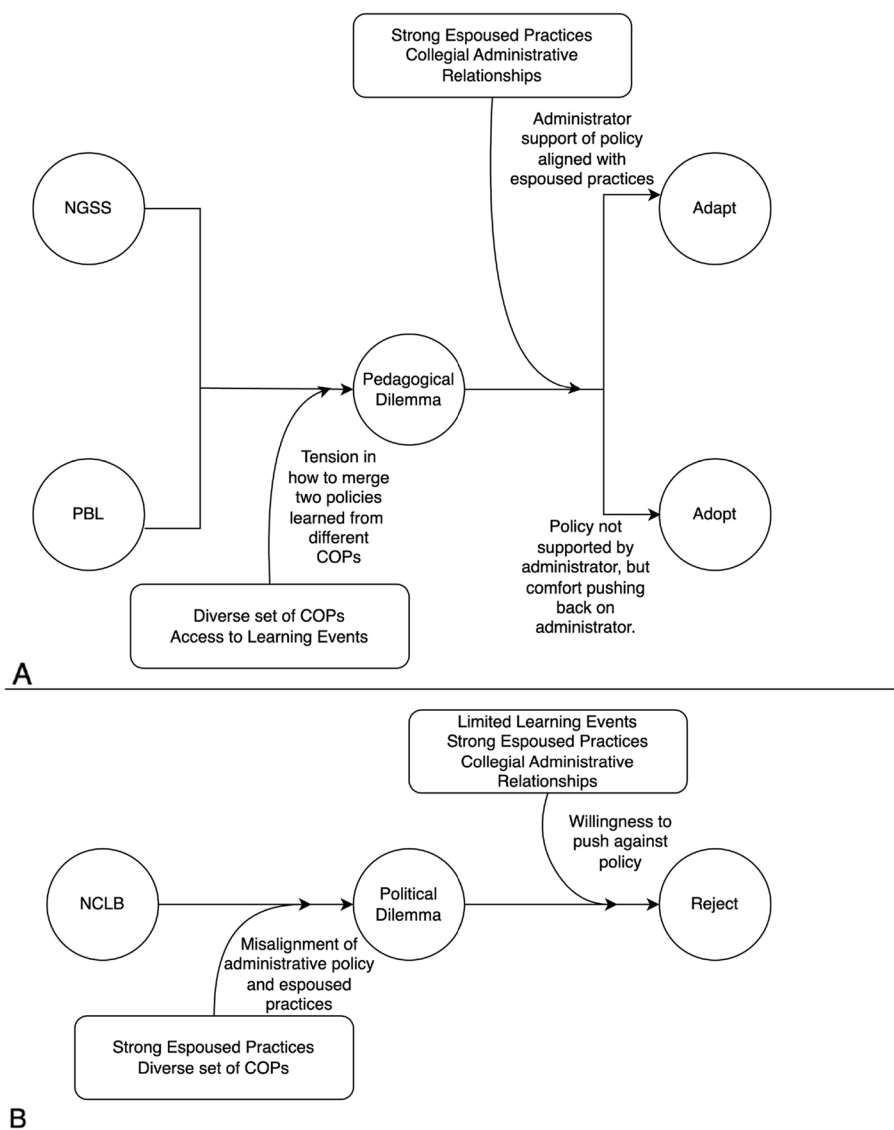
Fig. 3 Illustration of Talia's policy translation showing how (**A**) the NGSS and PBL interacted with her COPs and learning events to result in pedagogical dilemmas but produced different responses when interacting with her espoused practices and administrative relationship and (**B**) with misaligned *NCLB* related testing policy. COPs, and espoused practices, political dilemmas were mediated by limited learning events, collegial relationships, and strong espoused practices to reject policy

Fig. 4 Talia's scientific checklist for students

policies. Maggie truncated her external COPs over time, reducing her exposure to new ideas. She had been a member of national and local science teacher organizations and previously subscribed to national science teacher journals (Interview 20161118), but she retained ideas from these science teacher organizations in her teaching, such as the resources in her labs. Though aware of the NGSS (Interview 20161118), Maggie did not adopt the NGSS's three-dimensional view of learning in her practice. Maggie translated the NGSS as not new and not worth learning. Without diversity in COPs, Maggie's

conceptual dilemma about the NGSS went unchallenged, and she rejected a policy which may have enhanced science teaching and learning (Fig. 5a).

In contrast, teachers who engaged with a diverse set of COPs faced political dilemmas as they reconciled the competing authority of expertise in different communities. Talia, for example, engaged in multiple COPs inside and outside Brighton—the PBL COP at Wilson MS, the

