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Curriculum Customization Service – Program Evaluation

Report No. 4: Teacher Integration of Digital Resources into Instructional Practice

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Executive Summary

This report focuses on how and why DPS Earth science educators integrated digital resources into their instructional practice, with an emphasis on the role the Curriculum Customization Service played in the integration process. *Integration of digital resources* occurs when a teacher adopts a new technology, such as the CCS tool, and his or her instructional practices - planning, teaching, and professional development - are changed in a meaningful and lasting way.

The data we gathered during the 2009-2010 DPS field trial indicate that teachers integrated digital resources more frequently and more efficiently into their instructional practices. The CCS was designed to most directly impact planning and professional development. We discovered, however, that classroom teaching also was impacted when many educators incorporated the CCS directly into their day-to-day in-class routine by projecting instructional artifacts such as lab activities and animations onto a screen during class and by making supplementary instructional materials directly available to students via their own teacher websites and wikis.

We found that DPS Earth science teachers, as a group, already had very positive attitudes towards educational technology in general. Further, most teachers reported that they considered digital resources to be a vital part of their teaching practices. Nonetheless, the CCS appears to have been useful to this already technology-friendly cohort of teachers – a majority of teachers reported that the CCS helped them integrate digital resources into their teaching practices with more confidence, frequency, and effectiveness than was the case prior to the introduction of the CCS. We learned that teachers integrated digital resources in order to, among other reasons, improve student engagement, address misconceptions about key concepts, offer alternative representations of scientific concepts or phenomena, and differentiate instruction according to student differences such as reading ability and language proficiency.

Although many factors influence student achievement, our examination of test score data indicates that, overall, student performance on Earth science benchmark exams showed higher gains during the 2009-2010 school year – the year the CCS was first made available to all Earth science teachers – than they did during the prior school year.

About M. G. Saldivar

M. G. Saldivar is a visiting scientist at UCAR and a Ph.D. candidate in Cognitive Science and Educational Psychology at the University of Colorado at Boulder, where he is conducting his dissertation research under the supervision of Dr. Tamara R. Sumner. His research interests focus on information technology, cognition, and learning. A native Texan, Saldivar holds a B.A. in History and an M.Ed. in Educational Technology from the University of Texas. He is completing his doctoral work in 2011.

Introduction

Beginning in late July 2009, all Denver Public Schools (“DPS”) middle and high school Earth science teachers (n = 124) received access to the Curriculum Customization Service (“CCS”), a Web-based system that incorporates:

1. Content from DPS’s Earth science curricula (Investigating Earth Systems in Grade 6 and EarthComm in Grade 9);
2. Interactive digital resources from the Digital Library for Earth System Education (“DLESE”);
3. Instructional materials and interactive resources uploaded by teachers; and,
4. Science education standards from the State of Colorado and the American Association for the Advancement of Science (AAAS).

In order to facilitate the use of interactive digital resources in their classrooms, each DPS Earth science teacher was issued a computer projector. Teachers also were provided with CCS-related training and technical support by the CCS evaluation team. Teachers who participated in research activities, such as surveys and interviews, were compensated for their time at the standard DPS rate.

To assess the impact of the CCS on DPS Earth science teachers’ beliefs and practices, a team of researchers from the Boulder-based Digital Learning Sciences organization (a joint institute of the University of Colorado and the University Corporation for Atmospheric Research) conducted an evaluation of the CCS. This evaluation included both quantitative and qualitative data sources.

The Curriculum Customization Service was intended to produce five major outcomes, which are listed below. This report focuses on the **second** major outcome.

1. Teachers would customize their instruction to meet students’ needs and improve student engagement;
2. **Teachers would integrate interactive digital resources, such as videos and animations, into their instruction with greater confidence and frequency;**
3. Customized materials would support curricular coherence along with the use of high-quality interactive resources;
4. Teachers would share customized materials, and other Web 2.0 capabilities such as ratings and tags, with others via CCS; and,
5. Teachers would use the CCS to support their own professional development in both formal and informal settings.

