The Power and Promise of A Digital Tool for Teaching Inquiry Science

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Introduction

In combination with effective instructional materials, teachers are the most important factor in determining student learning (Ball & Cohen, 1996; Miller & Krumhansl, 2008). Research and practitioner experience indicate that high-quality professional development—face-to-face workshops, online courses/resources, or teacher support materials that accompany curriculum—is key to the successful implementation of productive curriculum reforms (Fishman, 2016). Yet there is also agreement that professional development is not as effective as it could be (Fishman, 2016).

High-quality instructional materials, accompanied by comprehensive and accessible teacher supports, play a major role in supporting teachers in engaging students in deep, meaningful learning in science. Our Education Development Center, Inc. (EDC) team—which included co-Principal Investigators Jackie Miller and Bill Tally and Katherine Paget, John Parris, and Irene Baker—designed a digital tool, the electronic Teacher Guide (eTG), to help high school teachers plan, implement, and modify standards-based reform instructional materials by providing access to rich multi-media science content and best teaching practice support. Portraits of how teachers plan, teach, and learn using new delivery platforms such as eBooks, tablets, and cloud-based curricula reveal how such a tool can support teacher learning and inquiry practices.

Over the past 30 years, the National Science Foundation (NSF) has supported the development of innovative and standards-based instructional materials featuring approaches that are based upon current understandings of how students learn science (Bransford, Brown, & Cocking, 2000). These materials provide students with rigorous, in-depth learning experiences that facilitate their movement from developing baseline knowledge to building higher levels of conceptual understanding. Support materials that accompany instructional materials, often in the form of extensive teacher guides, help teachers implement materials with fidelity to developers' intentions and the curriculum's integrity, as well as incorporate new instructional strategies into their practice.

Curriculum developers design these teacher guides based on the understanding that many teachers cannot access professional learning opportunities that support their use of innovative curricula and, therefore, printed guides must provide whatever implementation guidance and support teachers receive. Curriculum materials with features that promote teacher learning as well as student learning are termed "educative" (Schneider & Krajcik, 2002). Materials defined as educative emphasize the big ideas of a discipline, promote conceptual coherency, and identify prerequisite knowledge and misconceptions. By providing varied teaching strategies and embedded formative assessment tools, educative materials offer teachers extensive support that guides them in making instructional decisions based on students' thinking and learning styles (Gess-Newsome & Taylor, 2008).

Despite the best intentions of curriculum developers to provide accessible, useful teacher support materials in the form of teacher guides, use of the guides is often random and occasional (J. Carlson & B. Nagle, personal communication, April 1, 2006). Teachers say they seldom use the guides because the guides tend to be large, dense, and separate from student books, making them awkward, unwieldy, difficult to navigate, and time consuming to use.

Most teachers do not have the time to read extensive support materials no matter how potentially useful or well written. Teachers also need varying levels of support depending on their backgrounds and experiences. Finally, the linearity of print guides and the equal weighting of each part of the support materials make it difficult for teachers to customize their use of the material.

Digital affordances can overcome many of the difficulties inherent in print teacher guides by making the support materials and educative resources easier to use and readily accessible at "point of use" during planning and teaching. Digital features can enable teachers to customize student materials while keeping the intentions of the curriculum designers visible. A digital interface allows teachers choices in how much they want to read, when they want to read, and how deeply they want to delve. Digital student materials provide options for content presentation by using media such as videos, charts, animations, and graphics, which can help reduce the cognitive load that text often presents to students, and can appeal to different learning styles.

Based on this thinking, two goals guided our development of the eTG: (1) Reimagine and redesign the print guide for the genetics unit of Foundation Science: Biology, a curriculum development project funded by the NSF, as an exemplar of a cybertool that could improve learning by enhancing teachers' planning and teaching; and (2) Study its usefulness to teachers. Our hypotheses drew upon research into the role of educative curriculum in science teaching (Gess-Newsome & Taylor, 2008; Schneider & Krajcik, 2002) and, in particular, the role that materials can play in the development of teachers' subject-matter knowledge (SMK) and pedagogical content knowledge (PCK). As described in the next section, our eTG contains features designed to help teachers implement the materials with fidelity to the intentions of the curriculum and to promote teachers' learning of SMK and teachers' development of PCK. We hypothesized that the eTG, by providing easier access to features that support teacher understanding and use of the materials both during lesson preparation and the teaching of the lesson, would enhance teachers' SMK and PCK. We further hypothesized that increases in teachers' SMK and PCK would result in the ability of teachers to teach the curriculum with greater fidelity to the content and pedagogical intentions of the curriculum. Thus, we hoped this work would enable us to determine to what extent the features of the eTG could enhance the ability of teachers to implement innovative curricula effectively.

To examine these hypotheses about the value of the eTG as a curriculum planning and teaching tool, it was important to study it in the contexts of teachers' actual planning, teaching, and reflecting. We chose to use two descriptive case studies because this design is best suited for carrying out a detailed investigation of an intervention and the real-life context in which it occurs (Yin, 2003). Due to the complexity of the eTG design and the differences among teachers in terms of experience and pedagogy, each implementation of the eTG was likely to be a unique case. Generalizability of implementation was neither expected nor inferred, and it was important to seek reasons for specific uses, which the case study design allowed us to do (Gillham, 2000, p. 7).

