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Why a Digital Teacher Guide?

Jacqueline S. Miller and Katherine F. Paget
Education Development Center, Inc.

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Introduction

Teachers reaching to meet higher national standards often assemble lessons on their own, selecting from the wide variety of resources available on the web. This access to web resources can be an asset, but it can also be problematic. While many engaging resources can be found online, too often one casualty of cobbled-together lessons is the loss of many of the components of an effective science education. Teachers may be sparking students' interest and imparting lesson-level knowledge, while doing little to build cumulative conceptual connections that result in deeper learning.

Two of the most important factors in achieving deeper science learning in the secondary classroom are the quality of the instructional materials and how a teacher uses them (Ball & Cohen, 1996; Miller & Krumhansl, 2009). A great deal of educational research has identified the components of an effective, rigorous science education that can meet the needs of all students (Bransford, Brown, & Cocking, 2000; Gess-Newsome & Taylor, 2008; National Research Council, 2007). These components include coherent content, meaningful student-centered explorations, appropriate assessments, and accessible teacher supports that guide curriculum implementation and enhance teaching practice. This paper describes the development and testing of a cybertool that integrates these components to transform science teaching. The cybertool, an electronic teacher guide (eTG), makes teaching supports easier to access and use. The eTG guides the implementation of instructional materials in a way that reflects the intentions of the curriculum developers, while enabling modification of the materials and providing opportunities to enhance teacher pedagogical content knowledge.

Educational technologies are beginning to impact all aspects of teaching and learning. Students read their texts as e-books on computers, tablets, and even cellphones, and communicate about assignments at a distance electronically. Digital tools help teachers manage their classrooms, communicate with students and parents, enhance learning with videos, simulations, and other multimedia accouterments, and assess student learning. However, despite the vast array of digital resources available, instructional designers are not realizing the full potential of these tools in curriculum, assessment, and teacher professional development materials. In recent years, the availability of online professional development has surged, providing teachers with easy access to high quality professional learning experiences (Fishman, 2016). Much of these online materials are organized as interactive courses with a learning or content management environment presented in a more didactic approach of information transfer and tutorials (Fishman, 2016). Yet few, if any, examples exist of digital materials that help teachers implement specific instructional materials by providing supports for planning, teaching, and reflecting.

In response to this vacuum, our Education Development Center, Inc. (EDC) team, including co-Principal Investigators Jackie Miller and Bill Tally and Katherine Paget, John Parris, and Irene Baker, undertook to create and test the eTG, an interactive version of a print guide for the genetics unit of our F*oundation Science: Biology* high school curriculum. Our purpose in designing the eTG was to provide an exemplar of a cybertool that would both facilitate teachers' implementation of innovative curricula and enhance the educative impact of the curriculum on teacher practice. We provide here

a consideration of the role of technology in the classroom, an examination of the current utility and potential limitations of print teacher guides, a description of the eTG features that are designed to address the limitations of print guides, and a discussion of the results of testing the eTG in classrooms and with teacher reviewers.

Technology in the Classroom

Deeply digital materials, a term first coined by the Concord Consortium (Dorsey, 2009), take full advantage of the possibilities of digital technology. Deeply digital materials for both teacher and student are much more than textbooks rendered as PDFs with some digital features appended. Digital materials can seamlessly embed models, simulations, videos, and information-sharing structures that allow students to collaborate, design and conduct investigations, gather and analyze data, synthesize information, and use evidence-based explanation and argumentation to deepen their understandings of scientific concepts and phenomena while enhancing their scientific practices. Deeply digital materials can provide teachers with the tools to conduct in-depth discussions with students about their observations and experimentation, assess student learning at any point in time, and provide immediate and targeted feedback to students. They can also help teachers reflect on students' attainment of learning goals and dimensions of instructional success, modify and customize instructional materials for a range of students, and move their own practice to a more ambitious teaching model. Coupled with hands-on experimentation and classroom discussions in a blended learning environment, these tools have the potential to transform science education and optimize learning for all students.

In recent years, curriculum design and teacher practice have shifted towards integrating the use of technology as new digital affordances become readily available. According to Bob Tinker, Founder of the Concord Consortium and the Virtual High School (personal communication, October 14, 2013), the current norm for educational technology in schools is to use one or more of several modes: Internet research; PDF textbooks; technology-based experiences, such as videos and simulations generally in the form of apps on tablets and smart phones or gathered off the Web; and text-based curricula that include some technology-based activities. Teachers typically determine the placement and use of these approaches in the curriculum, and they are often peripheral to student learning.

