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A close look at change: the role of an instructional-team community on an Instructor's evolution during instructional reform

Katelyn M. Southard[1*†] , Susan D. Hester[2†], Jazmin Jurkiewicz[2], Joan E. Curry[3], Young Ae Kim[2], Jonathan Cox[4], Lisa K. Elfring[1], Paul Blowers[5] and Vicente Talanquer[2]

Abstract

In transforming undergraduate STEM education, it is important to understand the personal and contextual factors that impact instructors' reform efforts. In this study we explored an instructor's drivers and motivators for change in perspectives and practice, with an emphasis on the impact of an internal community (her 'instructional team') comprised of a co-instructor, graduate teaching assistants, and several undergraduate learning assistants (LAs). Data were collected over two semesters through classroom observations, interviews, faculty learning community discussion recordings, and team email communications. We identified pedagogical discontentment as a primary initial trigger for the instructor's engagement in instructional reform, guided by personal values and beliefs about student learning and the nature of her discipline. The instructional-team community, which was established during a period of instructional distress, provided 1) consistent support in instructional planning, implementation, assessment, and reflection processes, 2) unique access to different perspectives on the nuances of the teaching environment and student challenges, 3) increased space, time, and motivation for the instructor to more critically reflect on her teaching and engage in creative instructional design. This case illustrates the potential effects of instructional team-based communities on instructors as they work to improve their practice and reform their courses.

Keywords: Instructor change, Professional development, Instructional reform, Post-secondary teaching, Instructional-teams model

Introduction

Many voices have called for large-scale transformation of undergraduate STEM classes from traditional didactic lectures to environments that foster meaningful learning through active student engagement (AAAS, 2011; NRC, 2012). As college instructors transform their classrooms, it is important to learn how to

facilitate long-term adoption of evidence-based teaching practices. To design effective professional development activities and support instructors in enacting meaningful instructional reform, we must understand the factors—both internal and external to instructors—that impact engagement in this process (Auerbach & Andrews, 2018; Ebert-May et al., 2011).

There is a body of research investigating what shapes teachers' acceptance and meaningful incorporation of reform-based strategies into their teaching practice. Such work has highlighted the role of diverse factors on teacher change, including pedagogical discontentment

* Correspondence: ksouthard@arizona.edu
Katelyn M. Southard and Susan D. Hester are Co-first authors.
[1]Office of Instruction and Assessment, University of Arizona, 101, PO Box 210070, Tucson, AZ 85721, USA
Full list of author information is available at the end of the article

(Feldman, 2000; Southerland et al., 2011; Gess-Newsome et al., 2003), teacher self-efficacy (Southerland et al., 2011), teacher beliefs (Anderson, 2002; Woodbury & Gess-Newsome, 2002), and contextual factors such as formal institutional structures, the local culture, and accepted norms (Woodbury & Gess-Newsome, 2002). Much of this work, however, has focused on teacher change at the K-12 level (with some exceptions, e.g., Gess-Newsome et al., 2003; Henderson et al., 2009; Czajka & McConnell, 2016). Although many of these factors are likely to apply to instructors at the post-secondary level, key differences are likely to have implications for how to support successful reform. For instance, traditional institutional structures and practices in post-secondary educational contexts create specific challenges that have proven to be quite difficult to overcome (Stains et al., 2018). These challenges include lack of meaningful incentives to engage in educational reform and lack of time in a college culture that overvalues research over teaching activities. Furthermore, K-12 instructors are educated in pedagogical theory and methods and are typically required to participate in ongoing professional-development activities. In contrast, post-secondary instructors are typically experts in their disciplinary backgrounds but have little or no formal teaching training, and often find little institutional support for participating in professional development (e.g., Brownell & Tanner, 2012; Ebert-May et al., 2011; Kember & McKay, 1996). Such differences in context and experience impact the internal and external factors known to influence the success of reform efforts. Thus, investigations in post-secondary education settings are necessary to understand how theories built through research in K-12 can best transfer to and be useful for supporting meaningful reform at this level.

At the post-secondary level, there has been a focus on how to gain instructors' "buy-in" to reforms such as implementing evidence-based, student-centered teaching practices (Blumberg, 2016). Work following up with instructors who have indicated buy-in to the ideas of evidence-based instruction (Dancy & Henderson, 2010) and participated in professional development (Ebert-May et al., 2011), however, has demonstrated the significant gap that often exists between embracing these ideas and enacting them in practice. This highlights the importance of characterizing factors that have supported (or challenged) instances of instructors successfully changing their enacted practice to align with reform goals in higher-education settings after initial buy-in.

There is evidence that working collaboratively with others to improve teaching can have important impacts on instructors as they set out to reform their instruction. Characterizations of instructor change at the post-secondary level have demonstrated or suggested that

collaborating with expert others acting as co-instructors or coaches can support STEM instructors' successful adoption of reform-based practices (e.g., Czajka & McConnell, 2016; Gess-Newsome et al., 2003; Henderson et al., 2009). In both K-12 and post-secondary education, structured groups of peers such as action research groups (Feldman et al., 2001; Zuber-Skerritt, 1992) and faculty learning communities (Cox, 2004; Cox & McDonald, 2017) have also been discussed for their potential to support instructors' reform efforts.

Here, we consider the impacts of a different community on a college instructor's efforts to reform a large introductory undergraduate course: an instructional team comprised of a junior co-instructor, graduate teaching assistants and undergraduate learning assistants (LAs). We sought to characterize the factors that affected this instructor's decisions and actions, after initial buy-in to active and collaborative learning, as she engaged in significant, meaningful instructional reform over a period of two semesters. We were particularly interested in the role that her instructional team played in the evolution of her teaching perspectives and practice.

Theoretical framework
In analyzing this case, we drew on Gess-Newsome et al.'s "Teacher-Centered Systemic Reform" model. We chose this as a framework for its potential to provide a useful lens on the interactions between different factors impacting one instructor, "Jay" (pseudonym), and her engagement in a period of rapid, intense instructional reform.

Teacher-centered systemic reform model
Gess-Newsome and collaborators have developed a literature-based model for analyzing factors that can constrain or support engagement in instructional reform efforts (Gess-Newsome et al., 2003; Woodbury & Gess-Newsome, 2002). Their "Teacher-Centered Systemic Reform" (TCSR) model accounts for the influence and interrelatedness of contextual factors (characteristics of the different contexts in which teaching occurs), personal factors (characteristics of the individual instructor that are relevant to their teaching), teacher thinking (knowledge and beliefs about teaching and learning), and enacted practice (how an instructor plans and implements instruction).

At the post-secondary level, contextual factors include characteristics of the classroom, department, institution, and broader cultural contexts within which instruction takes place (Gess-Newsome et al., 2003). Such factors may be, e.g., physical, demographic, cultural, structural, or disciplinary. Contextual factors at the institutional and departmental levels are often central to conversations around barriers to reforming teaching at the post-

secondary level. In particular, lack of time and incentives for undertaking reform efforts, or adopting and maintaining reform-orientated teaching approaches, are commonly-cited reasons why college and university faculty do not adopt more reform-based practices (Brownell & Tanner, 2012). In fact, disincentives may exist, as undertaking serious reform can entail risks, e.g., due to poor teaching evaluations during early stages of reform, skepticism from peers or leadership (particularly in the face of student push-back), and decreased time for research, service and administrative activities needed to secure or advance one's career. Cases in which these types of factors are mediated, e.g., through involvement with a prestigious grant, however, point to the conclusion that addressing these barriers is necessary, but not sufficient, for fostering meaningful reform (Brownell & Tanner, 2012; Gess-Newsome et al., 2003). This is because personal factors and teacher thinking are also powerful mediators of instructional practice.

