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ABSTRACT

In an effort to address K-8 teacher confidence in STEM and increase basic genetics knowledge to a level consistent with its importance in society, we have developed, implemented, and evaluated a 7-day teacher professional development workshop. The overarching goal of our workshop is to facilitate the implementation of innovative DNA-based classroom activities in K-8 classrooms by (i) increasing teacher content knowledge, (ii) increasing teacher confidence in teaching STEM, and (iii) developing teacher interest in using engaging activities, so they are empowered to teach new content in compelling ways. We relied on case-based learning to provide relevance and context to scientific content that was not initially familiar to many of the teachers. Here we describe the workshop and its evaluation. Overall results suggest positive gains in teacher learning, confidence, and interest in the scientific content, as well as the intention to incorporate the scientific content and activities into their teaching.

Keywords: DNA, genetics, STEM teacher knowledge, case-based learning, teacher professional development, teacher PD, K-8 STEM, genetics education, genomics education

Introduction

The influences of K-12 STEM education extend far beyond students' academic experiences, both in terms of the STEM workforce and members of society being able to understand the implications of science encountered on a daily basis (e.g., advances in health care, websites to explore ancestry, and global climate change) (Holbrook & Rannikmae, 2007). There is evidence that STEM interest and engagement is influenced by K-12 education experience. For example, as noted in the 2010 K-12 Report by the President's Council of Advisors on Science and Technology (PCAST), students are not inspired or motivated by the science that they experience in schools, leading to a general disengagement with STEM topics. This loss of interest in STEM typically occurs during middle school (PCAST, 2010; Sorge, 2007; George, 2006). Factors that likely contribute to this disengagement include teachers' lack of confidence in teaching STEM topics, which in part can be attributed to an absence of extensive STEM knowledge (Epstein & Miller, 2011; Fulp, 2002a; Fulp, 2002b; Nadelson et al., 2013; PCAST, 2010). Furthermore, the problem is compounded by the limited amount of school time devoted to science (e.g., Fulp, 2002a).

Elementary and middle school may represent critical points for engaging student interest in STEM, and for establishing foundational science content and understanding. More than one report points to the interest young children tend to have in science (Eick, 2012; Epstein & Miller, 2011; Gelman & Brenneman, 2004). However, as noted above, teachers at earlier grade levels often lack sufficient STEM content knowledge and confidence to be the most effective, contributing to the documented negative impacts on student performance and a loss of interest in science well before they reach high school.

DNA, genetics, and genomics

There is an important need for members of society to possess a basic understanding of the scientific method and science knowledge to make informed daily decisions (e.g., PCAST, 2010). Genetics and genomics are particularly important, because of a gap between the rapid advancement of genetics and genomics research and the necessary literacy for society to take full advantage of the research advances (National Human Genome Research Institute, 2017). Genomic medicine involves the use of genome-level information to make diagnoses and treatment decisions (National Human Genome Research Institute, 2019). It is therefore critical that patients (i.e., any one of us at some point in our lives) and their doctors have a sufficient understanding of genetics to make informed decisions about their health and medical interventions. Additionally, with more members of the public participating in "recreational genetics" (i.e., using their DNA to explore their ancestry), genetics and genomic literacy is important outside of a medical setting (Bolnick et al., 2018). However, much of the basic science information is acquired and built in elementary school (National Research Council, 2007), and as noted above, many teachers at this level may not be confident in their science content knowledge.

A new initiative, Genomic Literacy, Education and Engagement (GLEE), has been proposed by the National Human Genome Research Institute as a means to promote genetics and genomics literacy for K-16 students, healthcare providers and the community at large (Genomic Literacy, Education, and Engagement [GLEE] Task Force, 2017). A K-16 GLEE teachers and students working group reported that half of the educators they surveyed do not teach genomics, for reasons including a lack of resources and lack of knowledge or skills to do so (Genomic Literacy, Education, and Engagement [GLEE] Task Force, 2017). One of the recommendations was to develop materials (including teacher professional development and curricular materials) (Genomic Literacy, Education, and Engagement [GLEE] Task Force, 2017). While the GLEE initiative postdates the inception of our teacher professional development workshop, our workshop goals are very much in alignment with the GLEE initiative, illustrating that we are attempting to meet a pressing need.

STEM Professional Development

One part of a solution to these challenges is effective teacher STEM professional development (PD) to increase teacher knowledge and capacity (e.g., Ertmer, Schlosser, Clase, & Adedokun, 2014; Garet et al., 2001; MacNabb et al., 2006; Nadelson et al., 2013; PCAST, 2010). Teacher professional development can take many forms—workshops of variable lengths, online continuing education sessions, professional learning communities, and one-on-one mentoring, to name a few (e.g., Appleton, 2008; Garet et al., 2001, Scher & O'Reilly, 2009). A variety of program assessments, teacher surveys, and meta-analyses of published reports have identified some factors that contribute to effective teacher STEM professional development, particularly with respect to short-term outcomes such as improvements in teacher content knowledge, confidence, and attitude, which we discuss in more detail below.

One factor is time, which includes both the total number of contact hours and the overall duration of the professional development (e.g., Gerard et al., 2011; Lehman, George, Buchanan, & Rush, 2006; Scher & O'Reilly, 2009; Sinclair et al., 2011). For example, in a survey of 1,027 teachers participating in professional development, increasing contact hours and the overall exposure (i.e., timespan) of the professional development had a positive impact on teachers' self-reported outcomes (Garet et al., 2001). Increasing the professional development timespan is often accomplished by providing on-going academic year support, through follow-up coaching sessions. However, short and intensive workshops can also increase teacher content knowledge and confidence (e.g., Nadelson et al., 2013).

Another important factor in successful STEM professional development is an emphasis on science content knowledge (Ertmer et al., 2014; Garet et al., 2001; Nadelson et al., 2013; Sandholtz & Ringstaff, 2011; Sinclair et al., 2011). The emphasis on science content knowledge is perhaps most effective when coupled with appropriate pedagogical approaches — i.e., "how to teach" and "what to teach" (Goodnough et al., 2014). It is important that the pedagogical approaches be specific to the discipline, and not simply general approaches (Garet et al., 2001). The combining of content and pedagogy can be accomplished by: modeling effective instructional strategies (particularly inquiry strategies); providing materials (e.g., kits and/or curriculum) that teachers can adopt and adapt; and providing opportunities for active learning in the professional development program (Garet et al., 2001; Gerard et al., 2011; Nadelson et al., 201; Sandholtz & Ringstaff, 2011; Sinclair et al., 2011).

Other factors that have been reported as contributing to successful professional development include opportunities for collaboration, e.g., including teachers from the same school or same grade level (e.g., Gerard et al., 2011; Goodnough et al., 2014) and opportunities for hands-on work with kits, models, and technology (e.g., Goodnough et al., 2014; Nadelson et al.; 2013, Sandholtz & Ringstaff, 2011; Sinclair et al., 2011).

We considered the above-noted factors coupled with our own expertise in teaching and learning as we designed our PD workshop. We prioritized active learning and inquiry approaches to mirror the nature of science. We also prioritized contextualized presentation of scientific content, relying on a case-based learning approach, as described below.

Case-Based Learning and Problem-Based Learning

Both problem-based learning (PBL) and case-based learning reflect origins in professional education (Servant-Miklos, Norman, & Schmidt, 2019). PBL was formalized in medical education to address the difficulty that medical students had connecting conceptual knowledge to applied clinical practice (Barrows & Tamblyn, 1980). PBL engages students in ill-structured, open-ended, authentic problems, in which students take responsibility for collaboratively defining the problem and the knowledge they need to solve it. The case or context accompanied by the problem statement is generally acknowledged to be a critical element of a successful PBL problem (Hung, 2016). Similar to PBL, case-based learning (CBL) has origins in professional education, namely in law and business education (Servant-Miklos, Norman, & Schmidt, 2019). In CBL, students encounter a realistic story or scenario, and students are meant to apply relevant knowledge during case deliberation (Ertmer & Glazewski, 2018).

PBL and CBL share a number of characteristics, and distinctions are not uniformly fixed or definite (Allchin, 2013; Ertmer & Glazewski, 2018). Both are inherently student-centered and driven by prompts to target relevant knowledge and skills within the disciplinary context (Allchin, 2013). Ertmer and Glazewski (2018) argued that one distinguishing feature is that in PBL, students encounter the driving question as the entry to acquire relevant knowledge, whereas in CBL, the purpose is application of previously acquired knowledge. Case studies appear to prioritize flexibility in how they are structured and delivered, and in the nature of the problems and questions that students are addressing (Herreid, 1997; Herreid, 2017). However, like PBL, case studies are grounded in authentic stories and scenarios, are student-centered, and develop disciplinary reasoning skills (Hmelo-Silver, 2004).

We have summarized the critical characteristics of PBL and CBL in Table 1, though similar to Allchin (2013), we agree that fine distinctions between the boundaries of both approaches are not certain. What does seem open to discussion is precisely how PBL and CBL are related. We argue they can be thought of as closely related approaches because they reflect characteristics based on active, student-centered learning driven by a problem or case (Savery, 2006; Savery, 2019). For example, Barrows (1986) considered the case method to be distinct from PBL, characterizing it as valuable for fostering self-directed learning, but organized and structured in ways that could limit the amount of student reasoning. On the other hand, Herried (1997; 2017) has argued over the years that PBL represents a type of case-study, which is conceivable given that cases can supply the occasions and driving contexts for learning in both CBL and PBL. One differentiation is located in how the learning space is created and how the problem is facilitated (Hmelo-Silver, 2004; Hmelo-Silver, 2013).