educational technology communities at Aldrin MS and Wilson MS, and science teacher organizations at the local, state, and national level. Although Talia was not a core member in each COP she engaged with, she acted as a boundary agent (Wenger, 1998) between communities and brought messages and practices from external communities into her teaching practice. For Talia, her COPs created tensions around what was more important to
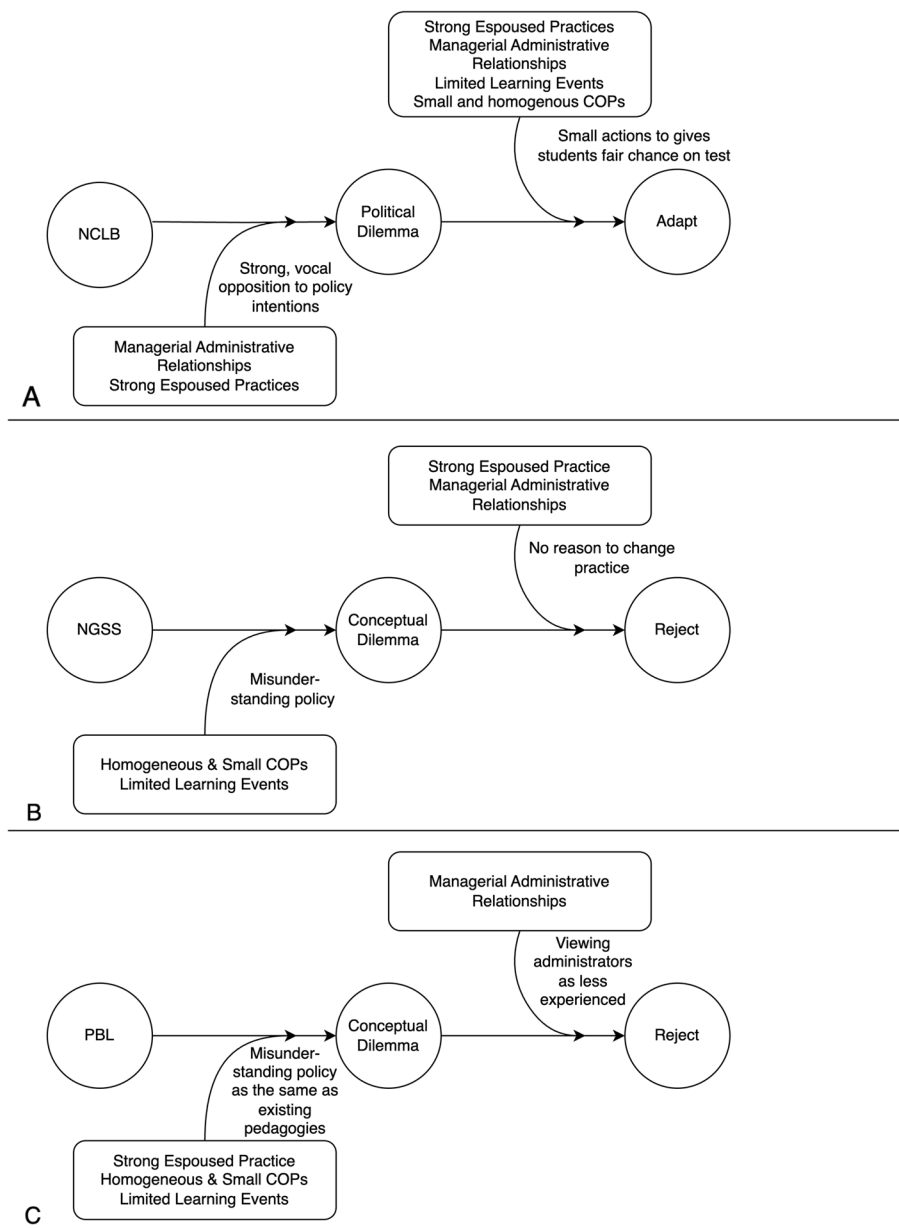

Fig. 5 Illustration of Maggie's translation of the three focal policies. **A** Strongly opposed to *NCLB* because of her espoused practices and view of administrators as managers, she experienced political dilemmas, but makes small actions to adapt the policies considering her interaction with the mediating actors. **B** Misunderstanding the NGSS due to limited opportunities to learn about the policy, Maggie navigated the conceptual dilemma by rejecting it, seeing her existing practices as similar and equally strong. **C** Conceptual dilemmas around PBL stemmed from her misunderstanding the policy as similar to her current practice, given that the policy was created by a less experienced administrator, she rejected it as a fad

emphasize, student center PBL or Science and Engineering practices of the NGSS, and Talia experienced a political dilemma (Fig. 3a). In response to this dilemma, Talia had students identify the NGSS and state standards relevant to their self-selected problem during a PBL unit as a way of translating the NGSS into her student-centered practice (Observation 20170206). Talia did not achieve the focus on science practices she believed necessary to the NGSS from her science COPs but adapted the NGSS to fit within her adoption of student-centered PBL ideologies. Talia's external COPs mediated political dilemmas by providing resources to translate policies through learning events and discourse with other members.

Espoused practices

Teachers' espoused practices, how teachers discussed pedagogical practices were categorized as strong or emergent. Teachers whose espoused practices were emergent were still identifying their ideas about what counts as good teaching, and they experienced conceptual and pedagogical dilemmas. To mediate conceptual and pedagogical dilemmas, espoused practices needed to align with a teacher's enacted practices, or teachers responded to policy by combining or rejecting policies. Teachers who held strong espoused practices clearly articulated their views on how teaching should and should not be, what they saw as important to teach or the pedagogical practice to teach it. When espoused practices and policies conflicted, political dilemmas emerged.

Kasey is an example of emerging espoused practices resulting in conceptual dilemmas and combining of policies (Fig. 6). She was still developing her espoused practices and enacted many different practices in her classroom. When discussing policies, Kasey's understanding of them was still developing. Kasey interchanged the terms problem and project as representing "P" in PBL as if they were synonyms (Interview 20170131). Unlike some of her colleagues who stated a lack of understanding of a policy, Kasey's conceptual dilemmas remained unstated, and she confidently combined misaligned policies.

In contrast, teachers with strong espoused practices adapted or rejected policies in response to political dilemmas. This occurred often around *NCLB*-related testing policies for teachers who expressed strong opinions about the lack of value in standardized test preparation. Maggie experienced a political dilemma when her espoused practices conflicted around *NCLB*-related testing policy (Fig. 5b). Her goals were not about test prep, but a love of science.