Personal factors in the TCSR model include characteristics of individual instructors relevant to their thinking and decisions about teaching. Personal factors include, e.g., the nature and extent of teaching experience, the extent and nature of preparation to teach, pedagogical knowledge and strategies, the extent and nature of resource-seeking and learning efforts, and professional and life experience (Gess-Newsome et al., 2003; Woodbury & Gess-Newsome, 2002). Because they make up an instructors' experiences and disposition about teaching and their discipline, personal factors shape teacher thinking, which encompasses knowledge and beliefs about teaching, the role of schooling, the role of the instructor, the nature of learning and learners, and the discipline or content being taught (Gess-Newsome et al., 2003; Woodbury & Gess-Newsome, 2002). Another key element of teacher thinking is the nature and extent of pedagogical discontentment, which arises when an instructor is dissatisfied with the effectiveness of their current instructional goals and strategies (Feldman, 2000; Gess-Newsome et al., 2003; Southerland et al., 2011; Woodbury & Gess-Newsome, 2002).

Gess-Newsome and colleagues have demonstrated the usefulness of the TCSR model as an analysis tool. For instance, in one study, they analyzed factors influencing a grant-funded reform effort for a college-level science laboratory course. Using the TCSR as a frame, they determined that many of the typical contextual barriers to reform had been removed or minimized by the grant, and highlighted the role of the designer-instructors' personal factors and teacher thinking in supporting or limiting the success of the reform effort (Gess-Newsome et al., 2003). Moreover, a strength of the TCSR is that it highlights the importance of considering interactions between contextual and personal factors, teacher thinking,

and enacted practice. For example, Gess-Newsome and colleagues used the TCSR as a template to identify key interacting factors affecting the course of a mathematics reform effort across two high schools. In particular, they found that contextual factors (aspects of department culture and nature of the reform messages) interacted with personal factors (teachers' sense of autonomy, their knowledge of mathematics, and their experiences with professional development) to influence teacher thinking about the necessity for pedagogical or curricular change and, ultimately, how teachers took up reform practices (or didn't) (Woodbury, 2000; Woodbury & Gess-Newsome, 2002).

Research questions
In the current case study, we used the TCSR as a framework for analyzing the key factors that influenced Jay's instructional reform efforts, and the unique role played by Jay's instructional team. We applied the framework dynamically, considering the evolution of and interplay between personal factors, contextual factors, teacher thinking and enacted practice over the period of the case study. In doing so, we addressed the following research questions:

1) What were the factors that motivated Jay's instructional reform? How did these factors impact Jay's instructional reform decisions?
2) How did personal factors, contextual factors, teacher thinking, and enacted practice interact and evolve over the period of reform studied? What were key events that impacted this evolution?
3) What role did the instructional team play in the evolution of key factors?

Methods
Study context
Institution
The case described here took place at a large public land-grant research-intensive university in the Southwest US. The university enrolls ~ 36,000 undergraduate students, including ~ 30,000 full-time students. The university serves a diverse student population. It is a Hispanic-Serving Institution (> 25% of full-time undergraduate students identify as Hispanic) with a substantial percentage of minority students (~ 40%). A large percentage (~ 30%) of undergraduates are first-generation full-time college students.

The instructional-teams project
This study is part of an overarching NSF-funded project, the Instructional-Teams Project (I-TP). The I-TP has been implemented since Spring 2017. The I-TP seeks to support STEM instructors' successful enactment of

evidence-based, student-centered instruction in their classrooms by focusing on three areas: high-functioning instructional teams, design and implementation of high-quality instructional tasks, and effective use of formative assessment. Instructors who participate in the I-TP commit to participating in professional development activities as part of bi-weekly I-TP Faculty Learning Communities (FLCs), recruiting team members to fill specialized I-TP team roles, and meeting regularly with members of their instructional teams. Direct support to the instructors from the I-TP is provided through (1) the FLCs in the form of structured professional-development activities, (2) access to the expertise of a FLC facilitator (an I-TP project member or veteran participant) and other I-TP project members, (3) feedback and insight from other FLC participants, and (3) training courses for student members of the instructional team. An informational recruitment flyer describing the I-TP components and expectations for team members, as well as an outline of I-TP FLC professional-development activities during the period of the case study, are included in the Supplementary Material. Further description of the project can also be found in (Kim et al., 2019).

Instructors participate in the I-TP on a volunteer basis, and are not incentivized to join the project. Participants are recruited through multiple channels intended to target instructors with interest in adopting or improving implementation of evidence-based instructional practices. Primarily, participants are recruited through e-mail or office visits to instructors on a list of instructors teaching in Collaborating Learning Spaces on campus, through announcements in other Faculty Learning Communities unrelated to the project, and through word-of-mouth referral by colleagues. As of Spring 2021, 22 instructors from 12 different academic departments have participated in the I-TP. These participants include tenured professors (7), career-track faculty (non-tenure eligible, teaching-focused faculty with representation in the Faculty Senate) (13), a tenure-eligible assistant professor (1) and a graduate student (1).

Case study subject selection

We selected Jay's case for intensive data collection upon her joining the I-TP because she seemed poised for a period of significant instructional change worth characterizing. A pre-participation interview revealed that Jay had become increasingly dissatisfied with her pedagogy, and that she had collected personal, anecdotal evidence of the value of small-scale, learner-centered instructional strategies in her own teaching and wished to build on those experiences. She joined the I-TP for its potential to support these efforts. Moreover, Jay—a tenured faculty member with a departmental reputation as an effective instructor—faced relatively little risk from

possible setbacks in her reform efforts. As a result, Jay planned a uniquely ambitious 'overhaul' of her large-enrollment introduction to environmental science course. The significance of the planned course reform, the drastic changes in instructional practices that would be required to carry out such reform, and the inherent attending challenges made Jay's case promising for observing significant instructional change. Finally, her participation in the I-TP during this period allowed us to investigate the potential role of an instructional team in supporting this change.

Course context

The I-TP encourages instructors engaging in significant instructional changes, like Jay, to tackle one course at a time. Jay selected her Introduction to Environmental Science course for reform as a part of the I-TP. This course is a general education course serving both Environmental Science majors and non-majors. During the two semesters in which data were collected for this study, the course was taught in a Collaborative Learning Space (a classroom specifically designed—or, as in this case, retrofitted—to support collaborative student activities, e.g., by having group tables rather than stadium seating, having white boards positioned around the room where students can work on them, screens distributed around the classroom for easy viewing throughout the room, etc.). Students were seated at tables of 4 with projector screens situated around the perimeter of the room. Class periods were 50 min long and met 3 days a week. Course enrolment varied in the two observed semesters (Fall, 144 students; Spring, 101 students).