Table 1. Comparisons of Key Features of PBL, CBL and DNA Instructional Cases

Feature / Characteristic	PBL	CBL	DNA Instructional Cases	Example: Why are Mexican Hairless Dogs Hairless?
Authenticity	Authentic/real-world problem	Authentic/real-world story or scenario	Authentic/real-world story or scenario	Authentic
Complexity and purpose	Complex; generation of knowledge during problem deliberation	Complex; application of knowledge during case deliberation	Complex; application of genetics concepts	Complex; apply knowledge of numerical and DNA sequence data to determine the cause of hairlessness
Nature of collaboration	Always collaborative	May be collaborative or individual	Collaborative (students work in small groups or pairs)	Collaborative
Nature of the Problem	Ill-Structured; open-ended	May be ill- or well-structured; may be open-ended or close-ended	Well-structured; close-ended	Well-structured; close-ended

What we have prioritized in our professional development approach with teachers is science inquiry coupled with scientific practices (Allchin, 2013) in which the case becomes the main driver for application of genetics content. As such, we designed our DNA instructional cases to be complex and generally close-ended. For example, we introduced genes, alleles, and their inheritance patterns using Punnett Squares (life sciences content) on the second day of the workshop, using a case titled "Why are Mexican Hairless Dogs Hairless?" This activity modeled interactive and inquiry STEM teaching. Using Mexican hairless dogs, rather than pea plants or "standard" human traits (like blue eyes, which may be less common in our student population), may be more engaging to students living in the local southwest border region. The teachers considered hypotheses and analyzed data to arrive at a genetically based conclusion about why the Mexican hairless dog is hairless. We subsequently revisited Punnett Squares in a DNA inquiry activity related to genetically informed treatments for cystic fibrosis, which provided an additional example to review and extend basic genetics content for the teachers.

Case-Based Approaches and Active Learning

CBL approaches are both a form of active learning and also incorporate active learning strategies, which can be defined as instructional approaches that foster deep engagement with content, concepts, and ideas in ways that are engaging and meaningful for learners (Prince, 2004). Such approaches often leverage peer-peer interaction in the classroom. For example, in a think-pair-share activity, students are presented with a question, then asked to consider it individually (think), then with a neighbor (pair), then with the entire class (share) (King, 1993). Student response systems (clickers) have been shown to enhance student performance (Preszler, Dawe, Shuster, & Shuster, 2007), with peer discussion having been identified as an important learning activity to realize the positive impacts of clickers (Smith, Wood, Krauter, & Knight, 2011).

Across various STEM disciplines, active learning has been shown repeatedly to have a positive impact on student learning, including in a large meta-analysis of studies in undergraduate STEM that considered 225 studies comparing various active learning strategies against matched lecture-based courses (Freeman et al., 2014). Performance of students in sections that incorporated active strategies was linked to higher exam scores and lower course failure rates when compared to students in lecture-based courses. Even relatively short active learning interventions (e.g., one week in a semester-long undergraduate physics course) have been shown to have a positive impact on student performance (Deslauriers, Schelew, & Wieman, 2011). Taken together, the research trend suggests a pattern of increased student performance when exposed to active learning pedagogies such as CBL, or active learning strategies embedded within a CBL case study.

Both students and instructors tend to find value in CBL. Based on surveys of faculty (Yadav, Lundeberg, DeSchryver, Dirkin, Schiller, Maier, & Herried, 2007) and students in courses that use an instructional case-based approach (Yadav & Beckermen, 2009), faculty and students expressed positive opinions about the use of instructional case studies in science teaching. Faculty felt that instructional case studies require student critical thinking, enhance learning, and encourage participation (Yadav et al., 2007), opinions that have been supported by student performance on topics taught instructional using case studies versus lectures (Yadav & Beckerman, 2009).

Instructional case studies can take many forms and formats (including dilemma cases, directed cases, debate cases, and PBL cases) (National Center for Case Study Teaching in Science, n.d.). Despite this diversity in format, instructional case studies generally share some kind of "hook" to engage student interest, present evidence or data for students to consider, and require some kind of conclusion or recommendation. These represent features that instructional case studies share with PBL.

CBL can support STEM teacher PD, particularly with elementary teachers who may not possess a strong science background (Ackerson & Hanuscin, 2007). There are many reports of teacher PD involving a variety of active learning strategies used both as instructional strategies (to increase content knowledge) and as modeling strategies (for future classroom implementation) (e.g., Ertmer et al., 2014, MacNabb et al., 2006). Other teacher PD relies on a single instructional strategy (e.g., PBL) for both increasing content knowledge and modeling a classroom approach (e.g., Weizman et al., 2008). In one study of elementary teachers in a three-year program with 50 teachers, CBL was an important component of the professional development in which the teachers both gained knowledge in science as well as facility with writing case studies for classroom implementation (Dori & Herscovitz, 2005). In another study, instructors used videocase instruction of a teacher presenting about seeds and eggs to foster changes about preservice teachers' ideas and beliefs about science (Abell, Bryan, & Anderson, 1998). Their facilitation surfaced a wide range of beliefs among the preservice teachers, particularly about the nature of science teaching and learning. More specifically, preservice teachers highly valued motivation and student interest, and seemed to place lower value on student learning and the strategies that create the opportunity to learn. What this suggests is that CBL in teacher preparation can be useful for deepening teacher knowledge as well as uncovering existing beliefs about the nature of teaching science, though we note the need for more investigation about how to do both simultaneously.

Our Pedagogical Approach to STEM PD

Our workshop design was based on strategies that had a literature-based rationale at the time we were designing the workshop. Many of these strategies have ongoing support in the more recent literature, as noted below.

1. We used a variety of active learning strategies for instruction/content knowledge, rather than focusing on one strategy (e.g., Deslauriers, Schelew, & Wieman, 2011; Freeman et al., 2014). Such "mixed instructional methods" approaches have documented success in increasing teachers' STEM content knowledge in a variety of settings (e.g., Glazewski, Shuster, Brush, and Ellis, 2014; Ertmer et al., 2014; MacNabb et al., 2006). Our approach included the use of interactive mini-lectures (made interactive by think-pair-share activities, collaborative clicker questions, hands-on modeling, and online simulations), and instructional case studies.
2. Case studies served not only as instructional tools, but as ways to model the types of DNA-based classroom activities that the teachers developed for their own classrooms. By modeling this approach, we provided support for teachers to develop DNA-based classroom activities that included a "hook," critical thinking, or analysis of some kind of data (e.g., DNA sequences).
3. As noted above, we intentionally modeled case-based learning approaches in the workshop. This modeling was intended to support teachers as they designed their own DNA-based classroom activities (Ertmer et al., 2014; MacNabb et al., 2006; Weizman et al., 2008) as well as build teacher confidence to implement such activities in their own classrooms (Ertmer et al., 2014; Sandholz & Ringstaff, 2011; Sinclair et al., 2011; Weizman et al., 2008). For example, as noted above in the Mexican Hairless Dog case, we taught important DNA concepts and modeled ways to teach them. Teachers experienced this case as if they were students first, and could then use it directly in their own classrooms to reinforce the same ideas if they chose.
4. We included workshop facilitators with a variety of expertise. In our case, this included a biology faculty member from the university (with expertise in genetics and undergraduate STEM education), a faculty member from a college of education at a different university, with expertise in K-8 pedagogy, and a research scientist from a research institute involved in bioinformatics and next-generation DNA sequencing. The inclusion of a variety of experts in the instructional/facilitation team has been noted by a variety of PD providers (e.g., MacNabb et al., 2006; Sinclair et al., 2011).
5. We fostered collaborative/collective participation by teachers. By encouraging applications from teams of teachers from a single school and valuing such teams as part of the application review process, we aimed to leverage the positive impact of school-based teams (Ertmer & Simons, 2006; Garet et al., 2001; Lee & Blanchard, 2018; Lehman, George, Buchanan, & Rush, 2006; MacNabb et al., 2006).

Research Purpose

As we have noted, CBL, as well as related PBL and active learning strategies, can be linked to a wide range of pedagogical and learning outcomes for teachers, ranging from no increases in content knowledge (e.g., Weizman et al., 2008) to small but significant increases in content knowledge (e.g., Ertmer et al., 2014) to substantial increases in content knowledge (e.g., MacNabb et al., 2006). Documenting conditions under which teachers do learn has implications for the design and use of CBL activities in teacher PD, particularly with regard to unfamiliar and complex science content and tools. Thus, we carried out an evaluation study to inform a deeper understanding of (i) what teachers learn from a summer PD workshop that relies on CBL and embedded active learning, (ii) what we observe about teacher perceptions of their own learning and of the genetics-based content, and (iii) what we observe about teacher interest in use of the workshop approaches and content in their own teaching, particularly with regard to potential benefits and challenges.