> *[Maggie] says [the standardized test] dictates what she needs to cover, but then she teaches in her way. She thinks the "testing culture beat the love of science out of the kids bad." Her goal is to make students aware of the environment and give them some love of science. She knows this may not set them up to score well on the [state standardized test], but that is not her goal. She wants them to be able to make choices in life using science (Interview 20160509).*

This love of teaching science was, for Maggie, at odds with testing goals and was consistent throughout the study. Her interviews made it clear she had strong opposition to the policy, saying "of course you have the stupid- oops, standardized tests" and laughing
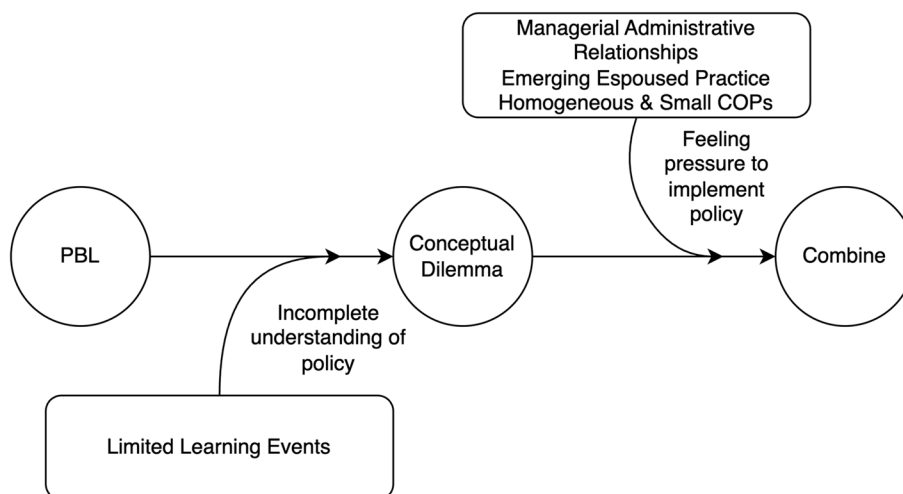
Fig. 6 Illustration of Kasey's translation of PBL mediated by limited learning events to understand the policy, experiencing a conceptual dilemma, but feeling the pressure to implement due to her COP and administrator's influence on her emerging espoused practices

(Interview 20161118). These tests were not aligned with her view of what assessment should be.

> *You have your standardized modalities that you have to do – sorry. I'll keep my opinions to myself. To me assessment isn't just about books and work, it's much larger. It's so much more than that (Interview 20161118).*

Observations of Maggie's instruction and collected artifacts supported this espoused practice. Her assessments included project rubrics and observation checklists of student skills more frequently than written tests and quizzes. Maggie adapted the *NCLB*-based testing policies by ensuring her lesson plans covered all tested information, as she saw this as only fair (Interview 20160530) but did not go beyond this in preparation for the state tests, keeping testing culture on the fringe of her assemblage. Though Maggie experienced a political dilemma related to her strong espoused beliefs around standardized testing, she adapted policy to comply with parts of the policy she saw as important to her students. Strong espoused practices in this case mediated political dilemmas and resulted in policy adaption.

Relationships with administrators

Teachers described relationships with their administrators as being collegial or managerial. These relationships were unique to interactions between administrator-teacher pairs, rather than any one individual or school. In managerial relationships, teachers described their administrators as authorities and perceived the administrator's pedagogical preferences as requirements which generated conceptual, pedagogical, and political dilemmas around policies. In collegial relationships teachers described administrators as collaborators, often having been former teaching colleagues. They were comfortable disagreeing with administrators about policies and negotiating political dilemmas.

Managerial relationships

Responses to policies when engaged in managerial administrative relationships varied with teachers' years of experience. Veteran teachers saw administrators as transitory task-managers, creating political dilemmas and policy rejection. Novice teachers viewed administrators as more knowledgeable authorities whose authority required compliance regardless of the administrators' understanding of the policy, creating conceptual dilemmas. Teachers then superficially adopted or combined policies to comply with administrators as policymakers. Neither group saw administrators as someone with whom they could negotiate the meaning of policies.

For these veteran teachers, the principal served as a less-experienced supervisor not a colleague, in Maggie's words, someone who "makes a note every time you sneeze" (Field Note 20160912). Maggie had been teaching at Wilson more than a decade longer than her current principal and had witnessed policies come and go with administrative turnover. Administrator-created policies were "fads" no different than current practices and were not worth her time to learn and make changes to her current practice (Interview 20160914), a perspective shared by other veteran colleagues. She had contributed to teacher-led curriculum reforms in the past that stalled with administration (Interview 20160914), implying collaboration on policy was not welcome. Thus, she rejected administrator policies which she saw as similar to her current practice (Interview 20161118) (Fig. 5c).

Novice teachers who experienced managerial relationships viewed their administrators as more knowledgeable authority figures. As a result of this relationship, novice teachers adapted or combined policies even when experiencing conceptual and pedagogical dilemmas to comply with administrator's wishes. Kasey, a novice teacher, exemplified this in her discussion of PBL mid-year.