To examine the impact of the CCS tool on teachers’ integration of digital resources, we drew upon the following data sources:

- A series of three surveys administered to all DPS Earth science teachers, at the beginning (n = 77), middle (n = 75), and end of the school year (n = 83)
- Interviews conducted with a cohort of 24 teachers regarding their adoption of the CCS tool
- Classroom observations conducted with a cohort of eight teachers who were identified as frequent CCS users
- CCS usage data logged by the server that housed the CCS

The research questions we address in this report are as follows:

1. How can we define "integration of digital resources?"
2. Did teachers integrate digital resources more frequently and more efficiently into their instructional practices, including planning, teaching, and professional development?
3. How did teachers integrate digital resources into their instruction?
4. How did teachers' beliefs and attitudes about digital resources, and their ability to integrate digital resources into their practices, change during the course of the field trial?
5. What types of resources did teachers seek, use, and value?
6. What is the relationship between digital resource use and student outcomes, such as academic achievement and student engagement?

Research Question 1: How can we define "integration of digital resources?"

In the literature on technology adoption by teachers, researchers tend to make a distinction between 'trying out' or experimenting with new technology and integration of new technology. *Integration* occurs when a user alters his or her practices in a meaningful and lasting way because a new technology has become an important part of the user's routine. This distinction between experimenting with and integrating new technology is vital to understanding not only teachers' use of the CCS but also teacher use of technology in general. A growing body of evidence suggests that (1) the presence or availability of technology does not guarantee that it will be used at all by teachers and (2) when teachers do make use of new technology, the impact on their instructional practices (and, in turn, on their students' academic outcomes) can vary greatly. A teacher that merely experiments with new technology but does not make it central to his or her teaching practices – that is, a teacher who does not integrate the technology - is unlikely to change his or her practices in a significant way.

As we noted, changing teachers' practices is the second of the anticipated outcomes of the CCS project: *Teachers would integrate interactive digital resources, such as videos and animations, into their instruction with greater confidence and frequency*. The CCS project seeks to foster teachers' integration of digital resources because prior research[1] has found that teachers who use digital resources more frequently in their practice tend to develop student-centric (rather than teacher-centric) classrooms.

Among other characteristics, student-centric classrooms encourage students to apply critical thinking to course material, to develop deep understanding rather than shallow rote memorization, and to cultivate an 'inquiry focus' whereby student learning is a process of discovery (akin to the scientific method) rather than a traditional process of 'knowledge transfer' from teacher to student. Research has found that student-centric classrooms tend to produce better academic outcomes than teacher-centric classrooms.[2] Among these outcomes are: longer retention of course material, a deeper understanding of key concepts, increased motivation to

[1] For an extensive review of the literature on technology-enhanced student-centered classrooms, see Hannafin, M. J. & Land, S. M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional Science, 25*, 167–202.
[2] King, A. (1993). From sage on the stage to guide on the side. *College Teaching, 41*(1), 30-35.

learn about the course topic, and strengthened critical thinking skills. In the following sections of this report, we will present evidence from our study suggesting that teachers who integrated the CCS into their teaching practice also reported engaging in a number of student-centric behaviors.

We began this section by asking: *How can we define "integration of digital resources?"* In contrast to mere sampling of or experimentation with new technology – such as a planning tool like the CCS – we view *teacher integration of digital resources* as the act of incorporating interactive digital resources into teaching practice to promote a student-centric classroom experience. An increase in student-centric instruction is characterized by one or more of the following: increased student engagement, deeper and more authentic 'real world' understanding of science phenomena, and increased application of critical thinking skills to course material and classroom activities. As we will describe, the CCS helped many teachers integrate digital resources into their teaching practices, which in turn impacted student outcomes.

Research Question 2: Did teachers integrate digital resources more frequently and more efficiently into their instructional practices, including planning, teaching, and professional development?

Before addressing the issues of 'more frequent' and 'more efficient' integration of digital resources, we describe our conceptualization of teacher instructional practice. For the purposes of our study, we divided teacher practice into three steps or stages: planning, teaching, and professional development. These stages are based both on our reading of the relevant literature as well as on data we collected from pilot CCS users in advance of the 2009-2010 field trial.

Planning is the process by which a teacher develops the lessons he or she will teach. Among the tasks associated with planning are: understanding curricular requirements vis-à-vis a given topic or concept, finding resources that meet those requirements and will help students understand the concept, and devising classroom activities such as lectures and labs that will engage students in the material being taught. An anecdote shared by teacher Vernon (all teacher names are pseudonyms) in an interview gave us a simple example of how teachers used the CCS for planning: *On* [a recent] *weekend, I was going to do some planning for the week, but I didn't have my teacher's edition* [of the course textbook] *with me. I can use it* [the CCS] *to download the book and… use that as a resource without having the book itself.*

Teaching is the act of delivering a planned lesson to students. When the CCS first was developed, we anticipated that it would be used primarily for planning tasks, but during the course of the field trial, we found ample evidence that a number of teachers were using the CCS during class as part of their teaching. In response to an open-ended survey question that asked what made the CCS useful, teacher Olivia provided an explanation of how the CCS was integrated into her teaching: *The* [curriculum-] *related websites, teacher shared and created materials, and the electronic versions of the text book* [are all digital resources] *that I can show in class*.