Methods

Context and Participants

Participants

Beginning in 2014, we hosted one workshop each summer. As the first year was a pilot, we are reporting here on years 2-4. We accepted a total of 36 teachers from our targeted school district, which has 75.7% Hispanic student enrollment. Demographic characteristics and grade levels taught by the teachers are shown in Table 2. The vast majority (86%) were female, and 39% of the teachers were Hispanic. The majority (58%) taught in elementary school (grades 2-5). Another 36% taught middle school (grades 6-8), and the remaining 6% taught high school.

Table 2. Demographic Characteristics of the Teachers

	Yr 2 (2015)	Yr 3 (2016)	Yr 4 (2017)	Total
Female	10	13	8	31
Hispanic	3	5	6	14
Grades 2-5 (Elem.)	6	9	6	21
Grades 6-8 (Middle)	6	3	4	13
Grades 9-12 (High School)	1	1	0	2
Total Teachers	13	13	10	36

Workshop Overview and Goals

We designed, implemented, and evaluated a 7-day summer professional development workshop focusing on basic genetics concepts, using DNA as a scientific theme. The workshop took place in late June, with the intent that teachers would implement their workshop knowledge and materials in the school year starting in August.

The overarching goal of our workshop was to facilitate the implementation of innovative DNA-based classroom activities in K-8 classrooms by (i) increasing teacher content knowledge, (ii) increasing teacher confidence in teaching STEM, and (iii) developing teacher interest in using engaging activities — so they are empowered to teach new content in compelling ways, thereby aiming to foster student motivation in science. We relied on cases to provide relevance and context to scientific content that was not initially familiar to many of the teachers. Note that while we used cases as a model for content delivery, and while teachers were encouraged and supported to use case-based learning as they developed their own classroom inquiry activities, our primary goal was focused on enhancing content gains and teacher confidence, and on "trying something new," rather than specifically teaching teachers to teach with cases. In other words, CBL represented a key strategy for the workshop, but not necessarily a requirement for the teachers when planning their own genetics and genomics implementations.

Research Design

In order to gain a deeper understanding of what teachers learned, how confident they felt about the content, and their perceptions of future implementations, we used an evaluative case study research design (Merriam, 1988). Evaluative case study starts from a place of context; more specifically, researchers seek to understand and convey the characteristic features, facets, and structure of a context in order to explain their implementation and research choices and make judgments about the outcomes. Thus, the goal is not generalizability, but, rather, meaning, coherence, and specific insight into the research problem. Erickson (1986) discussed this as particularlizability, meaning that outcomes of research and interpretive meaning are situated within a specific context, and the account of the context is critical. For example, our workshop with key goals toward genetics and genomics content reflects some features that may be particular only to us (i.e., workshop design). However, this is not to say that outcomes are relevant solely to our context. Bassey (2001) invoked the term fuzzy prediction, and argued that representation of a context carries implicit value across contexts that may share similar, recognizable features. Despite inherent limitations or unique characteristics, for example, associated with the specific context of our 7-day workshop or the nature of participant perceptions, there are features that may carry relevance for others attempting to understand teacher PD and possibilities therein.

For this first evaluation of our workshop, we were interested in answering a "what is" question (a description of what is happening to teachers during our PD workshop) (Bass, 1999). Once we have carefully described what is happening, we can begin (in future studies) to try to understand why it is happening, which would include a finer dissection of the relative contributions of different PD elements to the described outcomes.

The Summer Workshop

By using CBL in the form of DNA instructional cases as a primary strategy in the workshop, teachers experienced the instructional cases as students, reflected on the cases, and had the opportunity to develop and adapt cases and embedded activities for their specific student needs, classroom settings, and grade levels. Our intention was to foster excitement to use case studies by immersing the teachers in these activities (as students and as designers) throughout the workshop.

The workshop included previously developed DNA instructional case studies (http://www.stcnm.org/resources), which were designed to introduce content as well as serve as models for teachers to design their own DNA-based classroom activity.

The workshop and its initial development have been described in more detail elsewhere (Shuster, Claussen, Locke, & Glazewski, 2016). Briefly, our model was a 7-day summer workshop targeting elementary and middle school teachers from a single school district. While our primary focus was teachers in grades K-7, we received applications from teachers in grades 2-10, and accepted teachers from these grade levels. The workshop was facilitated by a team including a faculty member in the biology department at the host institution, doctoral students in biology, two program partners (i.e., one collaborator with pedagogical expertise and another with critical bioinformatics expertise from another partner institution), and an external evaluator.

As noted above, the first two days of the workshop were designed to ensure that all teachers were introduced to key content. This culminated in a facilitator-modeled DNA instructional case study on Day 2. The remaining five days of the workshop continued to expand and reinforce teachers' content knowledge, model DNA instructional case studies, and provide time for teachers to develop their own DNA-based classroom activity. Our hope was that teachers would implement at least one activity or case study in their classroom in the following academic year.

It was critical for us to give teachers experience using specific tools needed for the case-based DNA activities. One of the primary tools is a widely used online bioinformatics application through the National Institutes of Health: Basic Local Alignment Search Tool (BLAST; https://blast.ncbi.nlm.nih.gov/Blast.cgi). This tool lets users input a DNA sequence, which it compares to existing sequences across multiple databases to locate areas of matching similarity. This allows the source of an unknown DNA sequence to be identified. While sophisticated in terms of the underlying algorithms and database access, the BLAST user interface is relatively straightforward, and can be easily navigated even by young students. The user either types in a short DNA sequence (~21 nucleotides/characters), or copies and pastes a longer sequence, and then hits a "BLAST" button to identify database matches. BLAST is both a scientific and a teaching tool, and from a pedagogical perspective, it supports scientific inquiry through use of tools that scientists use to make comparisons and conclusions based on sequence information.

The culminating workshop activity for teachers was a mini-symposium during which teachers presented their newly designed DNA-based classroom activity to an audience of invited guests. It is worth reiterating that CBL was a strategy for the workshop though not specifically a target we set for the teachers in their activity design. However, we suspect this approach may have resonated with teachers, as a number of teachers generated DNA-based classroom activities that meet our definition of a DNA instructional case (Table 1). For example, one team posed a question about cheese: "If milk is white, why is some cheese blue?" designed to investigate the process of cheese-making and test ingredients of a given set of cheeses using BLAST. Another team designed an activity called "Meatball Madness" that engaged learners in solving a mystery of improperly labeled meatballs in DNA-based ingredient testing as well as food production and safe handling procedures.

Procedures and Data Sources

Content knowledge test

A 23-item content knowledge test was designed by a biologist and a pedagogy expert on the leadership team, with the intention of probing general concepts of biological relatedness and studying relationships relying on DNA rather than appearance. The content test included multiple choice answer selections and contained several released National Assessment of Educational Progress (NAEP) items. Some items probed the type of scientific tools used in various types of analyses (e.g., a microscope versus a telescope or a computer).

The content test was intended to be administered to both teachers and their students. Given this intended audience for the content test, we anticipated most teachers would be familiar with many of the content test items. These include items addressing general information about cells and DNA as well as the scientific tools used to answer different types of biological questions (sample questions provided in Appendix A). We anticipated teachers would likely be familiar with this set of sample items (but students would not be, prior to instruction). Other items addressed what we suspected would be new content to the teachers, such as concepts underlying the assembly and interpretation of phylogenetic trees (sample items provided in Appendix A).

Post-workshop survey

The post-workshop survey was designed by the project leadership team, including the lead biologist/workshop instructor, pedagogy expert, and external evaluator. The 17-item survey included both close-ended and open-response items, of which we included 10 items across two subscales for the purposes of this study. Teachers responded to the quantitative items using Likert scales. A majority of the survey items relied on five-point scales (i.e., from "Strongly agree" to "Neither agree nor disagree" to "Strongly disagree") while others used five-point quality or likelihood scales. The open-response questions primarily focused on workshop logistics (not included in the current analysis) as well as satisfaction items for teachers to provide their overall impressions of the workshop. While important for considering workshop improvements, these items did not directly address our current research evaluation interests. The full post-workshop feedback survey's 17 quantitative items had a high reliability, Cronbach's $\alpha = 0.82$. However, several of the survey items related more directly to our evaluation study. Specifically, three items probed teacher perceptions of their learning and the genetics-based content, with a moderate reliability, Cronbach's α = 0.74. Seven items probed teacher perceptions of using the workshop content in their teaching with a high reliability, Cronbach's α = 0.85.

Focus group

The external evaluation team facilitated the focus group, which was conducted on the last afternoon of the workshop (after teachers completed the post-workshop content test and survey). Each focus group lasted between 60 and 90 minutes. The purpose of the focus group session was to gain further insight into the teachers' attitudes and perceived benefits of the STC workshop. The teachers were queried from two different perspectives: as participants of the STC workshop and as teachers responsible for passing on this new knowledge to their students. The focus group protocol had four broad questions about confidence and anticipated barriers or challenges (see Appendix B).

Workshop facilitators and assistants were not present during the focus group, which was designed to create a non-threatening environment in which teachers could be more open to sharing their perceptions and opinions of their workshop experience. The sessions were led by two members of the evaluation team—one member concentrated on facilitating the group while the other took notes.