> *[PBL] has been the bane of my existence this year because I tried so hard [...] Talia was really into this last year, and I didn't know what it was, no one really knew what it was. So, Talia was like, at the forefront of that and then Keith [the principal] started getting really into it this year, so everyone had to like, figure it out. (Interview 20170131)*

Although PBL was not a formal requirement at either Wilson MS or Brighton School District, Kasey believed she had to do it because her principal was "getting really into it." In observation of Kasey's PBL instruction, students generated questions they could explore in their project (Observation 20170111). In her lesson plans, Kasey wrote, "Each group must first submit to me a document with 4 self-created and then answered questions that proves that you understand what density is and how to find it" (Artifact 20170111). In observations, students used the internet to both generate questions and answers (20170111). Together, this indicated the students' questions had an authoritative, correct answer which could be found on the internet or in a book, rather than complex PBL driving questions that required multiple learning activities to construct an explanation. To support students during this PBL unit, Kasey had students organize their notes in a Cornell Note format and tested the content akin to standardized testing, two other policies she expressed feeling required to do (Observation 20170111). Kasey's managerial relationship with her administrator resulted in

a sense of obligation to incorporate PBL, but facing a conceptual dilemma, she combined PBL with other policies in the assemblage (Fig. 6).

Collegial relationships

Collegial relationships with administrators did not completely negate dilemmas, instead teachers experienced political dilemmas and adapted or adopted policies. Teachers with collegial administrative relationships had often previously been teaching colleagues. Talia, a veteran science teacher previously co-taught with her principal, Frank, which fostered a collegial relationship. Frank had provided teaching support for special education students in Talia's previous science classes. Frank was enthusiastic when Talia joined the teaching staff, hoping she would "shake up" the science department (Field Note 20160829). However, as principal, Frank favored pedagogies to prepare for *NCBL*-related testing which Talia vocally opposed. He also expressed confusion about PBL, which Talia centered in her practice. During one observation, Frank visited Talia's class, stood in the doorway, and quietly muttered about how posters, necessary for their current PBL unit, still hung on her walls, in violation of policies during the *NLCB*-related state test in two weeks (Observation 20170331). Due to her knowledge of district-level support for PBL (Interview 20170201) and her collegial relationship with Frank, Talia rejected the policy around posters without fear of consequences from either district administration or her principal (Fig. 3b).

The four mediating actors from the teachers' assemblage interacted with various other actors to influence teachers' dilemmas and the ways in which they responded. However, these actors did not influence in isolation, they interacted with one another in the assemblage to magnify their influence. Therefore, we now look beyond individual scenes of actor interactions to the assemblage itself to understand the relationships and interactions of the mediating actors, dilemmas, and responses in play.

Teacher's policy play

Here, we take a process view of the assemblage through *productive play with policy* (Koyama & Varenne, 2012). Teachers' play with policy describes the ways in which they reconciled disparate policies with one another as they navigated their dilemmas to create cohesion in their assemblage, creating the amalgamation of responses to different policies. Looking simultaneously at the mediating actors, experienced dilemmas, and responses as networked effects in teachers' play with policy highlighted the importance of the cohesion among the mediating actors in mitigating policy dilemmas and supporting teachers' adoption of policy.

We focus on two teachers to illustrate variations in productive policy play. Talia exhibited more productive policy play as she leveraged the mediating actors over time to make sense of policies, while Kasey struggled to determine how to bring these three policies into her science classroom in cohesive ways. Talia's strongly aligned espoused and enacted practices, collegial relationships with her administrators, access to learning events around the focal policies, and her diverse set of COPs supported her productive policy play. Although she experienced policy dilemmas, resources connected with the mediating actors helped her mitigate these dilemmas through productive policy play to arrive at responses. This play resulted in Talia adopting PBL, adapting the NGSS, and rejecting *NCBL* related testing policies.

Conversely, Kasey had emerging espoused practices, managerial administrative relationships, lacked access to learning events around the focal policies, and engaged with small, localized COPs. Kasey faced conceptual dilemmas with each focal policy and others within the network. The resources provided from her interaction with the mediating actors were unable to help her overcome these dilemmas and she combined focal policies in ways that misaligned with policymaker intentions. In this section, we elaborate on the ways that the four identified mediating actors interacted in assemblage to afford or constrain each teacher's play with policies.

Low productive policy play

We defined low productive policy play as minimally cohesive integration of policies. We exemplify this through Kasey. The mediating actors in Kasey's assemblage interacted in ways that limited her ability to learn the intent of the policy and to help her find their place in her practice. Specifically, she had limited opportunities to come to understand policies due to a lack of access to formal learning events and as a result of her engagement with small and localized COPs. Combined with Kasey's still emerging espoused practices, she experienced conceptual dilemmas around the focal policies. Facing these dilemmas while still developing her espoused practice and seeing policies as coming from a more knowledgeable authority figure, her attempt to combine policies she did not fully understand resulted in superficial and misaligned implementation of all policies. We illustrate this in Fig. 7.