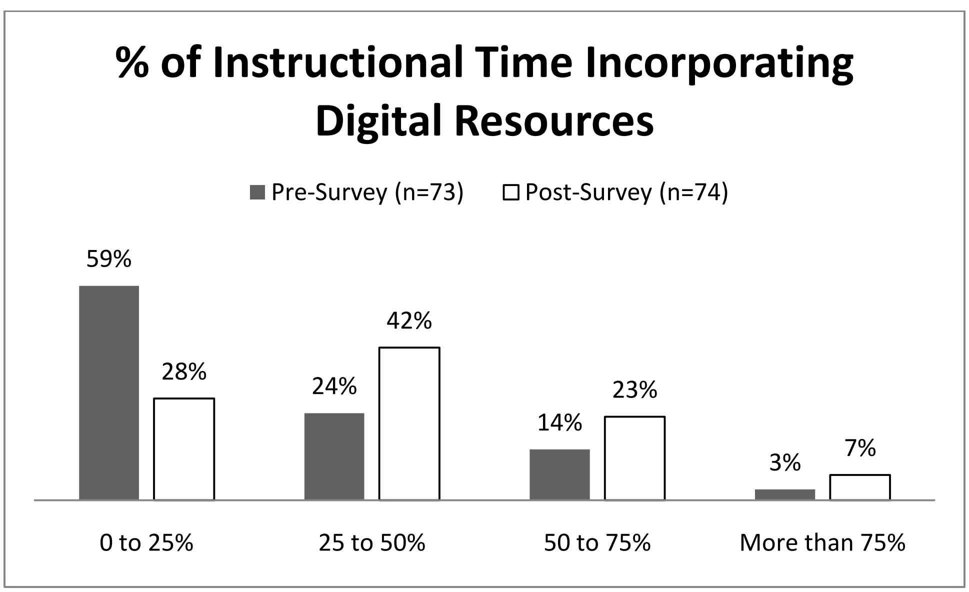
Professional development is an activity that helps strengthen and improve a teacher's own understanding of subject matter he or she teaches, and/or the pedagogical techniques necessary to teach that subject matter. Our data suggest that the CCS provided professional development opportunities to users in two major ways. First, teachers could improve their own understanding.

For example, when presented the survey question “The CCS has supported my own professional learning about Earth science and how to teach it,” approximately 80% of respondents agreed or strongly agreed. Second, teachers could gain insights into their colleagues’ teaching practices by accessing digital resources shared by other teachers. Nearly half of respondents to one survey agreed or strongly agreed that “The CCS has resulted in DPS teachers sharing resources with one another more than ever before.” When asked in an open-ended survey question how to discuss how they were influenced by the digital resources shared by other teachers, Dustin wrote, *I receive new and innovative ways at looking at the subject matter*. In response to the same question, Sonya stated that looking at materials shared by other teachers *Influenced my way of thinking about differentiated instruction.* (Differentiated instruction involves customizing one’s approach to teaching to account for differences between students, such as reading ability or English language proficiency; differentiation can help a classroom become more student-centric.)

Our second research question asks *Did teachers integrate digital resources more frequently and more efficiently into their instructional practices?* First, we consider frequency of digital resource integration.

In both our pre- and post-surveys, teachers were asked: *What percentage of your instructional time with learners incorporated interactive resources?* Figure 1 shows that, when comparing all pre-survey respondents with all post-survey respondents, the percentage of teachers who reported incorporating interactive digital resources 25% of the time or more increased. The percentage of respondents who incorporated digital resources into their teaching less than 25% of the time decreased. Although we cannot directly attribute this increased incorporation of digital resources to the CCS, many teachers did report that the CCS had a positive impact on their use of digital resources. We will expand upon this point shortly.