Jay's instructional team

The makeup and roles of Jay's instructional team during the case period is summarized in Table 1 (we have used pseudonyms for all team members). Jenny was a new faculty member hired into a teaching-intensive career track position the semester prior to the case study and assigned as a co-instructor for the course during the two semesters of the case study. Jenny had previously taught courses in forest management and conservation, and had developed and taught field laboratory courses in Environmental Science. This was her first experience with a large lecture-style course and with teaching the particular content of the course. Sarah was a graduate student who had worked closely with Jay for several semesters in a teaching assistantship role for other courses. She therefore had a good working relationship with Jay, though she had no particular knowledge of the course being reformed. Two of the LAs, Lane and Tay, were undergraduate students majoring in Environmental Science. They had each taken the course from Jay in a previous semester. The other, Peter, was a graduate student in

Table 1 Instructional-team-member roles

Instructional-Team Member	Role Description	Semester 1: Fall	Semester 2: Spring
Instructor	Faculty member responsible for the **planning**, **implementation**, and **assessment** of student learning.	Jay	Jay/Jenny
Learning Assistants	Undergraduate and graduate students who scaffold and support students' learning by asking **probing** questions, **pressing** for in-depth explanations, **guiding** student thinking, etc.	Lane, Peter	Tay
Instructional Manager	Undergraduate or graduate student who takes **on classroom-management responsibilities** (e.g., student group organizer, materials point-person).	Jenny	Sarah
Learning Researcher	Undergraduate or graduate student who acts as a **real-time observer of student thinking** in the classroom by **noticing patterns** in student ideas and **analyzing products** of student work. Learning Researchers may also provide pre- or post-implementation feedback on instructional tasks.	Sarah	Albert

Description of the roles and responsibilities of Jay's instructional team members during the case-study period. These specialized roles are a central characteristic of the I-TP instructional-teams model (Kim et al., 2019)

Environmental Sciences who was interested in gaining classroom experience. None of the LAs had previous experience teaching or serving on an instructional team. They received academic credit for their service in the course and participation in an associated teaching workshop led by Jay.

Professional development context

As part of their participation in the I-TP project, Jay and Jenny participated in professional development activities in I-TP FLC meetings every 2 weeks; these focused on building an effective team, instructional task design, and formative assessment (an outline of these activities is included in the Supplemental Materials). Sarah, the Learning Researcher, participated in a 1-credit I-TP-led course focused on collecting, interpreting, and communicating evidence of student thinking for formative assessment. The LAs, Lane, Peter, and Tay, took part in a teaching workshop led by Jay as part of the credit requirement for their service in the course (a structure that Jay "inherited" from her predecessor), in which they worked with Jay over the course of the semester to each develop and implement a day of instruction on a course topic.

Data collection

In order to observe change, specifically factors that facilitated change and assisted in navigating barriers, we used a variety of data collection methods over two semesters (Fall, Spring). The data collection was designed to investigate changes in instructor perspective and teaching practices.

To observe Jay's reflections on her instructional perspectives, decisions, and practice over the two semesters of the case-study period, we conducted five semi-structured clinical interviews lasting between 1 and 2 h. These interviews were conducted before (pre) and at the end (post) of each of the two target semesters, and at the middle of the fall semester. Interview questions were intended to prompt Jay's reflections on her personal perspective of her instructional changes and instructional-team dynamics. Observations and audio recordings of bi-weekly I-TP FLC meetings (a total of 15 1-h meetings over the two semesters) were also collected in order to observe changes in the ways Jay discussed her teaching philosophies and practices in a peer-community setting.

In order to observe evolution in Jay's instructional practice as well as the impact of the instructional team community on instructional design, implementation, and reflection, daily classroom observations were conducted by the first author during both target semesters. These observations included observations of pre- and post-class impromptu meetings between Jay and her instructional team. Daily audio recordings of the classroom were also collected over the two semesters. We collected instructional artefacts (e.g., PowerPoint slides, worksheets, discussion prompts) from two units of instruction, as enacted in three different semesters (one semester before the case-study period and the two semesters of the case-study period). In order to further capture team communications, all team emails were archived. In the fall semester this encompassed 41 email threads, and in the spring semester this encompassed 64 email threads. Email threads could include as few as one email from a single sender to the team, or it could include a string of many email communications between multiple senders. Pre- and post-semester semi-structured clinical interviews and/or focus groups were also conducted with a subset of consenting instructional-team members. Participation in all interviews was entirely voluntary.

Data analysis

We conducted multiple rounds of qualitative data analysis, guided by our research questions. Although different data sources were the primary foci for different analyses, immersion in the data from different sources informed our analysis at all stages, and emerging

findings were cross-checked with other data sources for disconfirming or supporting evidence.

To build an organizer for analyzing and relating key events and developments during the case-study period, we used classroom observation notes and classroom audio files to create a three-tiered timeline. This timeline included descriptions of 1) instruction and classroom events (e.g., unit/topic, activities, highlights of classroom observation notes), 2) observed changes in approach to instructional tasks and formative assessments (e.g., "[Jay] adds structure to task in response to student and team feedback about confusion"), and 3) changes and major events in instructional team development and evolution (e.g., "Impromptu post-class team meeting observed after this class for reflection and evaluation of how this instructional change went").

Using the TCSR as a frame, we then set out to characterize factors and elements of Jay's teacher thinking that motivated instructional reform and influenced the decisions Jay made throughout her reform efforts. Guided by this aim, we iteratively analyzed interview transcripts, FLC observation notes and transcripts, and class observation notes for relevant emergent themes. We began by independently reading through the data and making "open notes" about potentially relevant instances. Through comparison and discussion of these notes, we consolidated notes into intermediate codes or subthemes. We cross-checked emerging codes/subthemes against all data sources, for counterevidence or additional supporting evidence. Finally, we grouped intermediate codes/subthemes into organizing themes. We have included a table presenting an example of this iterative process for the theme, "Evolving pedagogical discontentment as a motivator for change", in the Supplementary Materials.

To add to our understanding of how Jay's instructional practice changed in this time, we performed cross-semester instructional task analyses on two units, using instructional artefacts from each unit (e.g., PowerPoint slides, worksheets, discussion prompts), audio files and in-class observations (for the two target semesters), and instructor reflections from interview transcripts. These analyses characterized structural changes to the instruction within those units over the course of three semesters (one semester before joining the project and the two target semesters). We first constructed an outline of each unit in each semester. We then compared activities from each unit across the three semesters for similarities and differences in task design and implementation. In doing so, we moved between stages of identifying potential similarities and differences in design and/or implementation, and systematically analyzing each semester's instructional artefacts from the unit to identify any evidence that might challenge the emerging claim (e.g.,

instances of a feature in one semester's unit tasks that was proposed to be absent, or the rarity of a feature across another semester's unit tasks when that feature was proposed to be characteristic).

All data collection and analysis were approved by the institutional review board at our university (IRB 1409498345).

Results

Jay's reform of her teaching practice is a case of evolving, interrelated contextual factors, pedagogical discontentment, teacher thinking and enacted practice. Throughout the reform period, Jay's instructional decision-making was driven and guided by her evolving pedagogical discontentment and teacher thinking. Her instructional reform efforts were initially constrained by the barriers of lack of time and limits to her pedagogical understanding, which were both alleviated with the increasing integration of her instructional team into her teacher thinking and enacted practice. Central components of this integration were increased team communication and greater incorporation of the team into instructional planning, design and implementation. Both of these components were initially spurred by an instructional crisis leading to acute pedagogical discontentment, and reinforced by the positive impacts that the team's increasing contributions had on Jay's enacted practice.

Contextual and personal factors that set the stage for reform

As introduced in *Case study selection* above, there were contextual and personal factors that initially set the stage for her reform efforts. Importantly, Jay was a tenured professor, so her job security was not at risk due to setbacks along the way. Moreover, since becoming tenured, Jay had undergone a shift in her responsibilities from primarily research to primarily teaching responsibilities. The shift began a few years before the case-study period and was driven by a combination of factors. Jay had secured tenure on the strength of her research productivity, but was losing interest in growing her research program in directions that would advance her career. When two faculty members retired in the same year, Jay's department needed an instructor to take over two large-enrolment courses important to the department. Jay saw this as an opportunity to expand her teaching, which aligned well with her perceived strengths based on her experience. Later, Jay reflected that, "they had a need for teaching … [and] I knew I was good at that; the experiences that I'd been having were good, the students responded well."