"Digital affordances can overcome many of the difficulties inherent in print teacher guides."

The case study design is also useful for exploring significant features of each case (Bassey, 1999). For example, we wanted to examine the process that leads to change in teachers' practice; the case study design supported us in exploring this feature because it captures how events occur in real time (Simons, 2009). Another aspect of the case study design is the use of multiple sources of data. In our research, we carried out interviews and observations, examined documents (modified slide decks), and reviewed artifacts (student work products). Finally, case study research of an intervention is an important method for generating more targeted research questions and providing data that can improve the intervention.

Two in-depth classroom implementations provide the landscape for the following case studies. To examine the hypotheses above, we chose teachers with different levels of preparation for biology teaching. The teachers initially appeared to fit the designations "expert" and "novice." Ms. J was a 10-year veteran biology instructor with years of experience teaching Biology 2, in which molecular genetics is a prominent aspect of the curriculum. Based on a review of her prior teaching materials, her SMK was extremely high, showing adeptness at guiding students through a rigorous conceptual approach to understanding molecular genetics. Mr. H was a first-year biology teacher, though an experienced teacher of Earth science and integrated science-and-society courses, and a graduate student doing research in biology. As this year was his first teaching biology, we expected his SMK to be low-to-medium and his PCK for biology to be low. Both teachers were fluent in technology use.

There were major differences between Ms. J's and Mr. H's schools and students. Ms. J taught in a large public high school in suburban Massachusetts. Her students were heterogeneous in ethnic background and middle- to upper-middle class in socio-economic status. During the case study, her students were taking a yearlong Biology 2 class that was lab-based and focused on molecular genetics. All of her students had completed a year of Biology 1. Mr. H taught in a medium-sized alternative high school in New York City. His students were mostly minority and from immigrant families and, according to Mr. H, achievement-oriented though underprepared for high school science study. His students were taking a Biology 1 class during the case study, which included molecular genetics but emphasized connecting biology to social issues.

The eTG guides teachers in engaging students in a 2-week unit on molecular genetics from the Foundation Science: Biology curriculum. Students consider transgenic plants as an approach to understanding the biochemical basis of traits. Students first brainstorm about what they know about genes, traits, and genetically modified organisms (GMOs). They read about potatoes that have been genetically modified to increase their nutritive value and potatoes that have been modified to resist pests. They are then challenged to decide whether their school cafeteria should offer genetically modified French fries and, if so, which kind. To gain enough information about how organisms are modified so that they can make an informed decision, students carry out an investigation in which they insert a new gene into bacteria and observe a new trait. Following the investigation with bacteria, they read about how scientists genetically modify plants to obtain desirable traits and about the pros and cons of GMOs. Armed with this information, they decide whether their school cafeteria's cooks should use GMO potatoes and take a stand on their position using evidence to defend their decision.

About the Electronic Teacher Guide

The eTG includes a variety of features designed to foster thoughtful adaptation of the curriculum and enhance teachers' PCK and SMK.

1) **A Navigation Bar and Teaching Sequence Preview** reinforces the instructional sequence (PCK) and assists teachers in finding student content and teaching supports in the learning experience (the equivalent of a chapter) and in the planning, teaching, and reflecting tools.

2) **An eBook** contains the text of the student book with the integrated teacher text, including detailed background explanations for teachers (SMK). Teachers can toggle between views of the eBook as the integrated document or as the student book only.

3) **My Lesson Planner**, an editable slide presentation, shows each unit's intended flow of ideas and activities. Each slide contains materials for students and materials for teachers (visible only to teachers) which indicate the activity's purpose, discussion, or reading (PCK); science background (SMK); teaching strategies; and other supports. Teachers can modify the slides in the basic deck and save the deck in PowerPoint.

4) **Web Resources** provide vetted images, videos, and interactives related to unit concepts. Each unit includes a hyperlinked concept map on which a teacher can see an overview of the concepts covered and click on a specific term to obtain related resources (SMK, PCK).

5) **Essential Supports** offer multimedia resources to support teachers in holding productive classroom discussions, using formative assessment, understanding the content structure of the curriculum, and making mindful modifications of the instructional materials (PCK). Links to these resources are placed in the eBook at the point-of-use when the teacher is preparing to teach or reflect on a lesson. Additionally, they are collected in the Essential Supports section of the eTG, where they can serve as teacher learning resources over time on an individual basis.

6) **Taking Stock**, an interactive Reflection Tool, enables teachers to consider the effectiveness of various components of their teaching and use these reflections to revise and tailor their teaching to meet students' needs. Three Taking Stock instruments, one for each of three learning experiences in the genetics unit, support teachers in reflecting on their classroom implementation. The instruments provide self-evaluation opportunities that teachers can use to modify the curriculum and improve their practice (PCK).