Figure 1



The data in Figure 1 pertain to digital resources overall. As we argued above, it is possible for teachers to experiment with technology in a way that does not lead to its meaningful integration into teaching practice. Accordingly, teachers also were asked in both our pre- and post-surveys to report the frequency with which they used various types of resources for teaching. Specific resources, such as “handouts,” “animations,” and “audio/visual materials” were offered as choices. We collapsed all these various choices into two categories of resources, which we termed *digitized traditional resources* and *interactive digital resources*.

Digitized traditional resources included downloadable handouts and in-class presentations, such as PowerPoint-based slideshows; these resources were accessed in digital file form but were otherwise not any more interactive than resources a teacher might obtain from existing sources, such as the student textbook. In other words, digitized versions of traditional resources do not necessarily require that a teacher change his or her practices because they can simply supplant resources a teacher already is using.

In contrast, interactive digital resources, such as animations and video clips, exist only in digital form – one cannot, for example, print out an animation of a subduction zone, which is where one tectonic plate moves under an adjacent tectonic plate. For this reason, using a novel interactive digital resource should require more planning and forethought on the part of the teacher because it must be integrated into a lesson, not merely inserted in place of an existing traditional resource. Research suggests that teachers who make a purposeful effort to plan their lessons tend to develop classroom activities that engage students in higher-order thinking rather than simply rote learning. (It is, of course, possible for teachers to use both traditional and interactive resources in the same lesson, as data we present later in this report illustrate.)

Figure 2

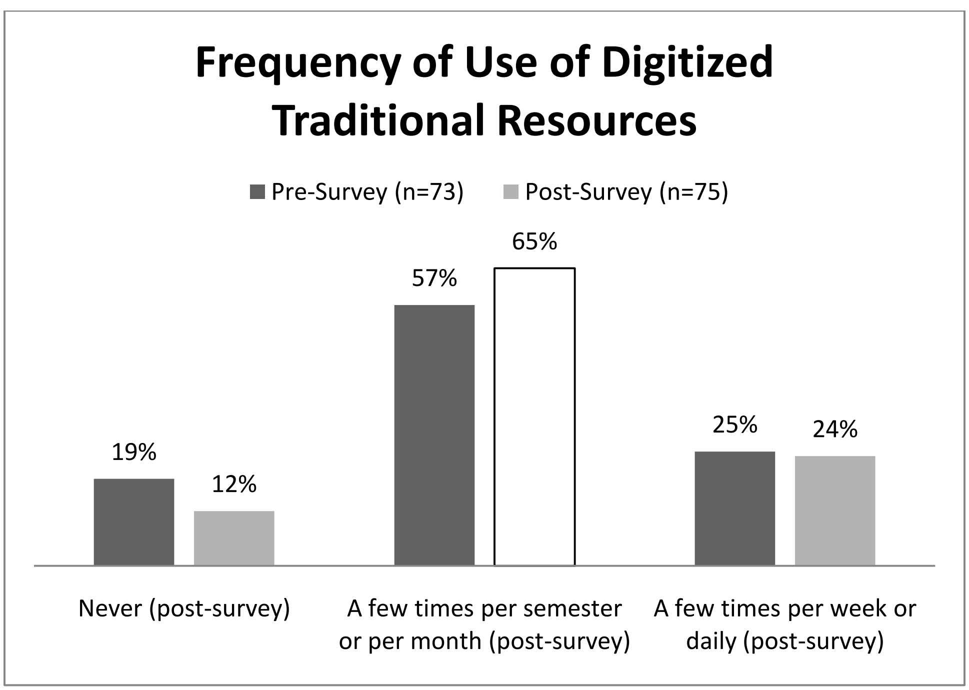


Figure 2 illustrates the changes in use of digitized traditional resources when pre-survey responses are compared to post-survey responses. In the top range – those who reported using traditional resources “a few times per week” or “daily” - usage was almost unchanged, suggesting that those ‘power users’ of traditional materials were already finding traditional materials that met their instructional needs. The number of respondents who never used digitized traditional resources at all, however, decreased over time, while in the mid-range – respondents who reported using, for example, handouts or PowerPoint slideshows “a few times per semester” or “a few times per month” - users of traditional materials increased slightly. This suggests that during the CCS field trial, more teachers were incorporating traditional digitized materials than was the case before the CCS was introduced.