Although she identified as a good instructor, Jay also brought a personal perspective of openness to change. In retrospect, Jay reflected,

You know, before you have a shift, you don't know there's a shift to be had. See, that's the thing: you don't know what you don't know ... . And if you don't know, you can't imagine, until somebody says, "try this, try this, try this," and, once you do it, then you're like, "Oh, this is--there's something here." (Jay, follow-up interview)

Jay's identification of herself as a good instructor and her openness to new ideas contributed to her willingness to reform her instructional practices when she encountered dissatisfaction with the outcomes of her teaching.

Drivers for engaging in instructional change: pedagogical discontentment
Dissatisfaction with student engagement
Jay had been teaching since 1996, primarily small (< 25 students) upper-division and graduate classes. Her teaching practice was through 'interactive lecture' in which she delivered information through a set of Power-Point slides peppered with Socratic back-and-forth dialogues with individual students. In 2012 she began teaching two large-enrolment (~ 150 student) general-education courses, serving majors and non-majors, as described above. It was at this point that Jay became dissatisfied with the lack of student engagement during her classes:

And so I realized that in going through this, as I was doing my lecturing, and you know, doing kind of the same sort of thing that the students weren't... they were, I could just tell that they weren't engaged, I could read the room and tell that maybe a few people were but not all of them. (Jay, Fall pre-interview)

While the interactive lecture approach generated the desired levels of student interest and engagement for her previous courses, Jay discovered that this method was unsuccessful in the large-enrolment general-education courses she was now teaching. This dissatisfaction with student engagement led her to start experimenting with different instructional strategies. First, she began to include non-planned small-scale moments of peer interaction:

I just thought-, it was just instinctive. I tried kind of this 'talk to your neighbor', kind of 'wake up!' [laughs] You know 'wake up!' and I got a good--the

energy came back and so I thought 'oh!' you know? (Jay, Fall pre-interview)

She noted that her experimentation with peer interactions was not driven or guided by formalized professional development, but rather through 'instinct', noting that '*it wasn't anything deliberate, it was just a sense for how to make this a more fun thing*'. Motivated by the positive, desired outcome of increased student engagement as assessed by '*reading the vibe of the room*', Jay began to plan collaborative group activities ahead of class, remarking that '*I realized I could make-, I could do bigger things*'.

A change in the context of Jay's teaching—from small, upper-division courses to large, introductory ones—caused a change in the outcomes that she observed from her enacted practice. Low levels of student engagement led Jay to experience a sense of pedagogical discontentment with her previous interactive lecture style of instruction. This drove Jay to "instinctively" incorporate impromptu opportunities for students to collaborate with one another and discuss course concepts in class. Upon observing an improvement in student engagement, she was encouraged to adopt a more deliberate approach to incorporating those opportunities.

Dissatisfaction with the level of student thinking
By the time she joined the I-TP, Jay had come to highly value collaborative instructional tasks for their ability to engage students. She was dissatisfied, however, with a perceived lack of success pushing students to higher levels of thinking. She remarked on this in her first, pre-participation interview:

I don't like having people sitting around shooting the breeze. I try to, you know, sometimes maybe my question isn't probing enough, maybe it is too open-ended so they answer, 'oh yes, I like that' or 'I don't like that'. But it's like 'why don't you like that!?!' So there's some of that kind of stuff that I can, I could, you know, improve. (Jay, Fall pre-interview)

Jay experienced her dissatisfaction with students' lack of higher-level thinking as discontentment with the types of questions that she asked. She was aware that her limited pedagogical knowledge was constraining her ability to elicit the types of thinking that she wanted her students to practice. This acknowledgement, and the related pedagogical discontentment, left Jay open to undergoing continued professional development and significantly redesigning her course.

Factors shaping instructional change: teacher thinking

Central elements of Jay's teacher thinking shaped how she engaged in reform—particularly when her enacted practice failed to support the resulting goals. In particular, Jay's instructional priorities related to student engagement and critical thinking, as well as her view of the nature of the course content, were important factors in how she approached instructional reform.

Importance of student engagement and student-interest-driven instruction

As explored in the section above, Jay highly valued student engagement, to the extent that a lack of such engagement drove her early instructional reform efforts. Prior to her involvement in the I-TP, Jay's investment in student engagement led her to explore Ken Bain's work in using student-interests as drivers for learning in college classrooms (Bain, 2011). Jay was so inspired by this concept that she re-created a unit in her graduate-level environmental science course (10 students) to test these ideas.

> "I was applying the Ken Bain idea of having students-, having it connect to their own personal interest. Their questions. And the students brought in [research] papers that they were interested in. [...] I drove them then, into the papers. [...] And there came a point where all of the students got stuck on some universal features of chemistry. Colloidal chemistry. Particle chemistry. That was the start. They all came and were like 'I need to know this because it's important to me'. It was important because they brought it in, and they had a personal investment in understanding that paper." (Jay, Post-Study Reflection Interview)

Exposure to Bain's ideas and this positive experience with her graduate-level course led Jay to incorporate a commitment to student ownership through student-generated questions as a driver for student engagement into her beliefs about teaching.

Importance of critical thinking

In addition to student engagement, Jay highly valued students' ability to critically analyze information posed in the media as well as their own preconceptions about environmental issues. Thus, she wanted students in her courses to have the opportunity to evaluate different sides of an argument and develop data-driven evaluation skills. For instance, in discussing her instructional priorities going into the I-TP, she remarked,

> So one of my main goals is to get them to take things apart. [...] The whole class is really about getting

> past the news stories. So getting them to question the things we see in the news all the time. But they have a lot of preconceived notions you know, just by being a human here. So I try to come from a science point of view. (Jay, Fall pre-interview)

Jay's prioritization of students' critical-thinking skills and 'science point of view' shaped the instructional decisions that she made and how she evaluated the success of her instruction.

Non-linear nature of the course content

Finally, Jay's beliefs about the nature of her discipline significantly impacted her approach to teaching content in the course. She articulated this view at the beginning of her I-TP participation:

> So these classes are not, like chemistry classes. In some ways those seem easier to me because it's like 'ok', you know, 'do this'. 'You've got these problems'. And then the next thing you do is 'this' and you do it that way. This is really ... this is environmental science. I could start anywhere in the book and go anywhere I want to. So it's a little different. I think there's a, a completely... I don't know, it's a different animal. (Jay, Fall pre-interview)

Jay viewed the nature of content material in environmental science as non-linear in comparison to other fields of study such as chemistry, in which she earned her PhD. Thus, she did not see herself as being constrained to a particular content sequence, a view that profoundly impacted her instructional decisions as she set out to redesign her course.

Although Jay was committed to reforming her instructional practices and redesigning her introductory course, she encountered barriers in tackling certain areas of reform. Some of these barriers were noted by Jay as challenges early in the reform process, some were acknowledged by her retrospectively, and others were evident in our observational analysis. We discuss the most significant of these barriers below.

Barriers and challenges
Lack of time

A significant contextual barrier that Jay noted early on was a lack of time. This is consistent with the literature on faculty-reported barriers to reform, and is not surprising given Jay's professional responsibilities (at this point she was routinely teaching three courses a semester and maintaining a scaled-down research program). As an example, she discussed the time barrier in terms of the difficulty she was facing using in-class student work to assess students' understanding and progress.

[W]hen I could actually read them all [in-class student work], or have a look at them, I could get a lot of insight into what was going on. I often didn't have time. The TA would look at stuff, [but] I was on to the next thing, you know? Just because of the sheer volume of stuff coming in. (Jay, Fall pre-interview)

She knew that students' collaborative products offered assessment opportunities but was struggling to manage the large volume of information generated by different student groups in the available time. The lack of time to devote to these types of activities limited Jay's ability to enact elements of what she recognized as best instructional practices.