Collection Procedures and Data Analysis

Assessment and evaluation overview

Our assessment strategy for the workshop relied on data from multiple sources: (1) pre-workshop and post-workshop content tests, (2) a post-workshop survey, and (3) a post-workshop focus group. All assessment instruments were administered by the external evaluator, and the program staff (specifically, the PI/workshop leader and graduate assistants) were not present when teachers were completing the assessments.

Content knowledge tests

On the first morning of the workshop, we administered the knowledge test (before any formal programming occurred). We then administered it again on the last afternoon of the workshop, after all formal programming was completed. The mean pre-workshop and post-workshop content test raw scores were calculated for each teacher (i.e., the mean of the sum of correct answers on each test), and we conducted a paired-samples t-test to evaluate the significance of any potential gains.

Post-workshop survey

Teachers completed the post-workshop feedback survey on the last afternoon of the workshop (after they completed the post-workshop content test). Responses from teachers from all three years were compiled (n= 35) for each item as a mean score. In each category (perceptions of learning and of the genetics-based content, and perceptions of using the content in their teaching), we report means and standard deviations for each individual item, as well as the overall means and Cronbach's alpha for all items in the two categories.

Focus group

The evaluation team facilitated the focus group, which was conducted on the last afternoon of the workshop. All teachers were invited to participate in the focus group session. Utilizing a semi-structured protocol developed by the evaluator and PI, the focus group protocol had four questions, which were asked to gain insights into the teachers' attitudes and perceived benefits of the STC workshop. The same questions were asked at each focus group and in the same order. The evaluators also asked probing questions to clarify teachers' answers as well as to expand and explain their responses. The teachers were queried from two different perspectives: as participants of the STC workshop and as teachers responsible for passing on this new knowledge to their students. The session also included a prompt to provide the teachers with an opportunity to submit suggestions for possible workshop improvements. All sessions were audio recorded, and targeted statements that informed this case study purpose were transcribed. Utilizing the notes and the transcripts, the external evaluators employed inductive qualitative analyses to synthesize the trends and patterns among the teachers' responses. The inductive qualitative analyses allowed the "research findings to emerge from the frequent, dominant, or significant themes inherent in raw data" (Thomas, 2006, p. 237). The trends and patterns that developed, from the evaluators' point of view, were the teachers' main messages.

Results

Teacher Content Knowledge

The mean scores of the pre-workshop and post-workshop content tests for each year are noted in Table 3. A paired t-test was run to determine whether there was a statistically significant mean difference between the pre-workshop and post-workshop content test mean raw scores. Similarly, a paired t-test for all 35 teachers in the three years was used to evaluate the overall changes for all workshop years (combined). In each year, the change from pre- to post-test was statistically significant. Overall (with all three years combined), the teachers' content knowledge improved during the workshop: the mean post-workshop content test raw score (M=19.5, SD=2.2) was higher than the mean pre-workshop

Table 3. Teacher Content Knowledge Scores

Year	Teachers	Returning Teachers	Mean Scores		p-value	Mean Diff. (Post-Pre)	Effect Size
			Pre (Raw Score)	Post (Raw Score)			
2	12*	0	15.5	19.5	p<0.001	4.0	1.57
3	13	2	16.3	19.8	P<0.01	3.5	1.31
4	10**	0	14.6	19.0	P<0.01	4.4	2.03
Yrs 2-4	**Total**	**Total**	**Overall**	**Overall**		**Overall**	**Overall**
	35	**2**	**15.5^**	**19.5^**	**p<0.001^**	**3.9^**	**1.58^**

*Twelve of the 13 teachers completed both the pre-test and the post-test in Year 2.

**Ten of the 11 teachers completed both the pre-test and the post-test in Year 4.

^Values represent the teachers grouped together into one overall dataset.

content test raw score (M=15.5, SD= 2.8), reflecting a statistically significant increase and a large effect size, $t(34)=10.141$, $p<0.001$, $d=1.58$. In other words, teachers improved their science knowledge and increased the content knowledge raw score by an average of 3.9 (SD=2.3), out of a possible 23 points.

Content Areas of Highest Gain

Because we were interested in specific areas of learning gain, we looked more closely at specific items. Five items had relatively low pre-workshop means, and statistically significantly higher post-workshop means. These items included one item about the cell type of bacteria (prokaryotic), three items asking about the interpretation of a phylogenetic tree, and an item asking about the closest relationship between organisms based on another phylogenetic tree (see Appendix A). As we suspected, teachers were not skilled at interpreting phylogenetic trees before the workshop, but had significant gains in this area. Based on pre-workshop means on items related to plant and animal cells (e.g., items asking them to identify cells that contain organelles, and where in a plant or animal cell the genetic material is found had pre-workshop percentage means of 62.9%; an item asking them to identify the nucleus on a diagram of a cell had a pre-workshop percentage mean of 76.5%), it was clear that teachers were more familiar with many aspects of plant and animal (i.e., eukaryotic) cells. Given this familiarity with eukaryotic cells, we were surprised that teachers were not familiar with the prokaryotic cell type of bacteria (pre-workshop percentage mean of 32.4%), as prokaryotic cells are one of the two cell types found in living organisms. However, this was clearly mastered by most teachers during the workshop (post-workshop percentage mean of 94.1%).

Overall, there was a significant improvement from the pre-workshop administration to the post-workshop content test. Not surprisingly, given that the test was designed to be administered to students in grades 3-8, the pre-workshop content test scores were quite high (~15 of 23 items answered correctly), suggesting that many of the teachers were already familiar with much of the basic science content and concepts. However, despite the high pre-workshop test scores, there was still significant improvement, and this appears to be driven at least in part by high gains on five items.

Teachers Impressions of the Workshop

Survey findings

The average scores for the three items related to teachers' perceptions of their learning and the content are shown in Table 4. The mean scores were high (4.77–4.91 on a 5-point

Table 4. Mean scores for survey items related to perceptions of learning and the content

Survey Item	Mean	SD	N
I learned more about the biological sciences by participating in this program.	4.91	0.28	35
My understanding of bioinformatics, genetics, and genomics has increased by participating in this workshop.	4.89	0.32	35
I am personally more interested in bioinformatics, genetics, and genomics because of my participation in this workshop.	4.77	0.43	35
All Learning/Content Items	4.86	0.28	35

agreement scale where 1 is "Strongly Disagree" and 5 is "Strongly Agree"). The mean scores indicate that the teachers not only learned the content but also became more interested in the workshop topics.

Perceptions of using the content in their teaching

The average scores for the seven items related to teachers' perceptions of using the content in their teaching are shown in Table 5. Similar to scores on perceptions of learning and the content, the mean scores related to using the content in their teaching were also high (4.74–4.97 on a 5-point scale), suggesting that teachers are willing, interested in, and able to use the content in their classrooms.

Focus Group Findings

The focus group findings also support the teachers' perceptions of their learning of the content as well as using it in their teaching. With respect to teachers' perceptions of their learning and of the content, the teachers reported having a positive learning experience, which was facilitated by the PI and workshop facilitator creating a safe environment for them. The teachers expressed belief that their science knowledge improved, which made them more likely to implement their DNA-based classroom activity in the following year. For example, one teacher described their knowledge level as "very low" prior to the workshop and, after completing the workshop, he/she felt "much more confident" in teaching science to their students. Other teachers, especially those teaching in elementary schools, indicated that they did not possess robust science backgrounds. One teacher described the workshop as "completely out of our lane as non-science people." This teacher continued and compared their workshop experience to their other learning experiences. The teacher stated, "Maybe I learned [the science content] in college the first time, but didn't connect to it as much as I do now, and I got a lot more out of it. I learned so much this week, different than what I normally study or work on."

Teachers attributed these learning gains to several workshop aspects. The teachers uniformly appreciated the inclusion of hands-on activities, the use of "stories" (in the form of the instructional cases) in the teaching activities, and the modeling of teaching strategies by the facilitators. One teacher noted, "[The workshop facilitator] made it relatable to real stories so we could connect instead of making it real abstract and told stories that made us interested in what we were learning and then … went and gave us the facts and the information and then … let us practice and then [the facilitator would] kind of go through that cycle again." Another noted that they might have been more interested in science as a child if the science had been made more relevant "but if I had the stories and the connections, all about the human interest story, because that's what makes me interested." While they noted that the material was complex, teachers indicated that the content was made accessible to them without being made to feel intimidated or "dumb." One teacher noted, for example, "I didn't ever feel like an idiot for being in here and not knowing everything." Despite being "non-science people," teachers did not feel out of place during the workshop. One teacher stated, "[The workshop facilitator] did a good job with us, not necessarily being experts in the kind of thing, [where] I didn't ever feel like I was an idiot for being in here and not knowing everything."