Figure 3

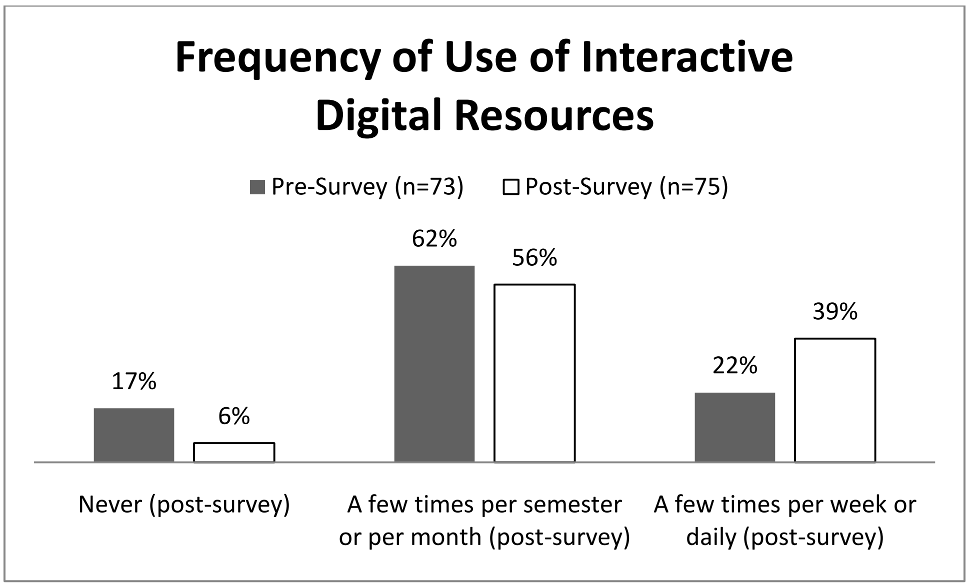


Figure 3 illustrates the changes in use of interactive digital resources when pre-survey responses are compared to post-survey responses. The number of respondents who never used interactive resources at all decreased by more than 10%. In the mid-range (“a few times per semester” and “a few times per month”) usage of interactive resources decreased slightly. However, in the top range (“a few times per week” or “daily”), usage of interactive digital resources increased by about 17%. It appears that, overall, use of interactive digital resources – the kinds of resources that tend to require more planning and forethought on the part of the educator to integrate into instruction – increased during the course of the field trial.

Recall that our second research question asks *Did teachers integrate digital resources more frequently and more efficiently into their instructional practices?* Having addressed frequency of digital resource use, we now consider changes to the efficiency of digital resource integration. In our context, we define *efficiency* as a measure of how frequently teachers integrate digital resources into their teaching practices given the amount of time spent searching for those digital resources. In other words, if a teacher spent *X* hours searching for digital resources, how much instructional time incorporated digital resources? The most efficient approach would be to spend relatively few hours searching for digital resources while a relatively large percentage of instructional time incorporates digital resources.

Based on data gathered during our pilot study in the 2008-2009 school year, as well as from our study of pertinent prior research, we knew that a common complaint from teachers was that they often spent a great deal of time searching for digital resources (suggesting that they understood the value of incorporating such resources into their teaching practices). Despite all the time they devoted to the task of searching for digital resources, however, they often found relatively few useful resources. The CCS was intended to help make this process of searching for digital resources more efficient by not only helping teachers locate resources, but also by ensuring that those resources were applicable to their instructional needs because they were integrated with curricular learning goals. Our findings suggest that, overall, teachers who responded to our surveys did indeed become more efficient.

Precise formulae for calculating efficiency vary somewhat among researchers, but we used a formula that is commonly applied to workplace efficiency: the amount of time spent preparing to perform a task divided by the amount of time spent actually performing the task (see Figure 4). We assigned numerical values to the amount of time teachers reported searching for digital resources on the pre- and post-surveys. Then, we assigned numerical values to the percentage of instruction that respondents reported incorporating digital resources on the pre- and post-surveys.

Figure 4

Efficiency Calculation

$$\frac{\text{Number of hours spent searching for digital resources}}{\text{Percentage of instruction incorporating digital resources}}$$

By dividing the number of hours respondents reported searching for digital resources by the percentage of instruction that incorporated digital resources, we arrived at a pre-survey ratio of 2.1 and a post-survey ratio of 1.7 – a decrease of approximately 24% pre- versus post-survey. This suggests that, overall, DPS Earth science teachers became more efficient at integrating digital resources into their teaching practices after the CCS was introduced. Although we cannot directly attribute this increased efficiency directly to the CCS, the data we gathered suggest that teachers who used the CCS regularly found it to be a valuable tool for planning instruction, as we will further illustrate below.