A Tale of Two Classrooms: Ms. J and Mr. H

We explored three questions in our case studies: In what ways and to what extent do features of the eTG prove useful for teachers' planning and teaching? In what ways and to what extent does the eTG help teachers develop their SMK and their PCK? To what extent does use of the eTG features help move teachers along the continuum from novice to expert? The question relating to the eTG as a dynamic planning and teaching tool was addressed in both the biology classroom implementations. Mr. H taught the same lessons using the eTG tool in two consecutive years, enabling us to address the question concerning change in practice over time.

In both schools, staff researchers observed Ms. J's and Mr. H's classroom sessions over a 2-week period and conducted pre-post interviews with each teacher. Researchers collected and analyzed the slide decks created by the two teachers and student products (posters and debate notes) created during the 2-week implementations. In the pre- and post-interview, we asked teachers to comment on the eTG features (i.e., the Teaching Sequence Preview, the navigation bar, the Teacher Notes on the slide deck, teacher and student versions of the eBook, Essential supports—specifically the examples of productive discussion and formative assessment, the reflection and Web resources tools). Classroom observations were primarily a log of the activity stream, with the researcher annotating the edited slide deck sent daily by the instructor.

Case 1: Ms. J

Ms. J, a 10-year veteran teacher in a Massachusetts suburban high school, has taught a Biology 2 class in which molecular genetics is a prominent aspect of the year's curriculum. The transformation lab served as the focal point for her curriculum enactment. Ms. J had a solid science background with an undergraduate degree in biology and a master's degree in virology, worked in a variety of labs during college (academic, National Institutes of Health, and industry), and was employed at a biotech company before deciding to switch careers. Ms. J worked mainly with eTG's slide deck, the Web Resources tool, and the Essential Supports for productive discussion and for formative assessment.

Because Ms. J emphasized the molecular and cellular bases of developing transgenic organisms, her modifications to the basic deck resulted in a 60-item slide deck replete with detail and diagrams concerning lab procedures, the bacteria used to transform plant cells, and specifics about the processes of bioengineering. Although Ms. J engaged students in various practices of science (e.g., developing questions, arguing from evidence, and obtaining, evaluating, and communicating information), the core science content and the analysis and interpretation of experimental findings took precedence.

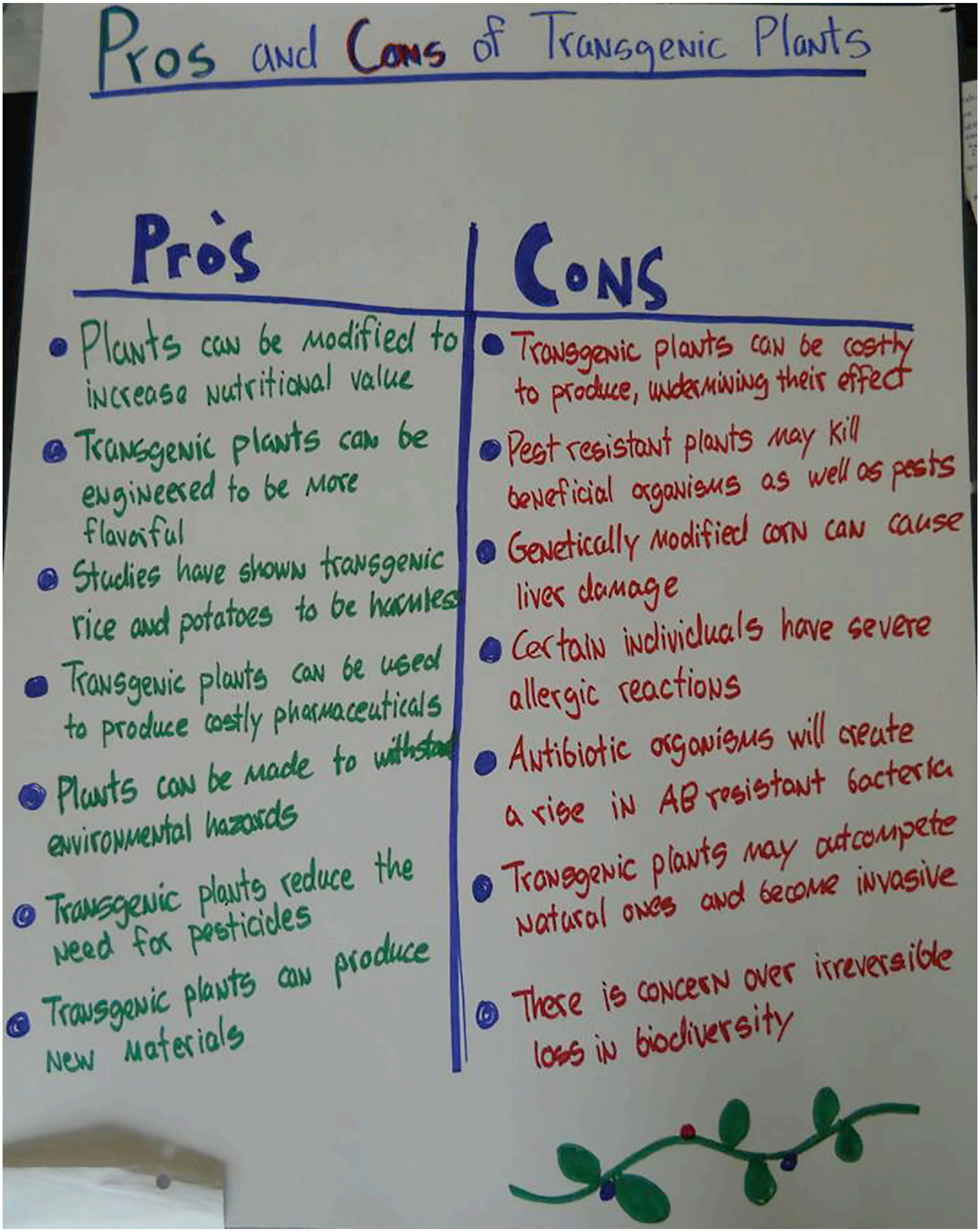
Using the Slide Deck for Planning and Teaching. After an initial orientation to the eTG, Ms. J blocked out two weeks on her school calendar and then appeared to plan her lessons day by day (she sent her slides for each day's lesson to the researcher the night before she taught each lesson). In the pre-interview, Ms. J reported that she appreciated the Teaching Sequence Preview because it clearly conveyed the overall plan for the unit lesson by lesson. Over six sessions, Ms. J continually modified the basic slide deck on a daily basis. During the first session, she added images of observable traits and GMOs. For Session 2, she added diagrams of the lab procedures from the Carolina Biological online manual whose lab kit we supplied. In Session 3, her slides included class directions (e.g., sit in lab groups), specific daily assignment requirements (e.g., answer lab questions x and y), and embedded review questions (e.g., what is a plasmid? which tubes went into the warm water bath?). By the end of Session 3, she had included the homework assignments in her slides, even though she had also written the assignments on the board and posted them on the school website. By Session 5, she had added a fair amount of science content concerning the process of genetic engineering. By Session 6, her slides were inclusive, with classroom management directions, criteria for policy statements, summaries of the focal content, and time allotments for each component of the session. The deck of 60 slides increasingly reflected her own voice, both as a means to an end (i.e., communicating ideas and sharing expectations for students) and as a way to make explicit each session's structure both to students and herself.