Table 5. Mean scores for survey items related to using the workshop content in teaching

Survey Item	Mean	SD	N
I am more interested in incorporating bioinformatics, genetics, and genomics activities into my classes because of my participation in this workshop.	4.83	0.38	35
I am more confident in my ability to teach bioinformatics, genetics, and genomics-related topics because of my participation in this workshop.	4.74	0.44	35
How likely are you to implement one or more of the STC bioinformatics, genetics, and genomics activities in your classroom in the coming academic year?	4.97	0.17	35
I learned some new approaches to teaching bioinformatics, genetics, and genomics to my students by participating in this workshop.	4.91	0.28	35
I think that my students will be actively engaged by the STC bioinformatics, genetics, and genomics activities.	4.83	0.38	35
The STC bioinformatics, genetics, and genomics materials appear to be useful in terms of helping students learn.	4.80	0.47	35
This program brought together several biological concepts in a useful way for my teaching.	4.80	0.41	35
All items related to using workshop content in teaching	4.84	0.27	35

Teachers also complimented the workshops' structure, particularly how the examples (DNA instructional cases) were intertwined with the science content. The examples were introduced at precise intervals such that they broke up instruction and did not allow science lectures to extend beyond the teachers' attention spans. In other words, the examples provided an interactive component, which kept teachers' interests. A teacher explained, "The model [the workshops' facilitators] followed made a lot sense. She built the content knowledge first last week … we got adequate work time. Plus, little activities in the [the workshop] so we didn't get too stressed out or bored or anything like that. [The workshop] flowed really organically. It was awesome." It is incorporation of these examples (in the form of instructional cases) that kept the teachers interested in what they were learning.

One cohort of teachers credited their confidence and knowledge to implement the workshop activities to the use of hands-on activities. As one teacher stated, the hands-on activities were followed by a thorough explanation of the activity and related content. Thus, teachers could "make more connections." A teacher, for example, was concerned about her capacity to implement the phylogenetic tree activity, as she had not yet grasped the concepts. However, she said that the "light bulbs came on" after the workshop facilitator demonstrated the activity using pipe cleaners (fuzzy sticks). With the facilitator's assistance and demonstration, the teachers "totally can" conduct the workshop modules.

Teachers also indicated that they will use the content in their teaching. At each focus group, teachers indicated that they planned to implement the workshop CBL modules in their classrooms. Teachers indicated that the activities were complimentary to their classroom instruction and that students would not only be interested in the content but also enjoy it. Teachers described the workshop CBL modules as "real world" examples. One teacher explained that "kids really like when they can connect [the science content] to the real world." It was noted that students may not always have the background knowledge "to envision things that could be," but real-world examples allow them to make those connections. Teachers also indicated that they enjoyed the modules themselves and believed that their students would as well. A teacher stated, "If we're excited as teachers, they usually pick up on that."

Teachers also expressed excitement that the workshop empowered them to make adaptations or adjustments to the workshop materials, especially given that they created their own DNA-based classroom activities. Such adaptations allowed them to make the modules to align with state standards. A teacher stated, "I wanted to make sure that [the workshop module] was relevant to the kids, so I'm pretty excited about doing some activities with my kids because it is part of what we have to teach." Despite their willingness to implement the modules, teachers did express some apprehension regarding their ability to do so with fidelity. Teachers were concerned with simply being able to retain the science knowledge gained from the workshop. More specifically, the time between the workshop and when they implement a workshop activity could be six months or more. One teacher, for example, stated, "Come October, I don't think I'll remember exactly everything." Another attributed the difficulty in retaining their newly gained knowledge to "nobody would retain anything like that (the science content)" without "using [it] on a regular basis." This time lapse presented a deterrent, as teachers anticipated that their knowledge and memory would erode. Teachers feared that they would not be able to furnish answers "if the kids started asked really difficult questions" and wanted "to get into the real science of it." While acknowledging such challenges, most teachers overall expressed that they knew enough to teach their respective grade levels.

Teachers' confidence seemed to improve when they considered the possible technical support and other resources available to them, for example, a workshop glossary and access to the workshop facilitator during the school year. One teacher, for example, stated that she has "the resources now, and place to get information, and the basis for understanding it" and "where to go to find out." Another said that the resources allow them to "go back in the fall and … look those things up." Such resources appeared to help teachers be prepared to implement the workshop modules.

Discussion

As noted above, we had three areas of interest in the evaluation of our workshop and its impact on teachers. Specifically, we were interested in developing a deeper understanding of (i) what teachers learn from the summer workshop, (ii) what we observe about teacher perceptions of their own learning and of the genetics-based content, and (iii) what we observe about teacher perceptions of using the workshop approaches and content in their own teaching, particularly with regard to potential benefits and challenges.

Teacher Life Sciences Content Knowledge

The teachers clearly increased their life sciences content knowledge, as evidenced by the significant improvements in the scores from the pre- to post-workshop content test. While we are not able to make causal inferences about where or how they learned the material, we credit much of the gain to the fact that they were able to have multiple access points through demonstration and multiple DNA instructional cases to reinforce the knowledge that was missing or ill-conceived. This is consistent with previously documented teacher learning and pedagogical benefits in contexts that included curriculum-based PD coupled with demonstration and inquiry (Glazewski et al., 2014; Ertmer & Simons, 2006; Hartman, Renguette, & Seig, 2018).

The items with the highest gains (phylogenetic trees and prokaryotic cell structure) were reinforced with many of the DNA instructional cases used in the workshop. In one of these, called "Outbreak!", learners enter short DNA sequences into BLAST to identify possible pathogens (including fungi, parasites, bacteria, and viruses), research their pathogen, then evaluate their pathogen as a possible cause of a provided scenario (a cluster of sick patients in northern New Mexico). Several DNA instructional cases reinforced phylogenetic trees. One of these asks whether the giant panda is really a bear. Teachers consider bear-like and not-so-bear-like features of giant pandas, then use DNA sequences from giant pandas, a variety of bears, and some non-bears (raccoon, dog) to assemble a phylogenetic tree and draw a conclusion about the giant panda, based on its relationship to other organisms on the tree (yes, it is really a bear!). Other tree-based cases included an investigation of the relationships between bacteria in authentic Italian Parmigiano-Reggiano vs. American "parmesan" cheese, and the relationship between HIV strains in reconstructing and interpreting a phylogenetic tree that resulted in the indictment of a doctor accused of intentionally infecting a nurse employee with HIV (Shuster, Cheeptham, & Regassa, 2013).

Teacher Perceptions of Their Own Learning and of the Genetics-Based Content

Based on the survey results, it is apparent that teachers felt that they learned biological content, and more specifically that they increased their understanding of bioinformatics, genetics, and genomics, and became personally more interested in bioinformatics, genetics, and genomics. Their perceptions were supported by positive gains on the content test results. These survey findings were reinforced in the focus group. For example, teachers revealed that complex material was made accessible to them. They indicated that they enjoyed the DNA instructional cases, as revealed by comments about the "stories" that drove many of the activities and the "hands on" nature of some of the activities (e.g., using beads and fuzzy sticks to assemble and compare DNA sequences).

The fact that teachers actually learned more, felt that they learned more, and became more interested in bioinformatics, genetics, and genomics is important in the context of the increasing importance of these areas in healthcare and medicine (National Human Genome Research Institute, 2017; PCAST, 2010). As noted above, it is important at a minimum that both physicians and patients have a solid understanding of genetics and genomics so that research findings can be parlayed into more effective patient care (Buckles, 2018; National Human Genome Research Institute, 2017). One of the GLEE project working groups noted that half of the educators surveyed do not teach genomics, for reasons including a lack of resources and lack of knowledge or skills to do so (National Human Genome Research Institute, 2017). It thus appears that our workshop has the potential to reduce this barrier for our teachers. Reducing barriers is important; without their increased knowledge of genetics and genomics, our teachers may not gain necessary preparation for future encounters with precision medicine that in turn may create natural opportunities to foster student understanding regarding the impact of this field in science specifically and for society at large.

Teacher Perceptions of Using Workshop Approaches and Content in their Own Teaching

Teachers expressed high levels of interest and confidence in incorporating genetics-related content into their teaching. They also indicated that they were likely to incorporate genetics-related activities into their teaching, and that they learned some new approaches to teaching this content. Focus group findings also indicate that teachers are willing and excited to implement DNA instructional cases in their classrooms. However, the focus group also revealed that teachers did have some reservations about implementing workshop activities in their classrooms. These concerns were primarily about their own content knowledge, specifically how much of their newly acquired knowledge would be retained into the following school year. The interval between the end of the workshop and the implementation of the workshop activities could be as long as nine months, during which time teachers may not be consistently (or ever) using this information. Despite these concerns, teachers generally appeared to be willing to try to implement the activities, and were excited to use them with their students.

There is an interesting relationship between teacher confidence and classroom practice, which is useful to consider here. While is not possible to draw inferences about pedagogical change, it is worth reflecting on the types of PD practices that may positively increase teacher confidence as a precursor to change. For example, in one study comparing different PD types, the authors found the biggest confidence increases were within a session that included modeling, opportunity for peer collaboration, and follow-up coaching (Tschannen-Moran & McMaster, 2009). Furthermore, the authors speculated a key ingredient might be a time requirement needed to stabilize the practices. Thus, while some teachers in our project expressed concern about the time lapse between the workshop and the school year, it may be that this delay can serve to consolidate the knowledge and skills, particularly when coupled with follow-up coaching. Elsewhere, it has been proposed that another critical consideration is the role of peer context, as teaching is a collaborative endeavor that influences individual context (Ertmer & Simons, 2006; Nariman & Chrispeels, 2016; Tschannen-Moran, Hoy, & Hoy, 1998). As we considered in the planning of this workshop, teacher efforts can be enhanced within the support community of colleagues who can collaborate on the planning and co-design of new units.