Research Question 3: How did teachers integrate digital resources into their instruction?

To delve more deeply into the ways in which teachers integrated digital resources into their instructional practices, we raised the issue in interviews. Teachers described two major ways in which they used digital resources in their teaching: (1) to project an instructional artifact or resource onto a screen during class and (2) to make supplementary instructional materials directly available to students.

Sometimes teachers projected curricular content, such as excerpts from the student textbook, onto a screen in their classroom. These materials act as shared artifacts, visible to all students in the same way at the same time, which helped teachers focus students' attention on a given passage or graphic image. Getting all students on the literal same page was not easy to do before the availability of the CCS and the computer projectors provided to all teachers as part of the field trial.

Lilah stated: *Just being able to access the book* [content] *online and posting it up on the board has been a good thing… Kids, instead of looking down, looking up, looking down, they could just read it off of the wall. That has been a good part, and especially, when we're doing notes, it's easy just for me to point to it up on the board versus showing them, well, it's the fifth paragraph, it's the fifth line in your book.*

Lilah's example illustrates a scenario where a digitized traditional resource – textbook content – is used to guide a lecture or discussion that could have been carried out even if the CCS was not available. Other examples exist, however, of teachers using textbook content to engage students in classroom activities in new ways. During an observation of her classroom, Maribel used the CCS to access a Web-based version of the Earth science textbook. As part of the lesson she was teaching on potential and kinetic energy, Maribel projected onto the smartboard in her classroom an in-class activity from the text that called for students to perform various calculations and then note their answers in a table so that students could see the relationship between potential and kinetic energy.

Before the Web-based textbook content was available to her via the CCS, Maribel told us, she would have reproduced the table onto a handout and students would have completed the activity individually at their desks. By projecting the table onto her smartboard, Maribel was able to focus the class' attention in one place and they worked out the calculations and filled out the table as a group, which Maribel felt was more efficient and a better learning experience for her students relative to the prior approach to the activity. Thus, Maribel used a digitized traditional resource – an in-class activity from the student text – in an entirely new way. Moreover, as Maribel reported, that new approach positively impacted her students.

Textbook content was not the only source of in-class artifacts, however. Many teachers reported that they accessed digital resources to supplement textbook material. Overwhelmingly, the most popular kinds of digital resources teachers found via the CCS were graphic representations (e.g., pictures, diagrams, animations) of Earth science phenomena. In the following example, note the teacher, Carlie's, observations regarding students' engagement with and understanding of key concepts.

Carlie stated: *I think that since students are visual learners, they're hands-on learners, they're growing up in this technological age… Seeing the animations… Really drives home the idea or the topic… I ask them if it does help them* [to see graphic representations]… *If whatever they just viewed made the material make more sense, and often times, they* [say] *"Wow… That totally made sense… Can we see it again?" I think they benefit from it a lot, and they're vocal about it. They love it.*

Liz's experience was similar to Carlie's in that her students seemed excited simply by the presence of digital resources, which led to increased engagement and deeper comprehension. Liz told us in an interview, *I think, in general, my students are really interested in seeing any kind of* [digital resource]. [Digital resources are] *really engaging for students, because it's different than what they normally see in the classroom... When they walk in, they're just super-excited when they see the projector's set up.* [They say] *"Oh, yes, we get to watch a video," or "We get to see a PowerPoint." They come in automatically excited to learn… When I showed them the clip that was about Pangaea, it gave some background information on plate tectonics, and then it actually demonstrated to them how the continents drifted apart, and that helped them with their activity, because their job was to try and glue the continents back together as a puzzle.*

The CCS was developed for direct use by teachers, but some teachers have found that their students benefited not only from interacting with a given digital resource in class, but also from having access to the same digital resources after class for review and study purposes. Teachers such as Frank already had made a course Web site available to students. In addition to posting homework and other such materials to his Web site, Frank began to post digital resources he found via the CCS.

Frank stated: *I am essentially trying to make my own CCS for my students. CCS is for teachers, but I would like to see one that the students can use in an inquiry-driven classroom.*

Octavio, who also publishes a course Web site for his students, reported: *If I come across links* [to digital resources] *while I'm doing planning that I think that would help students study or recall information that we've covered in class, I'll take the link from the CCS and I put it onto my own Web page, so that the students can actually access it.*

As we have illustrated, teachers reported using digital resources in two major ways. As in-class instructional artifacts projected to the entire class, digital resources both imparted key concepts and guided students during class activities. As supplementary instructional materials made directly available via class websites, digital resources allowed teachers to direct students to alternatives to textbook content. Moreover, the fact that many teachers were incorporating digital resources into their instructional practices implies that digital resources were perceived as useful. We take up the issue of teachers' beliefs and attitudes towards digital resources in the following section.