View of instructional role as independent 'lone instructor'

Another significant barrier that Jay encountered early in her reform efforts was her own view of the role of the instructor as an independent actor. She came to recognize this as a barrier later. Reflecting on this at the end of the study period, she remarked that:

You know, everything I had seen leading up to any of this was, you know, just the instructor did all of these things. And it just didn't-, the fact that it was overwhelming and unmanageable just seemed to be a problem that I was having. You know? I just needed to manage better. (Jay, Spring post-interview)

Because she viewed it as her responsibility to single-handedly manage every component of instruction, she saw the challenges that she encountered as resulting from a personal failure to 'manage better.' This lone-instructor view limited her ability to recognize and rely on others as a resource.

Beginning stages of pedagogical knowledge development

Another barrier to Jay's early reform efforts was that her ideal teaching practice extended beyond her current pedagogical knowledge. As an expert in the discipline, her knowledge of the content area was high, and she had many years of experience successfully teaching advanced students in the discipline. The radical shift from teaching small upper-division and graduate courses to large introductory undergraduate courses, however, necessitated a new approach for her. This can be seen, for example, in her struggle to get the students in her introductory course as deeply engaged with thinking critically about the material as she would like (discussed above). At this point, her limited experience with students at this level, compared with her extensive experience with upper-division and graduate students and her own depth of expertise in the content area, made it difficult for her to predict how students in her introductory course would engage (or not engage) with course activities. Jay was also early in the process of developing pedagogical tools suitable for large introductory courses in general. For example, Jay was initially resistant to the idea of establishing, aligning, and communicating learning objectives. While she was willing to engage with activities centered around learning objectives during FLC meetings, it was clear that she did not yet see the value in integrating them into her practice. Jay was more invested in the potential of formative assessment, but she was also aware that she lacked strategies for making students' thinking visible in real time. When asked in her pre-participation interview about how she collected information about student thinking while groups worked on in-class tasks, Jay laughed and replied, '*No clue!*'

By the beginning of the case-study period, Jay had 'bought in' to the ideas of student-centered, evidence-based instruction, and held beliefs and goals consistent with this in her commitments to student engagement and higher-level thinking. Contextual factors, personal factors, and elements of her teacher thinking, however, presented barriers that caused her to struggle to effectively operationalize them in the design, implementation, and assessment of classroom activities. As we will argue below, however, the frustration and disappointment encountered as she struggled with these challenges created an opportunity for the development of an effective instructional team that ultimately played an important role in Jay's successful instructional reform.

Key developments in the case

Upon joining the I-TP project, Jay made the decision to overhaul her *Introduction to Environmental Science* class in a radical way. Her approach to course revision was driven by her prioritization of student engagement, and her conviction that meaningful engagement stemmed from students' interest in and ownership of the content studied. In order to allow for students' interests and questions to become the primary drivers of the topics studied, she decided to stop using the textbook and the Power Point lecture notes that had guided her teaching up to that point. In place of the highly-structured interactive lecture that she had previously used throughout the course, Jay opened the fall semester with a series of activities intended to give students the space to generate questions that would drive instruction for the first part of the course. Enacting this series of activities, known as the 'mind-mapping task', presented significant challenges that became critical in the evolution of Jay's instructional practice. Importantly, it served as a catalyst for Jay's reliance on her instructional team as a valued resource.

Consolidation of the team and transformation of Jay's views of instructor/team roles

As a first activity in the 'mind-mapping task', Jay asked students to answer the question shown in Fig. 1 using color-coded ABCD cards to provide their responses. She then asked students to use the information gathered in building their answer to develop a mind map. These maps were open-structured concept maps in which students had to connect relevant concepts and ideas with support and justification from sources. This activity was intended to model how to answer a socially relevant environmental science question using a tool for organizing ideas.

In a next step, Jay asked students to come up with any question they had about environmental science and explore it using the mind-mapping tool. This launched the class into what became a two-week-long activity. Consistent with her beliefs about the importance of ideas being student-driven, Jay deliberately limited instructor guidance and structure as a way to avoid hindering students' idea-generation and inquiry. As enacted, the result of this decision was that the presentation of the mind-mapping task lacked clear objectives and expectations, without guidelines for what types of questions were appropriate. It was also unclear what type of specific product students were expected to generate, or with whom—while students were first encouraged to brainstorm ideas on whiteboards with their tablemates, they were not given instructions on whether to work individually or in groups, or whether a group should choose a common question to investigate. The lack of structure and clearly defined objectives or expectations resulted in widespread confusion, frustration, and uneasiness among students.

Students' discontentment was felt by both Jay and her instructional team. Jay expressed dismay at the difference between her intentions—to engage the students in a challenging task that would allow them to pursue their interests—and students' observed frustration. Her distress at this outcome, however, prompted Jay to be more open to her instructional team as a resource for improving instructional planning and implementation. At the same time, the team members' observations of students' frustration motivated them to share their own ideas and feedback. This began a shift in the role of the instructional team from relatively passive 'classroom helpers' to active collaborators.

The shift in the role of the instructional team could be seen in the communication between Jay and the team. At the beginning of the semester, prompted by the I-TP FLC facilitator, Jay had established one-way pre-class email communications to inform her team of the upcoming events of the day, but did not establish an expectation that they would provide feedback. This was consistent with her initial view of the instructor as an independent decision-maker and instructional designer. In the second week of the semester, prompted by the crisis they saw unfolding in the classroom, members of the instructional team began responding to these emails with ideas, suggestions, and recommended modifications to provide students with more guidance. The pre-class emails quickly evolved into a community forum for the collaborative design of the daily instructional tasks and the delegation of instructional responsibilities during task implementation. In addition to expanded email communication, a new line of communication was opened when team members began informally meeting with Jay after class to provide feedback on the day's activities and make suggestions for moving forward. By the seventh day of the mind-mapping activity, these post-class meetings had become unofficially established as a time for the team to reflect and plan together.

Fig. 1 Mind-mapping instructional task initial prompt

Moving forward, these lines of communication became a norm for Jay and her instructional team, and an important part of Jay's instructional practice. At the end of the case-study period, Jay reflected on this shift and described her approach to establishing open communication and feedback as a team expectation from the start of each semester:

I mean, [prior to the case study period] we really didn't have a team concept. We were a group of people, but I was clearly the one just coming to class and going, 'Okay, here we go!' […] [N] ow, it's like we're all in it together, you know? […] I'll start right off with that [in future semesters]. […] I'll do it by example by sending the stuff early and saying, 'Okay, here's what we're gonna do, please give me feedback.' […] If I don't get feedback I'll go, 'Okay, what is your feedback?' I mean, I know how to do that because I know now what I want as far as engaging the team which will then engage the classroom. (Jay, Spring post-interview)

Jay experienced a shift from viewing herself as the lone instructor, solely responsible for planning instruction, to the leader of a collaborative team that is 'all in it together.' She and her team opened lines of communication that invited the team members into instructional planning and reflection as collaborators. As the instructional team became more involved in the planning and reflection stages of instruction, team members became more engaged in the implementation of instruction within the classroom, as well. Jay reflected on this connection to a colleague during an FLC meeting in the second semester of her participation, remarking that the team

wanted to provide feedback and that they also gave me positive feedback about actually sending [instructional plans] ahead of time. And I also noticed that the result was that in class they weren't standing and looking at me trying to figure out what was happening next. They already knew. (Jay, Spring FLC Meeting)

Similar to the shift that Jay experienced in her thinking about her and the team's roles in planning instruction, Jay came to integrate her team into her thinking about what happened in the classroom. Whereas she noted that, previously, she 'didn't really use them in the class in any way other than to pick up papers,' a change that she had noticed in her own teacher thinking was

thinking of tasks as something the team is going to do, not something I'm gonna do and they're gonna

help out with. Like, it really is something that we are all gonna be participating in. If I--trying to make sure that I'm just, I'm just leading, you know? I'm not trying to think of it in terms of me doing everything. (Jay, Spring post-interview)

Both in and out of the classroom, Jay came to think of her team members as valued contributors to her instructional practice.