Implications for Practice 1: "Mixed Approaches" for Science Instruction in Teacher PD Appears to be Effective

As noted within our pedagogical framework, we purposefully used a variety of active learning strategies for science instruction and content delivery, with a focus on CBL. Our design decision was based on several reports of STEM teacher PD and curriculum in which teachers were able to increase their science content knowledge in settings in which the content was delivered using a variety of strategies (e.g., Glazewski et al., 2014; Ertmer et al., 2014; MacNabb et al., 2006). Our specific approach included using instructional case studies with active learning strategies, including mini-lectures (with opportunities for collaboration via think-pair-share and clicker questions), hands-on activities (e.g., building DNA models and modeling DNA sequences using colored beads), and online simulations (e.g., of the steps of gene expression). For example, Ertmer et al. (2014) conducted a 9-day workshop with middle and high school teachers to support STEM learning, and they similarly engaged a diversity of instructional approaches such as modeling PBL implementation, mini-lectures, guest speakers, and field trips. They observed both increases in learning and confidence in teaching based on pre-post comparisons, and noted the importance of teachers experiencing confidence gains in order to gain facility and comfort in the classroom (e.g., Kolodner et al., 2003).

However, such observed positive impacts on teacher learning are in contrast to observations when PBL was reported to be used as a single instructional strategy for both content delivery and modeling (Weizman et al., 2008). The use of PBL by Weizman et al. (2008) was intentional, as the focus of the PD was specifically on use of PBL, with the expectation that teachers would develop and implement their own PBL units. However, teachers as a whole in their study did not make significant gains in their content knowledge (as measured by concept maps) (Weizman et al., 2008). It is hard to draw conclusions about comparisons of single- vs. multiple-methods of instruction in teacher PD in this case, particularly given the strikingly different mode of assessment used by Weizman et al. (2008). Given that our findings are consistent with other reports of gains in teachers' science knowledge after PD using a variety of instructional strategies, it is worth considering using a variety of approaches in teacher PD. Of course, future research questions can certainly address these disparate findings, and begin to explore more systematically the role of specific instructional strategies used independently or in combination. These are similar to questions being asked more generally about active learning strategies in undergraduate STEM education. There is wide acceptance that active learning "works" (Freeman et al., 2014), but there remain many questions about how specific types of active learning work best, for whom, and in what settings.

Implications for Practice 2: CBL Can Play an Important Role in Teacher PD

We argue that case-based learning played an important role in supporting teacher learning and confidence. This finding builds on research that has linked cases to positive outcomes associated with teacher learning and confidence. For example, Baron (2013) used construction of historic site stories to support teacher learning contextualized within place-based education, such as schools, churches, or other historically significant locations. Baron's overarching goal was to support multiplist thinking across various dimensions, such as origination of the site (and who was involved), stratification across time, and empathetic insight, to a mixed set of results. While participants were able to increase both the types of questions they asked and problem-solving strategies, Baron saw little gains across the targeted complex historical thinking dimensions. However, another key outcome was the increased use of primary sources and use of site materials in classroom lesson plans, signaling a potential shift in practice. As others have documented, deep learning that results in internalization of the content is difficult (Sandberg & Barnard, 1997). One aim, however, is that new knowledge will "stick," so to speak, and indeed, we saw evidence of content stickiness in the increased learning gains, which were corroborated by direct reference to the DNA instructional cases in the focus group when the teachers pointed to the meaningful "stories." This suggests a level of importance and memorability connected to the experiences. However, it would be inappropriate to imply that CBL can explain all the positive outcomes documented here; as we have already highlighted, we argue that results from this study also suggest that time for learning and planning and multiple exposures to the content may be jointly essential. Our current design, focusing on a "what is" question, is not able to decouple the impact of these factors, as well as the impact of school-based teacher teams, and teacher ownership of their newly designed DNA-based classroom activities. However, we can infer that CBL represents one critical feature.

Many teachers noted that they thought their students would be interested in the DNA instructional cases, particularly due to the "real world" connection. Teachers also indicated that they enjoyed the instructional cases. Other teachers thought that students would enjoy the instructional cases because of the inquiry-based approach, the student collaboration, and the hands-on nature of the activities. However, it is important to note that excitement does not necessarily translate into pedagogical change, which may, in fact, add more uncertainty. While we observed considerable evidence that the teachers liked what they learned, the support they received, and the ownership afforded by co-design, it is important to recognize the concerns teachers face when confronting complex content. It is reasonable to expect incremental changes rather than big leaps forward when it comes to classroom practice (Ertmer & Glazewski, 2015; Opfer & Peddler, 2011), and these efforts represent an important first step.

Overall, in our workshop, we set out to increase teacher content knowledge and interest and confidence in STEM teaching, particularly using DNA and genetics as a scientific framework delivered with CBL approaches. Over the course of three years, we documented growth in these areas among teacher participants. We suggest that educators seeking to target complex content would benefit from coupling CBL jointly with other strategies, such as collaborative planning and multiple exposures to the content. Furthermore, teachers need time to work with and practice the ideas and skills, which was afforded within our 7-day format. While we did not investigate the impact of follow-up coaching, prior research suggests it to be similarly critical to teacher learning, if not more so (Appleton, 2008; Tschannen-Moran & McMaster, 2009).

Implications for Practice 3: Diverse Expertise on PD Facilitation Teams Enhances the PD Experience

While not a theme that emerged from the focus groups or surveys, from a design perspective, the diverse (and non-overlapping) expertise on the facilitation team was critical. In our case, we had a university faculty member with expertise in biology and biology education, another faculty member with experience in K-8 classroom teaching and PBL practice and research, and a research scientist with expertise in bioinformatics (including online databases and tools). All three facilitators were called upon by teachers as they worked on their DNA-inquiry units, and each facilitator contributed information and feedback that could not have been contributed by the other facilitators. The use of diverse expertise on PD facilitation teams is widely reported (e.g., Ertmer et al., 2014; MacNabb et al., 2006; Sinclair et al., 2011), and from a design perspective, these experts were all necessary to meet the workshop goals.

One type of expert that was not represented on our facilitation team was a master teacher or teacher-leader—a K-8 teacher with experience developing and/or using DNA-inquiry units in their classroom (e.g., Ertmer & Simons, 2006; Lehman et al., 2006; Sandholtz & Ringstaff, 2011; Sinclair, Naizer, & Ledbetter, 2011). Such peer expertise could have been valuable in addressing some of the teacher anxieties about implementation in the classroom, and has been noted to be important in subsequent classroom implementation (Lehman et al., 2006). Future iterations could certainly include such a teacher-leader, and the impact of including a teacher-leader could be more specifically examined.

Implications for Research 1: Genetics and Genomics Education

The Human Genome Project was only completed in 2003 (Genetics Home Reference, 2018), but has afforded huge advances in our understanding of topics such as evolution and disease, and has provided new technologies that have enhanced our understanding of genetics in general. Given these rapid advances, we do not have a blueprint for how to educate teachers on these emerging areas. However, we recognize the critical importance of doing so, as teachers represent one of the first opportunities we have to reach the next generation of scientists (Maltese & Tai, 2011). While we have not collected data to investigate potential linkages between teacher knowledge and confidence and downstream classroom practice, this represents a critical next question to investigate in documenting research outcomes.

Given the plethora of "stories" that can be told from a genetics perspective (e.g., stories of patients, diagnoses, cures, treatments, and researchers), CBL appears to be a natural "fit" for teaching this content to teachers. While we have seen positive outcomes in this regard with our teachers, it would be illuminating to more closely investigate the role of CBL in genetics and genomics literacy, both in our teachers and in the students in their classrooms.

Implications for Research 2: Understanding the Impact of Various PD Elements

It is also important to look more deeply at the interplay between the essential elements of teacher PD that might lead to classroom change. We intentionally designed our experience to include case instruction with embedded active learning strategies, time for teacher planning and collaboration, and multiple exposures to content. We suspect that CBL represented a critical feature positively associated with gains in teacher knowledge and confidence, but we do not know for certain. We imagine the cases—often presented contextually and grounded in stories—helped anchor and stick the ideas, but future research should look more deeply at this conjecture, as well as the individual roles of specific active learning strategies in contributing to teacher knowledge and confidence.

Conclusion

As a future "what is happening" question, we are interested in evaluating how the positive workshop experience and attitudes translates into the classroom and impacts on students. As a future "why is this happening" question, we are interested in investigating how specific elements of our PD contribute to the outcomes we have observed. In terms of our original "what is happening in our workshop" question, we have been able to demonstrate an increase in teacher content knowledge and teacher willingness and enthusiasm for using DNA instructional cases in their classrooms. We sought to achieve multiple outcomes, including increased teacher knowledge and confidence. These outcomes reported here are situated in a complex instructional framework that includes extensive use and modeling of DNA instructional cases to teach science content, including active learning strategies that were highly valued by the teachers.

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References

Allchin, D. 2013. Problem- and case-based learning in science: An introduction to distinctions, values, and outcomes. *CBE-Life Sciences Education, 12*, 364–372.