These approaches barely begin to take advantage of the possibilities of the digital affordances that, if deeply embedded in the central life of the classroom, could help teachers enrich students' learning and tailor instruction to fit students' needs. Optimal use of technology-based materials would have the digital features as an integral part of the core curriculum, working synergistically with effective, educationally sound instructional materials. Several recent reports—including those from the President's Council of Advisors on Science and Technology (PCAST, 2010), NSF's cyberlearning report Fostering Learning in the Networked World (Borgman et al., 2008), and NSF's Blue Sky Workshop report (Center for the Study of Mathematics Curriculum, 2009)—have asserted that technology must play a major role in moving classrooms and instructional materials into the 21st century. The PCAST report and the NSF cyberlearning report envision coherent curriculum and technology as central agents of educational change. A common theme and recommendation among these reports is that successful learning occurs when students are guided through carefully planned, sequenced, and

executed content using technology to enhance and deepen the learning experience. To date, most of the move toward deeply digital materials has focused on student materials. Any accompanying teacher materials have been developed primarily as limited tools that facilitate classroom management and student data collection and sharing. Most of the technology-based teacher support has been developed as online courses and professional development activities.

Teacher Guides for Innovative Curricula

Over the past three decades, the NSF has funded the development of a variety of innovative curricula that feature new approaches to teaching and learning based upon current understandings about how students learn science (Gess-Newsome & Taylor, 2008; National Research Council, 2005, 2007). These curricula are designed to promote teacher as well as student learning. Termed "educative" (Schneider & Krajcik, 2002), they help teachers increase their pedagogical content knowledge (PCK) and move their practice to more ambitious teaching, while deepening their subject matter knowledge (SMK). The educative component of these curricula is generally supported by hefty teacher guides. The intent of these guides is both to facilitate implementation of the curriculum and to enhance teaching practice by supporting teachers in incorporating new instructional strategies and approaches into their instruction. Because no two classrooms are alike or have the same needs, these guides can help teachers modify and adapt the materials in ways that meet the needs of their students, while retaining the conceptual structure and pedagogy of the instructional designers. That is, the guides help ensure that the enacted curriculum reflects the intended curriculum (Drake, Land, & Tyminski, 2014; Miller & Krumhansl, 2009).

Despite the best intentions of instructional designers in providing accessible and useful teacher support materials, teachers' use of the guides is often random and occasional (J. Carlson and B. Nagle, personal communication, April 1, 2006). The reasons why teachers only use the guides sporadically are not totally clear. However, some of the reasons may involve the fact that the guides tend to be large, dense, and separate texts from the student books, and they can be awkward, unwieldy, difficult to navigate, and time consuming to use. Most teachers have neither the time nor inclination to read extensive materials, no matter how useful or well written. In addition, although teachers need different levels of support depending on their backgrounds and experiences in teaching, the print support materials are "one size fits all." They present large amounts of text in a linear format, display everything with equal weight and timing, and may fail to link the resources directly to the lessons. Further, teachers have little choice and guidance in appropriately using the guides.

Digitizing the Teacher Guide

Drawing upon different interfaces and modes, a digital format can have more or less text on a page, allowing teachers to choose how much they want to read, when they want to read, and how deeply they want to delve. Presenting supporting information in different media such as videos, charts, animations, and graphics can help reduce the cognitive load that text often presents and can appeal to different learning styles. Digital features for implementing curriculum can help teachers plan, manage, teach, and assess student learning. The educative features can support teachers in reflecting

on their own teaching and enhancing their practice by providing ready access to teaching supports and resources that build their SMK and PCK on an as-needed basis.

The process that we followed in moving our teacher guide from print to screen had three steps:

1. Develop an interactive, web-based eTG that provides instructional resources for planning and teaching an inquiry-based high school genetics unit and for enhancing teacher practice.
2. Test the eTG to examine usability and classroom implementation.
3. Conduct teacher pilot tests in classrooms and online teacher review panels to determine how and to what extent the eTG features prove useful as flexible and dynamic curriculum planning, teaching, and reflecting tools (i.e., identify which features teachers found most valuable and how they would incorporate them into their practice).

Our goals were to make our print teacher guide more accessible and useful for implementing a designed curriculum, model the incorporation of rich media for teaching, develop tools to support lesson planning and mindful modification of a designed curriculum, promote teacher reflection to enhance instruction, and provide multimedia resources to enhance teaching practice.