The challenges encountered in the mind-mapping task, and Jay and the team's response to them, triggered a transformation in the instructional team's role and dynamics. This, in turn, resulted in a lasting change in Jay's view of the roles of the instructor and team. Jay's new openness to her team's active and meaningful involvement in different aspects of instructional planning, implementation, and assessment was critical to advancing the transformation of her teaching practices.

Increased reliance on team and lowered time barrier
The development of an increasingly integrated and functional instructional team encouraged Jay to share and delegate practical and cognitive responsibilities. As her view shifted from that of lone instructor to coordinated team, so, too, did her enacted practice:

Now [the team is] included. It's the assumption that we are all in this together. And I don't have to have all the answers. I don't have to have it all worked out. Because it's a team! It's a team! (Jay, Spring post-interview)

Classroom observations and analysis of the team's email communication support this impression: although Jay did occasionally 'fall back' into trying to attempt to manage independently in the classroom, her team was increasingly involved in both instructional planning and implementation. This lowered the time barrier, freeing up Jay to devote more of her time and energy to reflect on and develop her teaching practice:

I basically took the role of doing everything last semester [before the reform]. […] Many things that I'm doing now were, oh you know, maybe places where I thought 'oh man! [I could try this]. You know? But I had no solution, or even enough time to think about the fact that it was a problem! (Jay, Fall mid-semester interview)

Because she was no longer 'doing everything' now that the team was handling some of the time-consuming responsibilities of instruction, Jay was more able to recognize, reflect about, and act on places where her instruction could improve.

Deepening pedagogical knowledge and evolution of enacted practice

Jay's shift towards a 'team concept' and the integration of the team into her teaching created a unique context for Jay to expand her pedagogical knowledge. As discussed above, the lowering of the time barrier as course-management and -planning responsibilities were shared with and delegated to others bought Jay more time and energy to devote to developing her practice. Beyond this, however, the team contributed to an environment in which Jay was both encouraged and supported in developing her pedagogical knowledge. This occurred through different mechanisms. For one, certain team members acted as cognitive partners, providing feedback and suggestions from different points of view and pressing her to reflect on and justify her instructional decisions. Moreover, her desire to clearly communicate her instructional goals to the team further pushed her to articulate her motives and more deliberately align them with specific elements of her instruction. In this way, Jay was both given space and support to reflectively develop her thinking about teaching, and pressure to reflect those changes in her enacted practice.

Because of their diverse roles and experiences, instructional team members pressed Jay for reflection and provided feedback in different ways. For example, Jenny primarily provided feedback on task structure and learning goals in the planning and reflection spaces. When asked about her role, Jenny noted that she viewed herself as a challenger, saying, *'Another thing I do […] is ask "what would you like to get out of this?".'* On the other hand, Sarah tended to provide more specific feedback on task design and implementation:

> *After class she [Sarah] always provides good feedback, as far as whatever is going on. […] If I sent out the learning objectives-, if I've got my deal and I've sent out the learning objectives, and she [Sarah] says 'have you thought about this?' Yeah, that's VERY helpful. (Jay, Fall mid-semester interview)*

A significant impact on Jay's pedagogical understanding and instructional practice was the development of her appreciation and skill for incorporating structures to scaffold instruction while retaining elements of student-driven inquiry. She retained her commitment to fostering student interest through ownership, her view of the flexibility that the 'nonlinear' nature the discipline afforded, and the importance of students critically evaluating claims and perspectives about environmental science. At the same time, she came to see a certain degree of structure as necessary for supporting productive student engagement in the course. This can be seen in the evolution of the example unit focused on air quality

(Tables 2 and 3). Prior to her participation in the project, Jay taught this unit within a single class period as an interactive lecture punctuated with student activities. Her discontentment with this kind of instruction prompted her to adopt a very different approach as she began project participation. As discussed above, in the first semester of project participation Jay expanded this unit into a multi-week open inquiry, reflecting elements of her teacher thinking around the importance of student-driven questions and her belief that structure inhibited student ownership. Her use of learning objectives was pro-forma, described by her as 'an afterthought', rather than used as a pedagogical tool. The lack of structure and clearly-stated learning goals motivating course activities limited formative-assessment opportunities. As her team became more central to her instructional implementation, Jay came to see learning objectives as a useful tool for communicating with her team about her goals in the classroom:

> *I learned a bit more about doing the learning objectives during the semester. And just because I have it in my head, it really doesn't help them [the team] if it's just in my head. And it would be more helpful for them to see kind of what we're talking about, where I-, where I envision to go. (Jay, Fall post-interview)*

Over time, with her team's feedback and collaboration, and her own observations and reflection, Jay began to increasingly accept learning objectives as a pedagogical tool. She discussed this in a FLC meeting during her second semester of participation:

> *I think before it was just an afterthought, the learning objectives … but when they started to challenge me to assess what was going on, then I really had to make it match. First, I had to generate [the learning objectives] and then I had to make them match up [with instruction and assessment]. (Jay, Spring FLC meeting)*

Beyond viewing learning objectives as a way to communicate with her team, she had come to see them as a way to align her instruction with her learning goals. Moreover, this was driven by a push to assess whether or not students were meeting those goals. By the second semester of participation, we see this change in view reflected in the design and implementation of the air quality unit (Tables 2 and 3). Learning objectives were emerging as an important part of Jay's instructional design that helped her build a more structured, scaffolded guided-inquiry unit with more clearly-stated expectations. She also used a variety of tools to assess students'

Table 2 Evolving instructional task structure for the Air Quality Unit

Course: Fundamentals of Environmental Science and Sustainability

Content Topic: The Atmosphere: Air Quality and Pollution

Semester Pre-I-TP Participation	Reform Semester 1 Fall	Reform Semester 2 Spring
• Interactive lecture: Driving Question Student Poll: Students asked to vote on whether they think air quality in the US is getting better, worse or staying the same. • Task 1: Data Exploration Activity: Individual exploration of Air Quality Index (AQI website). • Interactive lecture: Instructor defines relevant terms • Interactive lecture: Instructor presents foundational topics related to ozone depletion. • Task 2: Graphical Representation Activity: Students asked to graph the size of the ozone hole as a function of time while watching an animation.	• Task 1: Mind-Map Activity: Students individually come up with questions about air quality to explore through 'mind-mapping'. • Students introduced to a mind map building online program. • Students perform a peer-evaluation of mind maps. • Students generate potential quiz questions based on their mind maps. • Interactive lecture: Instructor introduces issues of ozone depletion and climate change. • Assessment: In-class, open note mind map and group quiz.	• Task 1: Small Group Whiteboard Activity: Students individually explore Air Quality Index (AQI website) to find data, create a list of observations and questions on whiteboards. Team collects observations/questions and funnels to Instructor for post-task discussion. • Task 2: Small Group Whiteboard Activity: Students provided with categories of air pollutants and asked to collaboratively investigate sources of these pollutants. • Assessment: Individual in-class quiz. • Interactive lecture: Students come to class with an article on ozone and a question they would like to have answered through interactive lecture. • Watch videos: Reproduce the chemistry of ozone formation and depletion from videos on group whiteboards. • Task 3: Question Exploration: Planned and impromptu questions for exploration using online resources, voting using ABCD cards, and whole-class discussion. • Task 4: Topic Sorting Worksheet: Students provided with a word bank of topics and 4 large categories, asked to work in groups. • Task 5: Identifying Misinformation Whole-Class Activity: Students provided with 4 pictures and captions from 'reliable' sources and asked to predict how misinformation may be presented. • Task 6: Potential Quiz Question Generation: Students work in groups to generate quiz questions, then peer review other groups' questions, for summative assessment. • Assessment: In-class quiz: Individual then group component. Peer grading of quiz during class.