Using the Essential Supports for Planning, Teaching, Productive Discussion, and Formative Assessment. Ms. J viewed all of the Essential Support videos for productive discussions. These six short videos model productive science discussions in classroom settings. One video demonstrates how teachers can use brainstorming to determine students' prior knowledge. A sequence of five videos show the progression of a discussion relating to the question of whether the school should serve genetically modified foods. Four teacher-led discussion sections culminate in a peer-to-peer student discussion. Ms. J reported that although she has conducted brainstorming discussions before, she never recorded students' ideas in ways that they could be revisited, a technique she observed modeled in the brainstorming video.

During the brainstorming, students talked in pairs about observable and non-observable traits. After discussing the topic with each other, students reported out about desirable traits, often reaching to the fanciful ("I want to have brains in all my organs, like an octopus"). Ms. J recorded students' prior understandings about traits on chart paper and assigned the pro-con GMO posters for homework. During Session 5, students presented their posters in class and examined classmates' posters using the curriculum's rubric to record their classmates' decisions and evidence supporting those decisions. Using their notes, they compared their classmates' decisions and evidence to their own posters. Each student had a chance to present his or her position, leaving no time for questioning or discussion. Ms. J reported in the post-interview that discussion of student posters was difficult to accomplish because she wanted to be sure that every student, even the shy ones, had a chance to present. During the sixth and final session, Ms. J repositioned the chart from the original brainstorming discussion to the front of the classroom. She then read students' responses to each of the brainstorming questions and asked students to decide which of their prior ideas were most accurate.

On page 9, we present a poster explaining a student's support of GMOs, and on page 10 we show a poster created by a student who could not come down firmly on either side of the debate.


GMO's: "they will feed the world"
AquaBounty's genetically modified salmon could provide a healthy and relatively cheap food source while "taking the pressure off of wild fish stocks". More people could be fed and the imminent problem of overfishing would be improved
Birds that are genetically altered could prevent the spread of flu to other flocks which would save the lives of many birds and possibly humans as well
• The genetically altered pig, the Enviropig, secretes less phosphorus which would decrease the water pollution that normal pigs cause
• Transgenic plants can influence the production of new vaccines and antibiotics that can protect people from previously invulnerable viruses or bacterium
• Food can be made to taste better
Golden Rice vs. White Rice
One bowl of the genetically modified "golden rice" with the yellow endosperm gene which indicates the presence of beta-carotene, a source of vitamin A, "can supply 60% of a child's daily requirement of vitamin A", a vitamin vital to the diet of a child being weaned and one that impoverished Asians have little access to as their main food source is regular white rice.
The Consequence of Prohibiting GMO's
The continued prohibition of certain GMO's will have "chilling effects on biotechnology". A great deal of scientists in this field have already left the US in search for a government who will aid their efforts instead of preventing them. GMO's could be the world's solution to famine, malnutrition, overfishing, substitution of chemical pesticides, viruses and bacterium that up to this point have been resistant to treatment. But if the US government keeps standing in the way, progress that could be made will continue to be stunted