A constraint to Kasey's play was limited opportunities to develop her espoused practices though formal learning events or a science teaching COP. Though in her third year as a Brighton teacher, Kasey had limited preparation in science. Brighton failed to devote professional learning time to science (Fig. 1) and her teacher preparation program had focused on math education (Interview
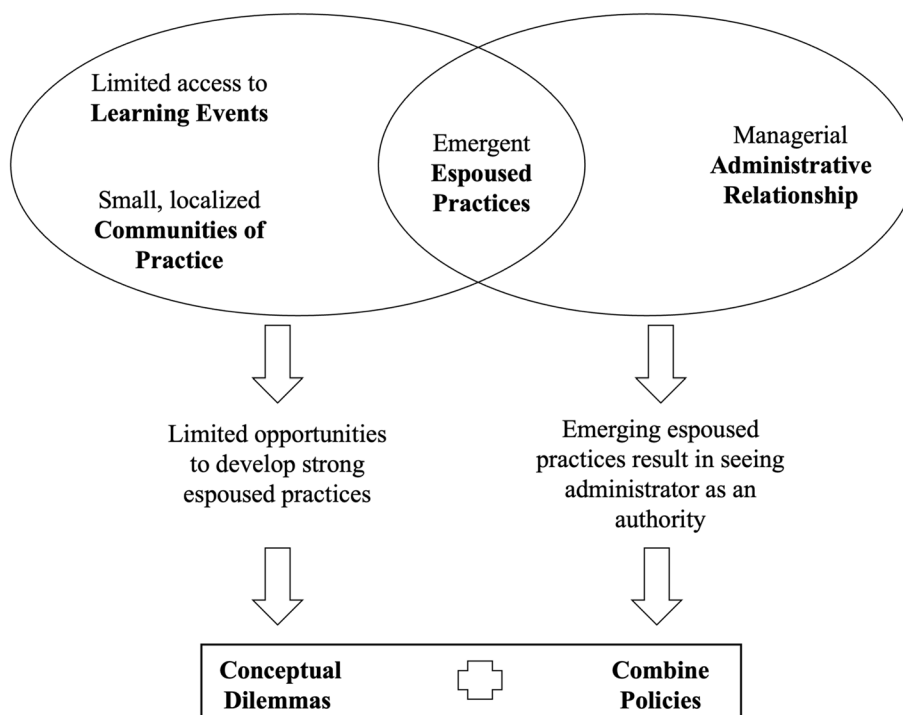
Fig. 7 Representation of Kasey's low productive policy play where the four cultural features do not support overcoming conceptual dilemmas and result in superficial implementation in a combination of policies

20160229). Therefore, after two years in Brighton, Kasey still identified as a math teacher forced into science.

> *[Talia's] a true science teacher, me and [redacted], are more math people who happen to also be certified in science, so they make us teach it. (Interview 20160229)*

Kasey saw Talia, her mentor and 2015–2016 grade partner, as a more knowledgeable teacher and science expert. In 2015–2016 Kasey described her views of science teaching in terms of, "Well, Talia says…", taking up others' views verbatim in her emerging espoused practices (Interview 20160229). Kasey was unaware of the NGSS – she was not connected with the external COPs who had introduced them to Talia and Maggie. Kasey could not respond in practice to a policy she didn't know existed, restricting her productive play with policy.

Further inhibiting Kasey's emerging espoused practices growth was her relationship with her administrators. Kasey saw both her principal and veteran teachers as authorities and in the case of the principal, as a manager. These people were more knowledgeable and thus, she needed to listen to them. She parroted Talia's espoused practices (Interview 20160229) and implemented PBL because her principal was "really into it", turning to veterans in other subject areas to help her learn this policy in

practice (Interview 20170131). However, PBL was not the only policy in the assemblage. Kasey combined the focal policies of PBL and *NCLB*-based standardized testing with myriad other policies in superficial ways, which did not meet the intent of any of these policies. In observation of Kasey's practice, she combined PBL with *NCLB*-related standardized test preparation practices, like tests and quizzes, but not with any science practices (Interview 20170131). Students used technology to gather information and design activities for younger students to engage with science demonstrations (Observation 20170111). Kasey's assessment focus was not on the science as much as the collaboration, communication, and creativity that was domain general in PBL, supportable by members of the non-science teacher COP. Without strong espoused practices, Kasey allowed authority figures to tell her how she should teach, failing to wrestle with her conceptual dilemmas, combining all policies into practice.

Kasey's policy play was limited by the interactions of the mediating actors. She took up the policies her superiors (principals, veteran teachers) shared with her and tried to place them all in her practices without being provided the learning events to fully understand them. She had little experience with diverse perspectives on science education and depended on colleagues to communicate policy messages to her. Because she was not

involved with external COPs, Kasey was unaware of the NGSS and how it might influence her teaching. Limited learning events and small COPs limited her espoused practices growth, and the managerial relationship with her administrator impressed upon Kasey that these policies were non-negotiable and must be shoe-horned into her practice. Kasey's policy assemblage thus formed a superficial amalgamation of multiple policies that neither built on one another nor supported students' science learning.

High productive play

Teachers with high productive play with policy engaged in deep sense-making and actively considered a policy's place in their classroom, exemplified by Talia. Talia's policy assemblage afforded her more opportunities to engage with learning events specific to the focal policies, many of these through her extensive COPs. However, these communities often espoused competing policies that were misaligned with one another, opening pedagogical dilemmas. Talia's strong espoused practices and collegial

relationship with her administrators created space for Talia to reject policies misaligned with her espoused practices. When the four mediating actors aligned to support one another, Talia's response was to adopt policies (Fig. 8).

With access to learning events and diverse COPs, Talia experienced pedagogical dilemmas and adapted policies. The many different learning events and COPs within and beyond Brighton SD came with multiple messages touting the importance of the different policies in each context. Internally, Talia engaged with PBL-based COPs and attended district-funded PBL learning events. Externally, Talia engaged with local, state, and national science teacher organizations where she learned about the NGSS science and engineering practices.