A breakdown of the structure of an instructional unit about air quality for three semesters. The semester before the case-study period (Semester Pre-I-TP Participation) the unit was carried out within one 50-min class session. In the first semester of the case-study period (Reform Semester 1), a low-structure mind-mapping task was conducted over nine 50-min class sessions. In the second semester of the case-study period (Reform Semester 2), an increase in structure and instructional strategies supported students' generation and investigation of questions of interest. In this semester, the unit was carried out over eight 50-min class sessions

thinking and progress towards those objectives, such as whiteboards, ABCD cards, and whole-class discussions. Notably, in addition to relying on members of her team as co-creators in planning instruction, Jay also came to rely on members of her team to carry out real-time formative assessment of student thinking during class. In an interview between the two semesters, she described this:

> I think I have to have someone else [listening to student reasoning in class]. … I thought, 'Oh, I can listen to what [students] are saying [in class], you know? … .But I realized I had no—I really didn't know how to distil it into anything that I could actually use. (Jay, Spring post-interview)

Jay embraced the importance of formative-assessment within her class, but became increasingly aware that she

was limited in her own ability to assess student thinking in real time. Because of her acceptance of her team as an instrumental part of her instructional practice, however, she was able to rely on them to support different types of formative assessment.

Epilogue: evidence of meaningful and lasting change

Although this study was primarily an investigation into the factors influencing Jay's reform efforts, we were also interested in whether there was evidence of meaningful and lasting change in Jay's case. We conducted a follow-up interview with Jay 3 years after the end of the case-study period. The one-hour, semi-structured interview prompted Jay to reflect on her past and current instructional practices and use of an instructional team. In the interview, Jay expressed a view of her team that indicated that her teacher thinking about the team's role had, indeed, undergone a lasting change:

Table 3 Alignment of key personal factors, elements of teacher thinking, and enacted instruction in the Air Quality Unit

Variable	Pre-I-TP participation	Reform Semester 1 Fall	Reform Semester 2 Spring
Personal Factor			
Pedagogical strategies	Limited, traditional ➔ Developing, 'active learning'	Developing, evidence-based	Developing, evidence-based, 'backwards design'
Resource-seeking and learning efforts	Faculty learning community (FLC) participation (not associated with I-TP) Classroom experimentation Literature (i.e., Bain, 2011)	I-TP participation Instructional team emerges as resource (co-constructors, co-implementers)	I-TP participation Instructional team acts as resource (co-constructors, co-implementers)
Teacher thinking			
View of instructor role	Independent developer, lead implementer	Independent developer, lead implementer → Team leader	Team leader
View of instructional team role	Limited classroom helpers	Limited classroom helpers → Co-constructors/ Team members	Co-constructors/Team members
View of learning motivators/ supports	Student interest, activity (e.g., opportunities to discuss) drive engagement	Student interest and ownership drive engagement; structure stifles student autonomy	Student interest and ownership drive engagement; some structure necessary to support productive engagement
View of content	Process-oriented, nonlinear	Process-oriented, nonlinear	Process-oriented, nonlinear
Enacted instruction in target unit (Air Quality Unit)			
Instructional approach	Interactive lecture	Open inquiry	Guided inquiry
Degree of structure	High	Low	Moderate
Use of learning objectives	None	Pro forma/ 'afterthought'	Developing integration into design
Use of formative assessment	Low, informal, opportunistic	Low, informal, opportunistic	High, structured, planned and flexible

One of the things I realized is that I can do more with the team than I can by myself. And just, you know, that I'm actually--not even just better. I can actually do more and so I become larger and we become larger as a unit. (Jay, follow-up interview)

The practices associated with this shift in view had also persisted. Following up on this remark, Jay described the coordination of her team during class activities—"if I had to do those [things] myself, it would not, it would not be as good a product. So that's sort of a low-level way to think about it, just the technical aspects [of running the class]"—and went on to talk about their creative contributions—"But you could upsize that to anything, right? You can upsize that to the learning objectives, to the activities, you know. They have this whole perspective to the execution of the activities." Jay had continued the practice of sending plans and activities to her team ahead of class meetings, both to facilitate coordination during implementation, and to invite their input. She had also continued to rely on her team for formative assessment, commenting that "you cannot, if you're the instructor, see all that stuff … I actually cannot get that

information without these people." Notably, Jay continued to integrate and rely on an instructional team in her teaching practice beyond the term of the particular team that was so integral to her initial drastic reform efforts. At the time of this interview, for instance, Jay's team was composed of five undergraduate students (she had not been assigned a co-instructor or a graduate assistant for the semester), all of whom were new to teaching and working with Jay.

Additionally, we characterized core features of our in-class task analysis (instructional approach, degree of structure, use of learning objectives, and use of formative assessment) in instructional artefacts from two semesters after the case-study period. The instructional approach (guided inquiry), degree of structure (moderate) and use of formative assessment (high, structured, planned and flexible) were maintained from the second semester of the case study. Learning objectives were more consistently integrated throughout the unit by this point than in even the second semester of the case-study period, an observation consistent with Jay's remarks in the follow-up interview on the evolution of her understanding of learning objectives as a pedagogical tool:

It took me forever to get me to understand that learning objectives are not a bad thing, you know? Because I always felt like [they were] restraining me or something ... [Now] I look back at my old slide sets and they just start with like a graph or something, and it's like, "Oh, that must be before [the reform] ... " and I'm like, "Why would I just have that as my first [slide]?!"

These observations indicate the persistence of Jay's shift in practice, and support that Jay's growing competence enacting that practice, as opposed to a reversion to her previous, more "traditional" practices, is responsible for the recovery seen in students' perceived effectiveness of course activities.

Finally, to address whether students' experiences of the course had changed over the multi-semester process of reform, we collected students' responses to teacher-course evaluations (TCEs) for the two semesters prior to the case-study period, the two semesters of the case-study period, and the two semesters following the case-study period. We did not collect TCE responses after that time because survey items were altered in future semesters, preventing direct comparisons. We found that students' perceptions of the effectiveness of in-class activities (the primary target of Jay's reform efforts) showed a pattern characteristic of major reform, falling drastically at the outset of Jay's reform efforts and then recovering over a few semesters to reach a new high (included in the Supplemental Materials).

Since the case-study period, Jay has received a Provost Award for Innovation in Teaching recognizing the results of the reform effort described in this study. She has also become a leader in teaching on campus, including serving as a Fellow and Chair of a college-level Academy for Teaching Excellence, which advances the educational mission of the college through mentorship, workshops, and recognition of excellence in teaching.

Discussion

Buy-in for active, collaborative, and evidence-based teaching practices is only one step in transforming instructors' perspective and practice. It is essential to understand not only what it takes to initially decide to move away from lecture-only teaching practices, but the factors that can influence change and aid in navigating barriers during the complex and challenging transformation process. By closely investigating change as it occurs, we can better understand the complexity of engaging in instructional reform after the initial 'buy-in' stage of evidence-based teaching adoption, as instructors build expertise and navigate large-scale transformations in their instructional perspectives and practice.