To guide implementation and support the curriculum's educative aspects, we developed six major features:

1. **An eBook** contains the print Teacher Guide integrated with the print Student Book. We developed this feature in response to the difficulty teachers experience in working with two separate documents, a teacher guide and a student book. Teachers view the eBook as an integrated document, while students only access the student book. The eBook synchronizes with the My Lesson Planner editable slide deck described below; each slide in the slide deck corresponds to the appropriate place in the eBook, enabling teachers to modify the slide with materials from the Teacher Guide and Student Book.

2. **An editable slide deck (My Lesson Planner function)** represents the intended flow of ideas and activities in the curriculum. The slide deck is an instantiation of content coherency. A deck (called the "basic slide deck"), prepared by the author as a model for teaching the Learning Experience (LE) (chapter equivalent), presents the content and pedagogy of the intended curriculum. The deck serves as teachers' lesson planner and has two purposes. In the planning process, the tool helps teachers think about prominence and sequence: what's most important, and in what order to present content to ensure coherence from one idea to the next. In the teaching process, the material on each slide contains information that the developer considered important for students to view as they carry out their investigations, readings, and discussions. This includes questions for students, activity instructions, or other information that teachers want to keep in the students' consciousness as they work. The slides also serve as an instructional prompt for teachers—a visual schematic to interpret, a question to discuss, a reminder of emphasis, a checkpoint to assess, etc. Teacher notes, visible only to teachers, explain each slide's intended purpose and provide teaching supports in categories such as Facilitate, Clarify, Review, and Go Deeper. Teachers can modify the slides in the basic deck to change the wording or image in the student

view or add a new slide containing additional materials from the eBook or Web Resources (see below). Teachers can then export their modified decks to PowerPoint and save them.

3. **Navigation tools** assist teachers in moving through and accessing the LE and the planning, teaching, and reflecting tools. A persistent navigation menu at the top of each LE page facilitates teachers' movement through the curriculum. The menu synchronizes with the eBook and the Deck Maker (see below) as each LE sub-section loads, with related slides appearing in a reading pane. The menu links to the LE's various phases and provides information about the LE's activities. A Preview button on the main navigation opens a Teaching Sequence Preview (TSP) that provides an overview of the LE, giving a brief description of what students will be asked to do in each session. The TSP can be scrolled to see the entire scope and sequence of the LE without navigating away from the current page.

4. **Vetted Web Resources** help extend student and teacher learning. The eTG includes a comprehensive, clickable map for concepts in each LE. Teachers can click on each concept in the map to obtain related resources such as images, videos, and simulations. Teachers can import additional images to their modified deck before they export the deck to PowerPoint.

5. **Four Essential Supports** provide multimedia resources to foster teachers' professional learning. This feature helps teachers engage students in productive classroom discussions, use formative assessment to gauge students' learning and tailor instruction, gain a deeper understanding of the curriculum's content structure, and make mindful modifications of the instructional materials. Brief descriptions of resources related to each of these topics follow:

- ***Productive Classroom Discussions:*** Teachers can access text describing productive talk in the classroom; a chart of productive talk moves; a video modeling how to use brainstorming to determine prior knowledge of students, introduce new content, and establish a safe classroom culture for sharing ideas; and a sequence of six videos showing the progression of a productive discussion related to genetically modified foods.

- ***Formative Assessment:*** Teachers can access a short text and three exemplars demonstrating the use of formative assessment to determine student achievement of learning objectives as they proceed through the learning experience.

- ***Content Structure:*** Teachers can access a short text and an animation discussing the importance of content sequencing and coherence in student learning.

- ***Mindful Modifications:*** Teachers can access a short text and an animation that describes why they might want to modify the instructional materials and provides examples of mindful modification including changing a story, simplifying, augmenting, or substituting an activity, modifying a reading, and adjusting the pathway of the Unit. As teachers navigate through the eTG, they find links to these resources in the eBook at the point-of-use when they will be preparing to teach or reflect on a lesson. All resources are available in the Essential Supports section of the eTG, where teachers can draw upon them as needed, over time.

6. **Taking Stock**, an interactive Reflection Tool, enables teachers to consider the effectiveness of various components of their teaching, and to revise and tailor their teaching to meet students' needs. Three "Taking Stock" instruments, one for each LE, support teachers in reflecting on their classroom implementation by providing self-evaluation opportunities. The instruments engage teachers in assessing students' progress towards meeting the lesson understanding goals, as well as analyzing dimensions of their instructional success. After teaching a lesson or a set of lessons, teachers can use Taking Stock to consider what went well, what did not go well, whether students made progress toward meeting learning objectives, and what adjustments they will make for teaching the next class or for the next year. This feature is part of the teacher's planning tools, helping the teacher modify and customize the taught curriculum, but also serves as a pedagogical support, helping the teacher to change his or her practice through reflection that can lead to more effective teaching strategies.