Pros and Cons of Transgenic Plants
Pròs
Cons
Plants can be modified to increase nutritional value
Transgenic plants can be engineered to be more flavorful
Studies have shown transgenic rice and potatoes to be harmless
Transgenic plants can be used to produce costly pharmaceuticals
Plants can be made to withstand environmental hazards
Transgenic plants reduce the need for pesticides
Transgenic plants can produce new materials
Transgenic plants can be costly to produce, undermining their effect
Pest resistant plants may kill beneficial organisms as well as pests
Genetically modified corn can cause liver damage
Certain individuals have severe allergic reactions
Antibiotic organisms will create a rise in AB resistant bacteria
Transgenic plants may outcompete natural ones and become invasive
There is concern over irreversible loss in biodiversity

Ms. J adopted some of the formative assessment opportunities embedded in the curriculum and, using the summative questions at the end of the chapter, created some of her own. For example, Ms. J asked her students to record new vocabulary words from the curriculum readings on sticky notes and submit the words to her twice during the 6 sessions, enabling her to learn which terms were new to them. Ms. J also administered a pop mini quiz midway through the unit. It involved a review of the prior week's lab and included the purpose of the antibiotic ampicillin in the experiment. She assigned summative assessment questions at the end of the unit to table groups, along with a recording sheet. After some debate, students recorded their group's answers and passed in their answer sheets to Ms. J. Students' responses to Question 4, which asked students to define the term "totipotency," informed Ms. J that many of them did not yet understand the concept. She then returned to this concept to clarify the idea and its applications.

Case 1 Summary and Results. Ms. J's teaching underscores the educative value of two features of the eTG, the slide deck and the Essential Supports. Using the slide deck, Ms. J created a set of slides modified from the basic deck that reflected her own teaching goals and her goals for the students. These modifications included (1) augmenting the science content and elaborating upon the lab procedures; (2) integrating strategies from the Essential Supports into her practice—returning to prior understandings and using summative assessment questions for discussion; and (3) planning for whole-class, group, and individual work. The slide deck served as an organizer for both Ms. J and her students. Her use of the brainstorming session to elucidate prior knowledge and the return to students' initial ideas at the end of the unit was new for Ms. J, indicating her incorporation of a teaching strategy gleaned from the brainstorming video into her practice. She watched the videos on productive talk in the classroom, but did not have class time for this strategy. If Ms. J were to teach this unit again, she might allow more time for discussion. Thus, in her first time teaching with the eTG, Ms. J, who is a relative expert when it comes to SMK, recognized an area of PCK in which she could improve—holding effective and engaged classroom discussions of the concepts—and used the resources of the eTG to accomplish this.

Case 2: Mr. H

Mr. H, a 13-year veteran teacher, was teaching 9th grade biology for the first time in a medium-size alternative high school in New York City. He was fluent with technologies, both for planning and for teaching, and routinely uses PowerPoint as a medium for preparing and organizing his teaching. The freshman biology course he taught was reading- and discussion-based rather than lab-based. While students study molecular genetics, the course emphasizes sense-making discussions that connect biology to social issues and debates. Mr. H was eager to teach the 2-week unit on molecular genetics because of the GMO debate as its center—he saw this as an ideal follow-up to his students' prior study of molecular genetics and protein synthesis. While he felt confident about the GMO debate, he was more wary about trying to carry out the transformation lab that was another distinguishing element of the unit. He had a fair amount of lab experience himself, but he had not taught many labs.

Using the Slide Deck for Planning and Teaching. Mr. H first previewed the entire unit using the Teaching Sequence Preview. He modified his slide deck as he went along, often the same day as the lesson. While planning, Mr. H introduced three broad types of changes into the eTG's core curriculum slides. First, he added elements that deepened the sense-making and discussion parts of the unit—areas that were already a strength of his teaching, such as writing and debate prompts—and elaborated the scoring rubrics for posters. Second, he changed the sequence around the transformation experiment, both because his preparation for the experiment experienced delays, and because he thought the presentation was too detailed for his students. Due to this change in sequence, students spent less time on the experiment, which may have resulted in conceptual gaps in student understanding of the underlying molecular concepts of the experiment. Third, Mr. H added procedural steps that were part of his classroom routines ("Do Nows" and homework assignments), enlarged and highlighted on-screen text for readability and emphasis, and added images, mostly for "color."