PBL aligned with Talia's espoused practice as it engaged students in authentic practice (Interview 20170201); however, bringing the NGSS and "doing science" together with PBL resulted in a pedagogical dilemma. Talia's external learning events related to the NGSS helped her understand the policy as reliant on students engaged in science practices such as planning and carrying out investigations
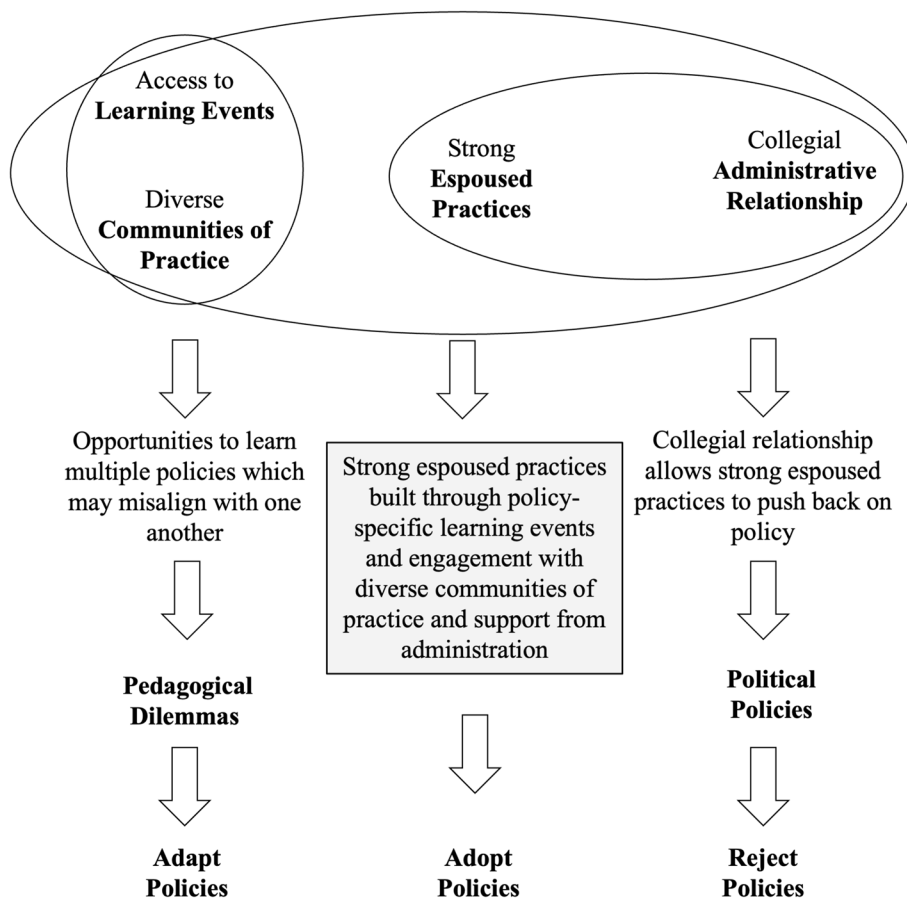

Fig. 8 Representation of Talia's highly productive play with policy in which the four cultural features interact to support her navigation of dilemmas and responses to policies

and analyzing and interpreting data. She did not know how to allow the students-driven instruction required by PBL, while also integrating the practices of science and the NGSS (Interview 20170531) as her students did not gravitate towards experimentation and investigation; instead, they looked to the internet for answers (Observation 20170228). In this way Talia had to adapt the NGSS policy to be able to merge with her understanding of PBL.

The interplay of strong espoused practices and collegial administrative relationship saw Talia rejecting policies in response to pedagogical dilemmas. Though aligned with Talia's espoused practices, they conflicted with those of Aldrin MS's principal, Frank. Frank highly valued the *NCLB*-based standardized testing scores and devoted temporal and fiscal resources to raising test scores in math and reading. Talia's strong espoused practices conflicted with Frank's views on *NCLB* compliance and she experienced a political dilemma. Talia said, "I struggled because some of these things are just not me [...] like review, study guides, and standardized tests and things." (Interview 20160310). However, as noted earlier, Frank and Talia's relationship was collegial and Talia rejected the *NCLB*-related test preparation pressure from Frank, caring little about scores related to her students' science achievement. When pressed in interviews to talk about the state standardized test, Talia shares that she really does not put much thought into them.

> *She knows her scores were really low from her evaluation, but she didn't bother comparing them to the other science teachers. She has no idea if other teachers were as low as her or not. [And doesn't seem to care about it.] (Field Note 20170201)*

Talia's strong espoused practices related to PBL and *NCLB* created a political dilemma, but combined with her collegial relationship with her administrators supported her rejection of *NCLB*-related testing policy.

When the four mediating actors aligned and supported teachers' policy play, teachers adopted policy, even when facing dilemmas. Talia had access to learning events and COP around PBL, which aligned with her espoused practices. Her collegial relationship with administration helped her adopt PBL when facing political dilemmas. Brighton-sponsored learning events for PBL initiated Talia's play with PBL policy. In 2015, Brighton SD sent Talia to a conference with Wilson MS's principal, the superintendent, and a few other teachers who became the base of Brighton's PBL COP. In this field note excerpt, Talia explains how she concluded that she could try PBL.

> *PBL came from the first "convening" of the TechFutures group, which she attended two years ago,*

> *along with Megan (superintendent) and Keith (current principal.) [...] She was shocked that they were promoting this, as she had just heard from Brighton School District that they needed to be doing the same [common assessments] across schools and rooms. She looked at Keith and Megan and said, "so you're saying I can do this?" and they were enthusiastic and supportive, "yes!" so she ran with it. (Interview 20170201).*

From her interaction with this learning event, Talia's image of Brighton shifted. She found collegiality in learning they shared her espoused practices. This shifted her response to PBL and the following school year, Talia began to adopt PBL.