Abell, S. K., Bryan, L. A., & Anderson, M. A. (1998). Investigating preservice elementary science teacher reflective thinking using integrated media case-based instruction in elementary science teacher preparation. *Science Education, 82*(4), 491–509. https://doi.org/10.1002/(sici)1098-237x(199807)82:4<491::aid-sce5>3.0.co;2-6

Ackerson, V. L., & Hanuscin, D. L. (2007). Teaching nature of science through inquiry: Results of a 3-Year professional development program. *Journal of Research in Science Teaching, 44*(5), 653–680. http://doi.org/10.1002/tea

Appleton, K. (2008). Developing science pedagogical content knowledge through mentoring elementary teachers. *Journal of Science Teacher Education, 19*, 523-545.

Baron, C. (2013). Using inquiry-based instruction to encourage teachers' historical thinking at historic sites. *Teaching and Teacher Education 35*, 157-169. https://doi.org/10.1016/j.tate.2013.06.008

Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education, 20*(6), 481–486. https://doi.org/10.1111/j.1365-2923.1986.tb01386.x

Barrows, H.S. and Tamblyn, R.M. (1980). *Problem-based learning: An approach to medical education.* Springer Publishing Company.

Bass, R. (1999). The scholarship of teaching: What's the problem? *Inventio, 1*(1).

Bassey, M. (2001). A solution to the problem of enertalization in educational research: Fuzzy prediction. *Oxford Review of Education, 27*(1), 5-22. https://doi.org/10.1080/03054980123773

Bolnick, D. A., Fullwiley, D., Duster, T., Cooper, R. S., Fujimura, J. H., Kahn, J., ... & Ossorio, P. (2018). The science and business of genetic ancestry testing. In O. K. Obasogie & M. Darnovsky (Eds.). *Beyond bioethics: Toward a new biopolitics* (pp. 422-427). Oakland, CA: University of California Press.

Buckles, S. (2018). 15 ways genomics is impacting our lives: Genomic literacy and pharmacogenomics. Individualized Medicine Blog, *Mayo Clinic*. Retrieved from https://individualizedmedicineblog.mayoclinic.org/2018/04/16/15-ways-genomics-is-impacting-our-lives-genomic-literacy-and-pharmacogenomics/

Deslauriers, L., Schelew, E. & Weiman, C. (2011). Improved learning in a large-enrollment physics class. *Science, 332*, 862-864.

Dori, Y. J., & Herscovitz, O. (2005). Case-based long-term professional development of science teachers. *International*

Journal of Science Education, 27(12), 1413–1446. https://doi.org/10.1080/09500690500102946

Eick, C. J. (2012). Use of the outdoor classroom and nature-study to support science and literacy learning: A narrative case study of a third-grade classroom. *Journal of Science Teacher Education, 23*, 789–803. http://doi.org/10.1007/s10972-011-9236-1

Epstein, D. & Miller, R. T. (2011). *Slow off the mark: Elementary school teachers and the crisis in science, technology, engineering and math education*. Washington D. C.: Center for American Progress. Retrieved from https://www.americanprogress.org/issues/education-k-12/reports/2011/05/04/9680/slow-off-the-mark/

Ertmer, P.A. and Glazewski, K.D. (2018). Problem-based learning: Essential design characteristics. In Reiser, R.A. & Dempsey, J.V. (Eds), *Trends and issues in instructional design & technology 4th Edition* (pp. 286-295). New York, NY: Pearson.

Ertmer, P. A., & Glazewski, K (2015). Essentials for PBL implementation: Fostering collaboration, transforming roles, and scaffolding learning. In A. Walker, H. Leary, C. E. Hmelo-Silver, & P. Ertmer (Eds). *Essential Readings in Problem-based Learning* (p. 89-106). West Lafayette, IN: Purdue Press.

Ertmer, P. A., Schlosser, S., Clase, K., & Adedokun, O. (2014). The grand challenge: Helping teachers learn/teach cutting-edge science via a PBL approach. *Interdisciplinary Journal of Problem-Based Learning, 8*(1). https://doi.org/10.7771/1541-5015.1407

Ertmer, P. A., & Simons, K. D. (2006). Jumping the PBL implementation hurdle: Supporting the efforts of K–12 teachers. *Interdisciplinary Journal of Problem-Based Learning, 1*(1). https://doi.org/10.7771/1541-5015.1005

Erickson, F. (1986). Qualitative methods in research on teaching. In M. C. Wittrock (ed.). *Handbook of research on teaching (3rd ed.)* (pp. 119-161). New York: MacMillan.

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410-8415. www.pnas.org/cgi/doi/10.1073/pnas.1319030111

Fulp, S. L. (2002a). *The 2000 national survey of science and mathematics education: Status of elementary school science teaching*. Chapel Hill, NC: Horizon Research Inc. Retrieved from http://2000survey.horizon-research.com/

Fulp, S. L. (2002b). *The 2000 national survey of science and mathematics education: Status of middle school science teaching*. Chapel Hill, NC: Horizon Research Inc. Retrieved from http://2000survey.horizon-research.com/

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Soon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915-945. https://doi.org/10.3102/00028312038004915

Gelman, R., & Brenneman, K. (2004). Science learning pathways for young children. *Early Childhood Research Quarterly, 19*, 150–158. http://doi.org/10.1016/j.ecresq.2004.01.009

Genetics Home Reference (2018). *What did the human genome project accomplish?* Retrieved from https://ghr.nlm.nih.gov/primer/hgp/accomplishments

Genomic Literacy, Education, and Engagement (GLEE) Task Force (2017). *Genomic literacy, education, and engagement (GLEE) initiative.* National Institutes of Health, Bethesda, MD. Available: https://www.genome.gov/pages/about/od/ecib/glee/glee_meeting_exec_summary.pdf.

George, R. (2006). A cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science. *International Journal of Science Education, 28*(6), 571-589. https://doi.org/10.1080/09500690500338755

Gerard, L. F., Varma, K., Corliss, S. B., & Linn, M. C. (2011). Professional development for technology-enhanced inquiry science. *Review of Educational Research, 81*(3), 408-448. https://doi.org/10.3102/0034654311415121

Glazewski, K., Shuster, M., Brush, T., Ellis, A. (2014) Conexiones: Fostering socioscientific inquiry in graduate teacher preparation. *Interdisciplinary Journal of Problem-Based Learning, 8*(1). http://dx.doi.org/10.7771/1541-5015.1419

Goodnough, K., Pelech, S., and Stordy, M. (2014). Effective professional development in stem education: The perceptions of primary/elementary teachers. *Teacher Education and Practice, 27*, 402-423.

Hartman, P., Renguette, C., & Seig, M. (2018). Problem-based teacher-mentor education: Fostering literacy acquisition in multicultural classrooms. *Interdisciplinary Journal of Problem-Based Learning, 12*(1). https://doi.org/10.7771/1541-5015.1659

Herreid, C. (1997). What is a case? Bringing to science education the established teaching tool of law and medicine. *Journal of College Science Teaching, 27*(2), 92-94.

Herreid, C. F. (2017). Puttin' on the ritz: How to put science into cases. *Journal of College Science Teaching, 47*(1), 54–56. https://doi.org/10.2505/4/jcst17_047_01_54

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Hmelo-Silver, C. E. (2013). Creating a learning space in problem-based learning. *Interdisciplinary Journal of Problem-Based Learning, 7*(1), 3–15. https://doi.

org/10.7771/1541-5015.1334

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education, 29*(11), 1347-1362. https://doi.org/10.1080/09500690601007549

Hung, W. (2016). All PBL starts here: The problem. *Interdisciplinary Journal of Problem-Based Learning, 10*(2). https://doi.org/10.7771/1541-5015.1604

King, A. (1993). From sage on the stage to guide on the side. *College Teaching, 41*(1), 30-35. https://doi.org/10.1080/87567555.1993.9926781

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., … Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design into practice. *Journal of the Learning Sciences, 12*(4) 495–547. https://doi.org/10.1207/S15327809JLS1204_2

Lee, H., & Blanchard, M.R. (2018). Why teach with PBL? Motivational factors underlying middle and high school teachers' use of problem-based learning. *Interdisciplinary Journal of Problem-Based Learning, 13*(1). https://doi.org/10.7771/1541-5015.1719

Lehman, J. D., George, M., Buchanan, P., & Rush, M. (2006). Preparing teachers to use problem-centered, inquiry-based science: Lessons from a four-year professional development project. *Interdisciplinary Journal of Problem-Based Learning, 1*(1). https://doi.org/10.7771/1541-5015.1007

MacNabb, C., Schmitt, L., Michlin, M, Harris I., Thomas, L., Chittendon, D, Ebner ,T. J., & Dubinsky, J. M. (2006). Neuroscience in middle schools: A professional development and resource program that models inquiry-based strategies and engages teachers in classroom implementation. *CBE-Life Sciences Education, 5*, 144-157. http://10.1187/cbe.05-08-0109

Maltese, A., & Tai, R.H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education, 95*(5), 877-907. https://doi.org/10.1002/sce.20441

Merriam, S.B. (1988). *Case study research in education*. San Francisco, CA: Jossey-Bass.