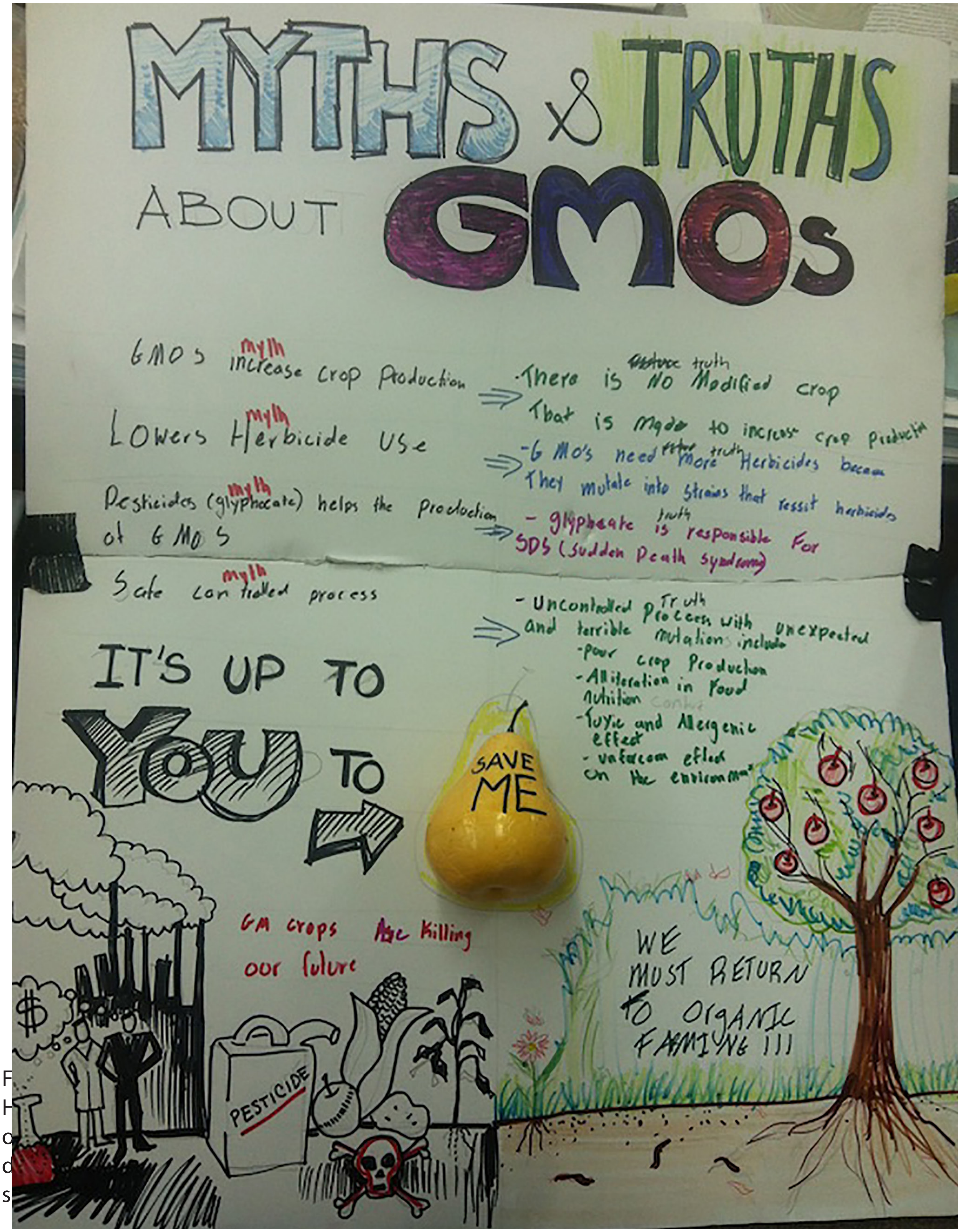
Using the Essential Supports for Planning, Teaching, and Conducting Productive Discussions. Mr. H did not spend much time watching the videos on teaching, because he felt the topics they covered, brainstorming and holding effective discussions, were practices he already did well. As students prepared to share their posters on the GMO debate, Mr. H moved about the class scoring the posters with a rubric, and having students score each other's presentations using the rubric. The shared posters led to valuable discussions that prepared for the last day's culminating debate in which students stood in a "value line" and argued their points, drawing on evidence from their research. For his rubric, Mr. H modified the eTG's rubric by adding details that reflected the Next Generation Science Standards (NGSS) emphasis on argumentation with evidence, which his school has embraced:

1. Demonstration of your understanding of the science behind GMOs
2. Central claim and evidence supporting claim (with sources)
3. Counterclaim, evidence supporting counterclaim (with sources), and evidence refuting counterclaim

On page 13, we show a poster for which a student received points for his central claim but lost points for supporting evidence and lack of counterclaims.

Mr. H found the Reflection Tool (in hardcopy form during this implementation) very useful and, after going through it activity by activity, he became increasingly aware that he may have omitted some important sections of the lessons and changed important aspects that could have altered the learning outcomes for the students.

The eTG as A Professional Learning Environment Supporting Change in Practice Over Time. Because Mr. H agreed to teach the unit for a second time—this time with his 10th grade biology class, we could address the question: *In what ways and to what extent does the eTG show promise as a professional learning environment that helps teachers deepen their practice over time?* Researchers collected observational and interview data related to changes in Mr. H's planning practices, instruction, and improvement in the quality of students' educational experience that may have resulted from his use of features of the eTG.