Table 1 on page 9 provides an overview of the eTG digital features, components of each feature, the function of each feature, and the kind of support the feature provides. Note: This table is excerpted from our 2016 chapter, "Taking Print to Digital: An Electronic Teacher Guide" in C. Dede, A. Eisenkraft, K. Frumin, & A. Hartley (Eds.), *Teacher learning in the digital age: Online professional development in STEM education* (pp. 127–144). Cambridge, MA: Harvard University Press.

Teacher Use of Features

To determine how teachers would use the different features of the eTG, we carried out two types of studies: pilot studies with five high school science teachers in urban and suburban Boston and in New York City over two weeks; and an asynchronous, online forum with 12 teachers in New Jersey and Pennsylvania over three weeks.

Pilot Studies

We conducted pilot studies with five separate classrooms in which teachers taught one LE using the eTG and print student materials. In the pilot studies, we addressed the following two questions by analyzing classroom observations, the decks the teachers created, and data from a pre- and post-teaching interview.

1. In what ways and to what extent do features of the eTG prove useful as dynamic curriculum planning and teaching tools?

2. 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?

Table 1. Features of the Electronic Teacher Guide (eTG)

Feature	Components	Function	Supports
Main Menu	• Unit Map • Table of Contents • Index of Essential Supports • Taking Stock Index	Provides access to LEs, Essential Supports, and Taking Stock reflection tools.	Implementation
Navigation Bar	• Learning Experience (LE) preview • Sections of LE	Allows navigation through stages of LE. The bar synchronizes with the eBook and My Lesson Planner. As stages of LEs load, related slides appear in the slide deck.	Implementation
Teaching Sequence Preview	• Graphic timeline of LE	Provides an overview and brief description of each LE.	Implementation
eBook	• Teacher Guide • Student Book	Provides an integrated version of the student book and teacher guide; materials from the eBook can be exported to the slide deck.	
My Lesson Planner (Deck Maker)	• Slide viewer that is synchronized with the eBook content and navigation • Slide presentation for each LE with student-facing materials and teacher notes • Slide editor that allows teachers to modify and create presentations • Preview and export to PowerPoint	Provides a Basic Slide Deck that can be modified and augmented from the eBook and Web Resources.	Implementation
Web Resources	• Clickable concept map of each learning experience • Vetted web resources	Allows access to reliable websites related to concepts in each LE. Sorts and sifts vetted resources.	Implementation
Essential Supports: Discussion	• Brainstorming video • 6 "Holding a Productive Discussion" videos • Productive talk chart • Productive talk primer • Short text on productive talk	Provides explanations, guidance, and modeling for using discussion in the classroom.	Practice
Essential Supports: Formative Assessment	• Short text with exemplars for each LE	Provides rationale for using formative assessment and examples.	Practice
Essential Supports: Curriculum Structure	• Short text on content sequencing • Animation on content coherence • Short text on modifying the curriculum	Provides a rationale and discussion for content sequencing and modifying curriculum.	Practice
Taking Stock Tool	• Interactive reflection protocol for LEs • Reflections saved to the user's account	Supports reflection on classroom implementation and progress toward instructional success.	Implementation and Practice

The results of the pilot studies indicated that:

- Teachers made effective use of certain features of the eTG in the planning, teaching, and reflecting modes. In particular, teachers found the basic slide deck, the Web resources, and the Essential Supports of greatest value and interest.
- Teachers customized the same materials in very different ways to meet their own instructional needs and the needs of their students.
- The eTG shows promise as a professional learning environment that can help teachers enhance their practice over time. For example, one pilot teacher incorporated a new strategy to help students think about what they learn, and she is considering how she can engage students in more productive classroom discussions. Another pilot teacher started to think about and pursue strategies to deepen his students' understanding of molecular genetics using different resources.

Asynchronous, Online Forum

In a second study, 12 teachers from New Jersey participated in an asynchronous, online teacher review forum. In this study, we examined the following two questions:

1. To what extent and in what ways are features and affordances of the eTG useful for teachers in planning to teach an inquiry-oriented science curriculum?
2. Are there differences between urban and suburban teachers in the eTG features they use and the kinds of modifications they make in the instructional materials?