A teacher-centred dynamic systems approach

A key insight behind the TCSR model is that it treats instructional reform as taking place within a system centred around the teacher (Gess-Newsome et al., 2003; Woodbury & Gess-Newsome, 2002). Our analysis of Jay's case points to the power of taking a teacher-centred *dynamic* systems approach. By its nature, reform entails changes to the system—changes that do not necessarily move the system directly from one stable configuration to another. Jay's case is an illustration of the complexity that can characterize the evolving interactions between the dynamic elements of the system: contextual factors, personal factors, elements of teacher thinking, and elements of enacted practice. For example, although certain elements of Jay's teacher thinking—such as her view of the disciplinary content as nonlinear—remained stable throughout the case-study period, the sources of the pedagogical discontentment that drove her engagement in reform evolved in response to the changing outcomes of her instructional practice. Meanwhile, the influence of Jay's instructional team on her instructional practice evolved with the shift in her teacher thinking about the roles of herself and her team—a shift that occurred in response to experiences shaped by consequences of her instructional practice.

Applying the TCSR as part of a teacher-centered dynamic systems approach gave us a tool for understanding the critical role that Jay's instructional team played in shaping her reform efforts. Importantly, because Jay's instructional team was embedded and invested in the day-to-day operations of the particular course being reformed, instructional team members were uniquely positioned to materially support Jay's efforts with specific actions and feedback in response to the changing circumstances. The role of the team evolved in concert with developments in Jay's teacher thinking and instructional practice, as she carried an expanding view of her team into the development of more sophisticated pedagogical strategies and approaches.

Moreover, we saw that, despite her voluntary participation in the I-TP, the extent and nature of Jay's ultimate reliance on her instructional team was more reactive, opportunistic, and necessity-driven than intentional and premeditated. Viewing an instructor as a responsive agent acting in real time in reaction to each moment's demands, perceptions, barriers, resources, and sources of dissatisfaction may speak to a reason why even well-designed and intensive "one-and-done" professional development experiences are unlikely to have profound and lasting impacts on many instructors' practices (Ebert-May et al., 2011).

Jay's team evolved elements of a community of practice

Previous studies have demonstrated the potential power of embedding others into the process of course reform (e.g., Czajka & McConnell, 2016; Gess-Newsome et al., 2003; Henderson et al., 2009). Jay's case is distinct in that members of her instructional team were not expert others positioned as mentors to Jay, who was senior to them in terms of position and experience. Although they did not bring a high degree of formal expertise, the different team members did bring unique perspectives and a social community context to Jay's engagement in the reform process. As the instructional team developed shared goals and experimented together with new pedagogical strategies, they developed elements of a community of practice (Wenger, 1998, 2012), resulting in a rich collaboration that effectively distributed the cognitive and material workload of instructional design and implementation.

In a community of practice, individuals within the community share an overarching goal and an understanding of the tools, strategies and procedures with/in which they engage while pursuing that goal. Different individuals within the community are recognized as bringing unique skills, knowledge, and experience to that pursuit. Thus, individuals within such a community participate in a collaborative practice that relies on the contributions and interactions of and between the different members, who occupy and are recognized for their diverse roles within the community (Wenger, 1998, 2012). Although we are not making the argument here that Jay's team meets all of the criteria of a community of practice as defined in the literature, we wish to draw attention to ways in which elements of a community of practice arose in this case, and how those elements impacted Jay's reform efforts.

Change persisted and positively impacted students' perceptions

Through her involvement in the I-TP, Jay had access to resources and different types of supports that prompted her to constantly reflect on her practice and likely facilitated the implementation of instructional changes. The progress that she made in her teaching and in her conceptualization of and reliance on her instructional team seemed to have persisted in the absence of project support. There is also evidence that students' perceptions of the effectiveness of Jay's instruction significantly increased, surpassing those expressed prior to and during her involvement in the project. These findings suggest that observed changes and their positive impacts were not a mere artifact of conditions enabled by the project.

Limitations

The generalizability of our findings is limited by the case-study approach followed in our investigation. The personal and contextual characteristics of the observed instructor and her instructional team may have been quite distinct from those of other instructors within and outside our institution. Nevertheless, Jay may be considered a representative case of tenured faculty who experience discontentment in their teaching practice and have the freedom, disposition, and support to implement change. Our qualitative analysis thus highlights important factors and issues in need of further investigation to better understand the role that instructional teams, or other forms of collaborative teaching, can play in enabling educational reform and advancing the professional development of college instructors. We also recognize that our methods of data collection, that involved real-time observation of the actions and conversations of study participants, may have affected their behaviors, and thus impacted the validity and reliability of our findings.

Conclusions

Implications for reform and professional development efforts in higher education

The results of our study highlight the major positive impacts that instructional teams can have not only on implementing evidence-based teaching practices in higher education but also in fostering the professional development of college instructors. Although aspects of Jay's case are unique, many of the benefits that contributed to her course reform have been noted by other I-TP participant instructors who have reported smoother implementation and increased in-class team coordination; greater support for responsive teaching and formative assessment; and support for task design and revision through feedback from multiple perspectives. They also describe having greater trust in and reliance on their teams, which have become more integrated into their instructional practice, affording them more time and cognitive energy to devote to the creative demands of instruction (Kim et al., 2019).

The incorporation of LAs to support active learning in large-enrollment courses has become a widespread practice in the US (Goertzen et al., 2011; Jardine & Friedman, 2017; Otero et al., 2010; Talbot et al., 2015). In our study, we observed the potential benefits of specializing and diversifying the roles that some LAs play in an instructional team by supporting classroom management, task design and evaluation, and formative assessment activities. Our findings suggest that such an instructional team, and likely other similar structures that enable collaborative teaching approaches, create time and opportunities for instructors to pay closer attention to student thinking in their classrooms, reflect on the impact of diverse instructional activities on

student learning, and design and implement interventions focused on student learning.

Our results also point to potential indicators of progress in college instructors' conceptualization, buy-in, and implementation of reformed educational practices. In our case, we saw instructor's motivations for change move from discontentment with the level of students' engagement to discontentment with the nature, level, and visibility of student thinking during classroom activities. This change was facilitated by interactions with members of instructional team specialized in formative assessment. We also saw a shift from doubtful and surface adoption of reformed practices (e.g., making learning objectives explicit) to meaningful implementation inside and outside the classroom. This change was fostered by the need to better guide and facilitate the work of the instructional team, and the constant feedback that the team provided on the design and impact of classroom tasks. Paying attention to these types of shifts in college instructors' motivations for change and actual "buy-in" for reformed practices may help better evaluate the impact of different professional development efforts in higher education.

Abbreviations
I-TP: Instructional-Teams Project; FLC: Faculty Learning Community; LAs: Learning Assistants

Supplementary Information
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Additional file 1. Supplementary Document 1: Instructional-Teams Project informational flyer. Supplementary Document 2: Outline of Faculty Learning Community activities. Supplementary Table 1: Example of emergent theme identification. Supplementary Fig. 1: TCE Evaluations of effectiveness of in-class activities.

Authors' contributions
KMS and VT contributed to study design. KMS, SDH, JJ, YAK and JC contributed to data collection. KMS and SDH carried out data analysis with support and feedback from JJ, VT and JEC. SDH, KMS and VT prepared the manuscript with support and feedback from JEC, LKE, PB and YAK. KMS, JJ, YAK, JC, LKE, PB and VT contributed to design and implementation of the I-TP program that created the context in which this study was conducted. All authors read and approved the final manuscript.

Availability of data and materials
The data set created and analyzed for this study is available from the corresponding author on reasonable request.

Author details
[1]Office of Instruction and Assessment, University of Arizona, 101, PO Box 210070, Tucson, AZ 85721, USA. [2]Department of Chemistry and Biochemistry, University of Arizona, Tucson, USA. [3]Department of Environmental Science, University of Arizona, Tucson, USA. [4]College of Veterinary Medicine, University of Arizona, Tucson, USA. [5]Department of Chemical and Environmental Engineering, University of Arizona, Tucson, USA.

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