MYTHS & TRUTHS
ABOUT GMOs
GMOs myth increase crop Production
There is truth No Modified crop That is made to increase crop production
Lowers myth Herbicide Use
GMO's need truth more Herbicides because They mutate into strains that ressit herbicides
Pesticides (glyphocate) myth helps the production of GMOS
- glypheate truth is responsible For SDS (Sudden Death Syndrome)
Safe myth controlled process
- Uncontrolled Truth process with unexpected and terrible mutation include
- poor crop production
IT'S UP TO YOU TO
SAVE ME
GM crops Are killing our future
PESTICIDE
WE MUST RETURN TO ORGANIC FARMING !!!

First, as part of his planning process, Mr. H consulted his eTG Reflection Tool notes from the prior year. He decided that student confusions about the transformation lab experiment were rooted in (1) his own lack of understanding of the structure of the experiment; (2) the insufficient class time he had devoted to the experiment and to teaching students about it; and (3) students' need for more careful scaffolding—especially through visuals—of the experimental conditions.

To remedy his lack of science SMK, prior to teaching the unit in Year 2 Mr. H did two things. He spent a summer conducting research in a genetics lab at Columbia University that clarified his understanding of the process of inserting a gene into bacteria, and he carefully read the eTG eBook's explanation of the lab and its underlying concepts. Armed with this knowledge, he planned a longer two-week approach to the experiment. Instructionally, in Year 2, Mr. H devoted more time to the learning experience overall, and provided more scaffolding and more opportunities for students to learn the key concepts in the unit. The class spent 10 days of classroom time rather than 7 on the entire unit and 5 days instead of 2.5 on the experiment. To provide more scaffolding, Mr. H fully developed twice as many teaching slides to aid students in understanding the experimental procedure. He had students draw each of the conditions and submit annotations of the drawings for feedback prior to researching and preparing their final debate on GMOs. The nine-day implementation culminated in a full-class debate on GMOs. Table 1 shows how two teams of students summarized their arguments.

Table 1. Responses from Two Teams: Are genetically modified foods ethical?

Pro	Con
• More nutrition and Amino Acids • Larger Quantity and Quality • Cure disease • Solution to the global food system --Adopt to global warming • Better in the long run --No need for pesticides • Longer shelf life • If people are educated and there are good labels it would be beneficial --Educate the public --Start early in school • Grow crops in unfertile land --Help developing countries/world hunger	• No knowledge of what the result could be (harmful crosses) • Mortality • Expensive $ • G.E. crops steal nutrients from crops --Competition --Low species diversity --Hurts ecosystem --It affects indirectly • Interrupts natural adaptation • If not studied + no label laws it will have a bad outcome • Small local farmers can't keep up or afford G.E. • "How do you define human?" --Not ethical --Laws/regulation on G.E. of plants/animals • Religious conflict --Manipulating species --Violating mother nature

Table 2. Summary: Should Our School Use Genetically Modified Potatoes in Our Lunches?

Pro	Con
• Not as many pesticides • More nutrients • Beneficial to some people/cultures • Educate the school/let them decide --Parental education	• Long-term effects --Environmental risks • Resistance gene could stimulate an adaptation in insects that makes them stronger --Pesky r-strategists • Allergic reactions • Expensive

Case 2 Summary and Results. Mr. H's experience underscores the educative value of the eTG in supporting and stimulating professional learning, helping teachers improve their SMK and, with it, their ability to impart that greater knowledge to students—leading to improvements in student learning. Mr. H's self-described strength was engaging students in argumentation and debate. Thus, the unit's debate about the use of GMOs in the cafeteria, and the poster presentation, were instructional strategies with which he was comfortable. Because he was not as strong in his conceptual grasp of the content and procedures of the bacterial transformation lab, in Year 1 he struggled to develop in students a conceptually coherent understanding of the lab. Although his students performed the transformation experiment in class, their ability to make sense of the results and provide molecular explanations was limited.

The eTG, with its opportunities to reflect on instructional practice and student learning, particularly the Reflection Tool feature, was a "wake-up call" for Mr. H. He realized that his practice, already strong in promoting argumentation and debate, fell short on the science content concerning molecular genetics. In response, he enrolled in a summer course to learn more about molecular genetics and used the eTG features to give students a deeper encounter with the lab in Year 2; this resulted in greater student understanding of the molecular genetics. Researchers found improvement in student understanding from both the Year 2 in-class comments and in final work products. In Year 1, no students were able to explain the experiment and its structure coherently. In Year 2, students could explain the experiment using their detailed annotated drawings of the conditions. While not always totally accurate, the drawings showed a solid grasp of the structure of the experiment. In addition, final student write-ups in Year 2 showed greater integration of the molecular biology of GMOs, as opposed to the focus on the social and environmental debates about GMOs, which predominated in Year 1. In Year 1, only 2 of 23 (9%) student posters integrated visual and textual descriptions of the processes by which genes are modified; in Year 2, this increased to 13 of 26 (50%) posters or presentations.

Conclusions

Educative curriculum is both the product—materials for teachers and students—and the process through which curriculum is enacted during teaching. We have seen how the eTG, a digital teacher guide containing components of an eBook of student and teacher materials, an editable deck of teaching slides, a filtered set of Web resources, and essential supports for professional learning and reflection, can function as a cybertool for curriculum planning and enactment for both "expert" and "novice" high school biology teachers. When teachers modify the curriculum as described in this paper, they create and enact new instructional resources that nonetheless remain faithful to the original conception of the curriculum. In these two classroom cases, we have seen how digital tools can serve as a professional learning environment grounded in concrete lesson planning, teaching, and revision.