Over a four-week period, teachers explored the various features of the eTG tool and responded to questions we posted in the forum. We then asked teachers to modify the basic deck for one LE as they would in preparation for teaching it. Data were collected by analyzing the responses to questions in the teacher posts, through post-forum 45 minute telephone interviews with all participating teachers, and by analyzing the modified slide decks. The following summary of findings resulted from our triangulation of these three data sources.

Essential Supports. Teachers found the resources for productive discussion, formative assessment, and reflection useful and valuable professional learning tools, and there was evidence that they had incorporated these tools into their planning.

- 7 of the 12 teachers said that the productive discussion materials, which included six videos and the supporting texts, were very effective in describing and modeling how to support discussions in the classroom and in elaborating on the importance of discussion in science learning.
- All 12 teachers highly valued the formative assessment materials. Every teacher considered them extremely useful in monitoring student understanding of the content and appreciated examples of different ways to assess student work along the way.

- Nine of the 12 teachers reported that the Reflection tool would be excellent for planning changes to subsequent implementations and/or a way to share evaluations with administrators. They also felt that the tool was extremely useful for keeping track of instructional successes and challenges to inform teaching.

My Lesson Planner. Teachers found that the basic deck that provides a vision of the pathway through the curriculum—and the ease with which they could modify it with the Deck Maker—was a compelling feature of the eTG tool. They reported the following additional benefits of the tool:

- The preview function and the navigation bar are powerful ways to keep track of and organize the learning sequence and the pathway to reach the LE's end goals.
- Having access to the teacher notes digitally enabled teachers to nimbly and easily modify the teaching sequence, which they felt was a great benefit.
- Teachers viewed the flexibility of the eTG tool as an important strength. All teachers noted that they appreciated the ease with which they could customize teaching decks for classes at different levels.

Differences between Suburban and Urban Teachers. Suburban and urban teachers modified the teaching slide decks differently.

- The six urban teachers in the forum substituted virtual simulations of the lab for the wet lab, added extensive vocabulary, and deemed the lesson appropriateness more for honors or higher-level students.
- The six suburban teachers in the forum all developed enrichment by refocusing the challenge to emphasize personal decision making, and making the use and importance of experimental controls more explicit. Suburban teachers did not emphasize vocabulary enrichment or plan to substitute a virtual lab for the wet lab.
- Although these differences in modifications between urban and suburban teachers were striking, there were no differences between these two groups in the features accessed.

Web Resources. Teachers appreciated the vetted online resources with which they could augment their instructional sequences. When asked, seven teachers agreed it would be a real benefit to share resources with other teachers, but several realized this would require someone to maintain and update the resources. Teachers reported that although they are quite savvy with searching for resources themselves, they liked having vetted resources available for them to use.

Conclusions

To provide an effective education in science to all students, teachers need to have multiple opportunities to enhance and diversify their instructional strategies through both structured professional development experiences and educative curricula. We designed the eTG prototype to bring together these factors in a single Web-based tool by providing a rich, research-based curriculum, tools for planning, modifying, and teaching the curriculum, and just-in-time professional learning resources. By bringing these factors together, the eTG prototype seeks to respond to problems that plague science teaching such as the challenge of implementing research-based curriculum and practice.

In its report on cyberlearning, a task force commissioned by the NSF called for proof-of-concept studies that strengthen proven methods of learning and have the potential to transform and improve learning by creating new learning environments (Borgman et al., 2008). An area of research that the report suggests is the identification of tools to facilitate the adaptation of materials to different learning and educational settings (Borgman et al., 2008). The report further states that effective bridging of cyberlearning to the classroom must begin with teachers who are comfortable with the use of cybertools and committed to implementing them.

We designed the eTG as a proof-of-concept digital tool that could support implementation of a core curriculum and provide accessible, user-friendly, and effective resources for teacher learning. Our work on the eTG provided the opportunity to investigate how such a tool is developed, which features teachers found most useful, and whether such a tool could support implementation of curriculum with fidelity to the intentions of the developers as well as provide resources for teacher learning.

From the studies to date, it is clear that teachers find certain eTG features extremely useful in planning and teaching their lessons; reflecting on their practice; modifying and customizing the basic curriculum; and accessing resources to augment instructional materials and to support short term, just-in-time, and long-term learning to enhance their teaching. It is unlikely that the eTG in its present incarnation can be applied directly to other curricula. However, an important next step would be to identify another platform that could incorporate the most effective and useful features of the eTG and that could be used for other instructional materials.

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EDC
43 Foundry Avenue
Waltham, MA 02453

edc.org | ltd.edc.org

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