Talia engaged in highly productive policy play reconciling *NCLB*-related standardized testing, PBL and the NGSS in her practice. Specifically, Talia experienced tensions between PBL and the NGSS, playing with the presence of both in her assemblage. From Brighton professional learning events, Talia understood how to use PBL in her classroom, and she understood how to use the NGSS from her external COP, but not how to integrate them. The integration challenged her, opening a space for play. Talia was reflective, identifying the missing science as a problem in interviews (Interview 20170201), naming her pedagogical dilemma around PBL and the NGSS. This created room for more productive policy play in her assemblage. Talia faced her dilemmas and actively attempted to reconcile their alignment with resources from her espoused practices, professional learning, diverse COPs, and her relationships with her administrators.

Discussion

This study's aims include a better understanding of policy as an actor within educational systems. By taking an ANT approach and examining policies as part of assemblages, the findings illustrate the interdependence of four mediating actors (espoused practices, learning events, COPs, and teacher-administrator relationships) in teachers' policy play (Koyama & Varenne, 2012). Policies did not create dilemmas or responses, rather, dilemmas and responses were networked effects of actors in assemblage. This work builds on prior science policy studies examining policy translation, particularly those where policy translation is framed as policy play (Koyama & Varenne, 2012). Our findings indicate a need to look more closely at the interactions of policies with one another in teachers' policy play, the dilemmas as learning opportunities, and the importance of social relationships with administrators in teachers' policy play.

Policy interactions in assemblage

Policies are networked actors in assemblages, they engage with other actors and influence translation of other policies. Previous work in education policy has explored the ramifications of policies like NCLB on the uptake of reform-based science pedagogy (Aydeniz & Southerland, 2012; Southerland et al., 2007). However, these studies often center one or two policies rather than examine policies within the system, or assemblage of a school. In their study of an Australian teacher education program, Lambert & O'Connor (2018) referred to these multiple interacting policies as a "policy storm" which created conditions of uncertainty and possibility, similar to the dilemmas faced by teachers in this study. We saw each of the three focal policies (*NCLB*, NGSS, and PBL) and other policies in the assemblage interacting in translation to create dilemmas and opportunities for learning and growth. Rory and Kasey worked to balance *NCLB* test preparation expectations with PBL implementation, uncertain of the policy's requirements. Talia struggled to rectify her perceived misalignment of PBL and the NGSS. For Maggie, the ghost of policies past remained actors, producing networked effects in her translation of PBL and the NGSS as more of the same.

Our findings build on past research by thinking about policies not as standalone items but as networked actors in assemblage. If sensemaking and understanding a policy is key to implementation (Spillane et al., 2002) and policies are each networked effects (Fenwick, 2010; Law, 1992), then how teachers make sense of one policy cannot be completely disentangled from any other policy. Maggie's experience with past policies influenced her translation of current ones, influenced by her current relationships with administrators, her COPs, and available learning events around policies, all components of the situated nature of educational policy translations (Braun et al., 2011). By viewing school culture through ANT, we identified four actors whose networked effects were more influential than others across policies in mediating dilemmas, responses, and translations in this context.

We must also consider the influence of the larger political sphere in school policy translations, those policies which do not specifically target education, but influence the system in which science education operates. In looking at the NGSS, Hardy and Campbell (2020) noted the interaction of politicization in implementation, such as controversy around topics like evolution and climate change. Colston and Ivey (2015) too found that larger political resistance to climate change limited opportunities for climate change education. This creates opportunities for future research to study local non-educational policies as actors in the assemblage influencing educational policy play.

Dilemmas as opportunities for sensemaking

This study indicates a need to expand how researchers think about policy translation in school networks, attending to the dilemmas experienced by teachers and mediating actors impacting policy translations. We build on previous work highlighting the importance of professional learning (Allen & Penuel, 2015; Akerson et al., 2009; Barab et al., 2002; Cobb et al., 2003; Pellegrino, 2013), COPs (Cobb et al., 2003, Gallucci, 2003), and administrators (Cobb et al., 2003; Stillman, 2011) in supporting policy translation, three of the four mediating actors found to mediate policy translation in relation to dilemmas in the assemblage.

Teachers benefit from learning events about policies in which they can voice their concerns and struggles related to policy changes (Akerson et al., 2009; Allen & Heredia, 2021; Allen & Penuel, 2015; Barab et al., 2002; Pellegrino, 2013), surface uncertainties and dilemmas and creating space for sense-making and reasoning about policies (Allen & Heredia, 2021; Braaten & Sheth, 2017; Stillman, 2011). Stillman (2011) refers to this sensemaking as a "reconciliatory process." Talia expressed her frustration with the tensions between PBL and the NGSS to the research team, but it was not enough. Talia's experience aligns with Casapari-Gnann's and Sevian's (2022) work in changing teachers' assessment practice – dialectic contradictions resulting from change of practice gave rise to dilemmas. Formal learning events planned for dealing with the uncertainty and ambiguity in teachers' policy translation can help mediate dilemmas' influence on translation (Allen & Heredia, 2021). COPs or a sustained professional learning community, a mediating actor in this study, are fertile ground for wresting with dilemmas (Allen & Heredia, 2021), however, the time and resources to engage in these types of practices are severely limited (Banilower et al., 2013; Braaten & Sheth, 2017; National Academies of Sciences, 2016).