Lessons from the Case Studies

In these two case studies, we observed teachers using a digital teacher guide to build on and transform their practice. Teachers who first appeared to be "expert" and "novice" biology teachers in terms of SMK, revealed themselves as having a range of strengths and weaknesses that they were able to work on over time. Ms. J, the SMK expert, realized that she did not have the range of skills she wanted in conducting effective discussions that would help students deeply integrate that knowledge. Thus, she made this the focus of her work. Mr. H, the PCK expert who was skilled at guiding rich, engaged classroom conversations about subject matter, discovered that his lack of content knowledge around molecular genetics was a stumbling block, which he then remedied.

In both case studies, two aspects appeared to be critical to the professional learning process: a well-designed and ambitious science curriculum to work from and digital tools to help teachers both modify the materials for their students and maintain fidelity to the pedagogical intent of the original sequence. The slide deck enabled teachers to understand the flow of the content and intent of each activity and reading; the digital tools enabled them to modify the materials within that overall context. The dramatically different ways in which these two teachers modified their slide decks suggested that these modifications might be important to study in their own right.

In a subsequent study, we recruited 12 teachers, half from inner city schools and half from suburban schools. In an online forum in which each teacher modified the slide deck for his/her class we found that teachers in urban schools substituted virtual labs for wet labs; added in extensive vocabulary/word banks; and added increased emphasis on ways to calibrate degrees of excellence of student projects. Teachers in suburban schools developed a refocused challenge; elaborated on the focus on genes and traits and human values; added information about isolation and restriction to the transformation lab; and made the experimental controls more explicit. In some cases, teachers added content to the slides (SMK). In other cases, teachers added opportunities and supports for discussion and formative assessments (PCK). The Essential Supports, as indicators of best practices—especially related to productive discussion, formative assessment, and reflection on practice—enabled teachers to augment their practice according to their unique needs and perceived strengths and weaknesses.

The case studies and online forum study outlined above indicate that features of the eTG can serve as powerful tools for studying how teachers plan, teach, and modify their curriculum. The features also can help elucidate whether giving teachers the opportunity to reflect on their teaching can result in improvements to their enactments of curriculum and to their practice.

The effects of the eTG supports on the teaching of a reform standards-based curriculum are just part of the story. Schools have a mandate to integrate technology (U.S. Department of Education, 2002; U.S. Department of Education, Office of Educational Technology, 2010). Significant efforts have been expended to increase access to technology and to provide technology-based activities for students. What is known about the use of increased technology access in classrooms Davies and West (2014) is that currently students primarily use technology to gather, organize, analyze, and report information, and that this use has not dramatically improved student performance on standardized tests. Davies and West concluded that improving access to technology, improving attitudes towards technology, and providing practice in technology use are not sufficient to improve learning outcomes, but must be accompanied by programs that promote pedagogically sound technology use. The eTG provides teachers with direct experiences of pedagogically sound technology use for their own learning. A subject to examine in the future is whether these experiences help teachers become more skilled in implementing pedagogically sound technology use with their students.

Implications for the Design of Digital Teacher Supports

1. **Mindful modification as the goal.** Curricula, even (or especially) inquiry curricula, are often viewed as "scripts" or sequences that teachers should enact as closely as possible to truly advance student learning. When designers acknowledge that teachers will and do modify and adapt the sequences, there is usually an implied "Yes, but…" as in, "Of course you should modify it to suit your classroom—but only as long as you do justice to the sequence we designed." We found that teachers appreciated the ability to easily modify teaching sequences via familiar technologies (online slides that were akin to PowerPoint). Curriculum producers would do well to approach the design of materials with the expectation of teacher modification, giving teachers both the tools to make the modifications easily, and clear rationales for the teaching sequences as designed.

2. **Student materials at the center.** Traditional textbook teacher guides often reproduce the student book in the center with teacher materials at the margins (termed a "wrap-around" edition). Our studies found that an electronic version of this design, a digital slide deck of student-facing materials that teachers could modify, accompanied by teacher-facing support materials (such as teaching strategies), is a powerful aid for both students and teachers. Teachers told us that having the student-facing slides front and center, and being able to edit and add to them easily, was the most powerful feature of the eTG.

3. **Fostering "flow" in planning.** In planning to teach a lesson, teachers must imaginatively project themselves forward in time and space to the classroom moment in which they will, armed with their teaching materials, encounter students and their (mis)understandings. Since a great deal of teachers' lesson and unit preparation consists of building and revising conceptual and instructional sequences, digital tools that enable teachers to easily construct and then preview their teaching sequences, then return and revise them, can be powerful. In the eTG, this took the form of a slide-deck of student-facing content that teachers could "flip" back and forth through in order to mentally test the sequences and check for conceptual and pedagogical coherence. In this way, they were able to both modify the original materials, and check for fidelity to them. Such pedagogical "envisioning" tools are a fruitful area for further exploration and development.

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