Nadelson, L. S., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher STEM perception and preparation: Inquiry-based stem professional development for elementary teachers. *The Journal of Educational Research, 106*, 157-168. https://doi.org/10.1080/00220671.2012.667014

Nariman, N., & Chrispeels, J. (2016). PBL in the era of reform standards: Challenges and benefits perceived by teachers in one elementary school. *Interdisciplinary Journal of Problem-Based Learning, 10*(1). https://doi.org/10.7771/1541-5015.1521

National Center for Case Studies in Science Teaching (NCCSTS). *Case types & teaching methods: A classification scheme*. http://sciencecases.lib.buffalo.edu/cs/collection/method.asp (accessed 1/22/19).

National Human Genome Research Institute. (2019). *Genomics and medicine*. Retrieved from https://www.genome.gov/27552451/what-is-genomic-medicine/

National Human Genome Research Institute. (2017). *The Genomics Landscape*, June 6. Retrieved from https://www.genome.gov/Pages/About/OD/Director's_Message/NHGRI_Genomics_Landscape_June_2017.pdf

National Research Council. (2007). Taking science to school: Learning and teaching science in grades K-8. Committee on Science Learning, Kindergarten Through Eighth Grade. R. A. Duschl, H. A. Schweingruber, & A. W. Shouse (Eds.). *Board on science education, center for education. Division of behavioral and social sciences and education* (p. 296-330). Washington, DC: The National Academies Press.

Opfer, V. D., & Pedder, D. (2011). Conceptualizing teacher professional learning. *Review of Educational Research, 81*(3), 376–407. http://doi.org/10.3102/0034654311413609

President's Council of Advisors on Science and Technology (PCAST) (2010). *Prepare and inspire: K-12 education in science, technology, engineering and math (STEM) for America's future.* Washington, DC: Executive Office of the President. Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-stem-ed-final.pdf

Preszler, R.W., Dawe, A., Shuster, C.B., & Shuster, M. (2007) Assessment of the effects of student response systems on student learning and attitudes over a broad range of biology courses. *CBE-Life Sciences Education, 6*(1), 29-41. https://doi.org/10.1187/cbe.06-09-0190

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223–231.

Sandberg, J., & Barnard, Y. (1997). Deep learning is difficult. *Instructional Science, 25*(1), 15-36. https://doi.org/10.1023/A:1002941804556

Sandholtz, J. H., & Ringstaff, C. (2011). Reversing the downward spiral of science instruction in k-2 classrooms. J*ournal of Science Teacher Education, 22*, 513-533. https://doi.org/10.1007/s10972-011-9246-z

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-Based Learning, 1*(1), 9–20. https://doi.org/10.7771/1541-5015.1002

Savery, J. R. (2019). Comparative pedagogical models of problem-based learning. In M. Moallem, W. Hung, & N. Dabbagh (Eds.). *The Wiley handbook of problem-based learning* (pp. 81-103). Hoboken, NJ: John Wiley & Sons

Publishing.

Scher, L., & O'Reilly, F. (2009). Professional development for k-12 math and science teachers: What do we really know? *Journal of Research on Educational Effectiveness, 2*, 209-249. https://doi.org/10.1080/19345740802641527

Servant-Miklos, V. F. C., Norman, G. R., & Schmidt, H. G. (2019). A short intellectual history of problem-based learning. In M. Moallem, W. Hung, & N. Dabbagh (Eds.). *The Wiley handbook of problem-based learning* (pp. 3-24). Hoboken, NJ: John Wiley & Sons Publishing.

Shuster, M., Cheeptham, A., Regassa L. (2013) *Murder by HIV?* Grades 5-8 edition. National Center for Case Study Teaching in Science.

Shuster, M, Claussen, K. Locke, M. and Glazewski, K. (2016) Bioinformatics in the K-8 classroom. Designing innovative activities for teacher implementation. *International Journal of Designs for Learning, 7*(1), 60-70.

Sinclair, B .B., Naizer, G., & Ledbetter, C. (2011). Observed implementation of a science professional development program for k-8 classrooms. *Journal of Science Teacher Education, 22*, 579-594. https://doi.org/10.1007/s10972-010-9206-z

Smith, M.K., Wood, W.B., Krauter, K., & Knight, J.W. (2011). Combining peer discussion with instructor explanation increases student learning from in-class concept questions. *CBE-Life Sciences Education, 10*(1), 55-63. https://doi.org/10.1187/cbe.10-08-0101

Sorge (2007). What happens? Relationship of age and gender with science attitudes from elementary to middle school. *Science Educator 16*(2), 33-37.

Thomas, D. (2006.) A general inductive approach for analyzing qualitative evaluation data. American *Journal of Evaluation, 27*(2), 237-246. https://doi.org/10.1177/1098214005283748

Tschannen-Moran, M., Hoy, A. W., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and its measure. *Review of Educational Research, 68*(2), 202–248. http://doi.org/10.3102/00346543068002202

Tschannen-Moran, M., & McMaster, P. (2009). Sources of self-efficacy: Four Professional development formats and their relationship to self-efficacy and implementation of a new teaching strategy. *The Elementary School Journal, 110*(2), 228–245. http://doi.org/10.1086/605771

Yadav, A. & Beckerman, J. (2009). Implementing case studies in a plant physiology course: Impact on student learning and engagement. *Journal of Natural Resources & Life Sciences Education, 38*, 50-55.

Yadav, A., Lundeberg, M., DeSchryver, M., Dirkin, K., Schiller, N. A., Maier, K., & Herreid, C. F. (2007). Teaching science with case studies: A national survey of faculty perceptions of the benefits and challenges of using cases. *Journal of College Science Teaching, 37*(1), 34.

Weizman, A., Covitt, B.A., Koehler, M.J., Lundeberg, M.A., Oslund, J.A., Low, M.R., Eberhardt, J., & Urban-Lurain, M. (2008). Measuring teacher's learning from a problem-based learning approach to professional development in science education. *Interdisciplinary Journal of Problem-Based Learning, 2*(2). https://doi.org/10.7771/1541-5015.1081

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*NOTE: Krista D. Glazewski, while presently serving as Editor of The Interdisciplinary Journal of Problem-Based Learning, was prohibited from any internal handling of this paper at the journal.

Appendix A

Sample Content Test Items

Research Area	Content Test Question	Description of Associated Item Image, if any	Content Test Answer Choices
A. Items that we suspected teachers would be familiar with:	Which cell types have organelles?		(a) plant cells (b) human cells (c) bacterial cells (d) both plant and human cells have organelles
	In a plant or animal cell, where is most of the genetic material found?		(a) in the cytoplasm (b) in the cell membrane (c) in the mitochondria (d) in the nucleus
	In the picture of a cell below, which numbered line is pointing to the part of the cell that contains most of the genetic.	Picture description: arrows point at (1) the nucleus, (2) a peroxisome, (3) a mitochondrion, (4) the cytoplasm)	(1), (2), (3), (4)
	What is the building block that all organisms are made up of?		(a) Fats (b) Cells (c) Organs (d) DNA
	What molecule stores the genetic instructions in humans?		(a) DNA (b) Proteins (c) Sugars (d) Fats
B. Items that we suspected would be new content for teachers:	On the tree shown below, which letter shows the most recent common ancestor of birds and crocodiles?	Diagram of a phylogenetic tree with birds, dinosaurs, and crocodiles.	(A), (B), (C), (D)
	On the tree shown below, which letter shows the most recent common ancestor of dinosaurs and birds?	Diagram of a phylogenetic tree with birds, dinosaurs, and crocodiles.	(A), (B), (C), (D)
	Based on the tree shown below, who are the Rummies most closely related to?	Diagram of a branching phylogenetic tree with five labeled organisms.	(A), (B), (C), (D)

Research Area	Content Test Question	Description of Associated Item Image, if any	Content Test Answer Choices
	You are walking in the desert with a group of scientists. You find a plant that looks like a cactus, but none of the scientists have seen this particular plant before. What could you do to confirm that it is really more closely related to other cacti than to other plants?		(a) Look on the internet (b) Take careful measurements and photographs to accurately describe it (c) Isolate its DNA and compare its DNA to the DNA of other cacti (d) Carefully describe where you found it, and its local habitat and environment.
	All birds have feathers and lay eggs. An arctic scientist has found an ancient animal frozen in the snow and ice. It has feathers, but the scientist is not positive that the animal is a bird. What else could the scientist do to decide whether or not this is a bird?		(a) Look for a beak (b) Look for more of these ancient frozen animals in the same area (c) Search past records of bird scientists for reports of similar animals, (d) Study the DNA from the frozen animal to see if it is closely related to birds.
	How can you tell if two DNA sequences from two different organisms are from closely related organisms?		(a) There will be many differences between them (b) There will be few differences between them (c) They will be present in every organism that you study (d) By determining when each sequence appeared in the fossil record.

Appendix B

Focus group questions

1. How confident do you feel with your knowledge of the science that was presented?
    a. Follow-up: How could the presentation of the science be improved?
    b. Follow-up: Was the presentation of the science concepts clear?
    c. Follow-up: Was there enough time for you to develop an understanding of the science concepts?
2. How confident do you feel about running the activities in your classroom?
    a. Follow-up: What are your current concerns, if any, about running the activities in your classroom?
    b. Follow-up: What barriers or challenges do you anticipate facing?
3. How do you think your students will respond to the STC activities?
    a. Follow-up: Do you think that they will be interested by the activities?
    b. Follow-up: Do you think that they will be able to learn from the activities?
4. How would you improve, if at all, the weeklong workshop?