Additionally, attention must be paid to the activity of COPs in the assemblage, as they do not always support policy play. Gallucci (2003) found that strong and open COPs supported teachers' policy translation, but if weak or closed, such as Maggie's grade level science COP, new ideas, practices, or policies were less likely to be taken up (Muncey & McQuillan, 1996). However, Gallucci' (2003) COPs in the study were grade level teams and did not account for the set of communities within and beyond the school that simultaneously push and pull on one another's epistemologies to influence policy translation. Talia's tensions between the NGSS and PBL, both important to her espoused practices and the COPs in which she was a member, were never fully discussed in concert with her peers or experts on both policies. Examining the strength and openness of either community alone would have missed the tensions between them.

Administrators influence policy translation by doing initial translation of policies at both district (Haverly et al., 2022) and building levels (Cherbow et al., 2020; McNeill et al., 2018; Wenner & Settlage, 2015), determining the human, social, temporal, or physical resources teachers have to engage in policy play (Spillane, 2005). These resources and tools serve as affordances for teachers to align their practices with the school culture (Rosebery & Puttick, 1998; Schmidt & Datnow, 2005; Spillane, 2005), but fostered dilemmas when misaligned with teachers espoused practices, learning events, or COPs. For the teachers in this study, it often occurred as teachers described *NCLB*-related testing policies as out of alignment with their perceptions of best practices. Maggie had strong, negative feelings about test preparation policy, but also a strong belief in being fair to her students. Coupled with her managerial relationships with her administrator, Maggie encountered a political dilemma and adapted *NCLB*-related testing policy to balance these tensions. Fostering collegial administrative relationships is an important future direction for science education research in teacher education and educational policy studies.

Administrator-teacher relationships in policy play

We advocate here for understanding better the role of social relationships between administrators and teachers in teachers' policy play. Previous work has shown that teachers' perceptions of administrative support for policy influences their implementation (Banilower et al., 2007; Milner et al., 2012) and that administrators can mitigate the effects of policies on teachers (Stillman, 2011). However, our data indicates that the personal history and relationships between administrators influences policy play too. Talia's experience teaching with Frank let her ignore his gruff commentary on her lack of *NCLB* test preparation policy adherence to continue with her PBL practices. Conversely, Kasey did not have this social history with her administrator. She viewed Keith as an authority figure whose policies were firm, requiring adherence, even when she did not fully understand how to do so.

Our findings align with other studies of teacher-principal social relationships which show these relationships influence job satisfaction, commitment, and perceptions of cohesion (Price, 2012), student learning outcomes (Price, 2015) and mitigation of teacher burnout (Van Maele & Van Houtte, 2015). These studies connected trust to the relationships which has also been correlated with social respect (Bryk & Schneider, 2002). In our study, Maggie was distrusting of her administrator, questioning policies, and rejecting them. Opportunities to develop the social relationships that foster respect and trust have potential to support

teachers' policy play. Future policy studies should examine these complex social interactions and their role in building trust as mediating dilemmas.

Finally, we want to highlight the importance of diversity of responses in policy play. Lethal fidelity to policies, opposite Brown and Campione's "lethal mutations" (1996), are just as detrimental to school networks. Full adoption of policies without play is not always the most productive or equitable path forward. Policies as written may harm the people it purports to help such as school discipline policies that harm students of Color (Scott et al., 2017), unequal school funding policies (Adamson & Darling-Hammond, 2012), or English-only policies for multilingual learners (de Jong, 2013). For Maggie, rejecting policies was a choice she made to provide her students with the highest quality education she could imagine. Talia chose to adapt the NGSS to meet multiple policies she saw leading to student success. Fostering policy play in school networks can help teachers negotiate policies without lethal fidelity, moving education forward through play.

Conclusion

Policy responses are temporal representations of an actor's sense-making of a single policy, yet teachers navigated multiple policies from multiple parts of the system. As they integrated various policies into an assemblage, teachers engaged in play with policy. Play with policy is process-oriented, weaving together the products of responses over time. The more cohesive this weaving, the greater the level of productive policy play. This does not mean a teacher adopted all policies, but that over time, they engaged in deep sense-making around the policy, considering its place within their assemblage and responding in practice. The level of play a teacher engaged in was influenced by the interaction of teacher's espoused practices, availability of learning events around the policy, relationships with administration, and engagement with COPs, mediating actors in the assemblage.

We see these findings as tools to assist teacher educators at both the in-service and pre-service levels in planning for future teacher learning around policies. As administrators, teacher leaders, and higher education faculty examine teachers' responses to policy, they can look for the dilemmas that teachers express in their talk during formal learning events and less formal discussions about the policy, as well as the implementation in classrooms during observations. Knowing the dilemmas influencing teachers' responses can then aid teacher educators in determining which assemblage components need more support or revision – formal learning events around the policy, COPs, espoused practices, or relationships with the administration.

Abbreviations

ANT   Actor-Network Theory
COP   Community of Practice
NCLB   No Child Left Behind
NGSS   Next Generation Science Standards
PBL   Project Based Learning, or Problem Based Learning

Supplementary Information

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Additional file 1. Demographic information for Brighton School District Middle Schools 2016-2017.

Authors' contributions

This study was part of KB's dissertation work, collecting and analysing all data. SM served as the dissertation advisor. All authors read and approved the final manuscript.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved through the Pennsylvania State University Institutional Review Board and all participants consented to the study.

Consent for publication

• All authors of the manuscript have read and agreed to its content and are accountable for all aspects of the accuracy and integrity of the manuscript in accordance with ICMJE criteria.
• The article is original, has not already been published in a journal, and is not currently under consideration by another journal.
• The authors agree to the terms of the SpringerOpen Copyright and License Agreement.
• The manuscript contains no identifiable information of participants, pseudonyms are used throughout.

Competing interests

The authors declare that they have no competing interests.

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