Research Question 4: How did teachers' beliefs and attitudes about digital resources, and their ability to integrate digital resources into their practices, change during the course of the field trial?

We surveyed DPS Earth science teachers about their views on digital resources both at the beginning and at the end of the field trial. As Figure 5 shows, approximately 80% of respondents to our pre-survey agreed or strongly agreed with the statement “Using interactive resources effectively is important to my personal success as a teacher.” Remarkably, the exact same percentage of post-survey respondents agreed or strongly agreed with that statement. Figure 6 illustrates that 82% of pre-survey respondents agreed or strongly agreed with the statement “Using interactive resources in the classroom enables me to better meet the learning needs of students in my classroom.” An even greater percentage – 90% - of post-survey respondents agreed or strongly agreed with that statement.

Figure 5

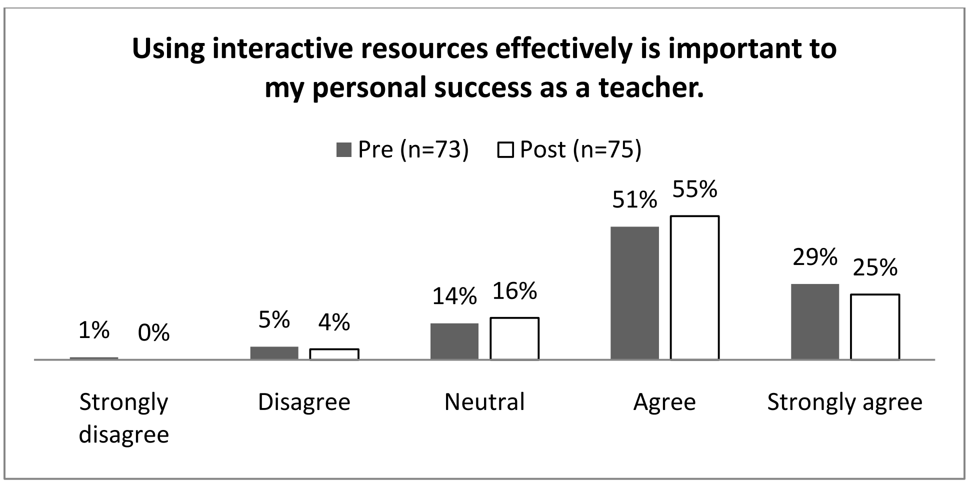
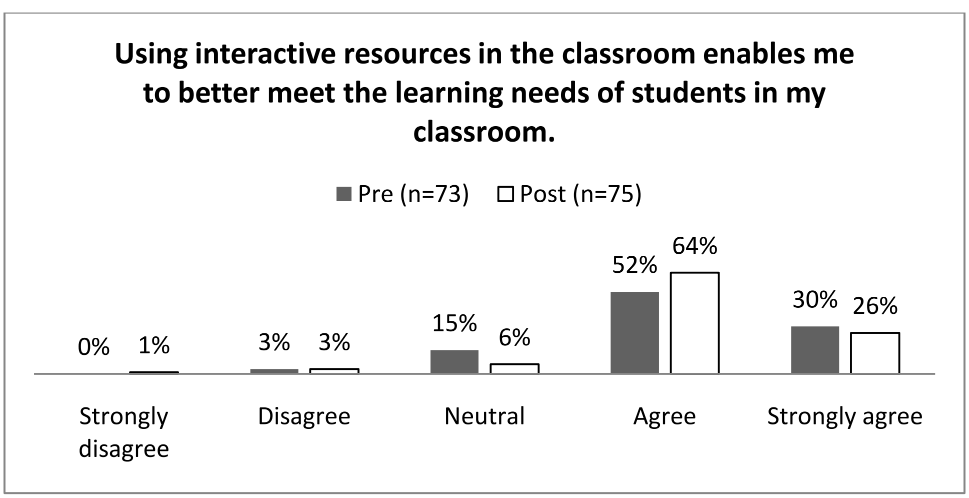


Figure 6

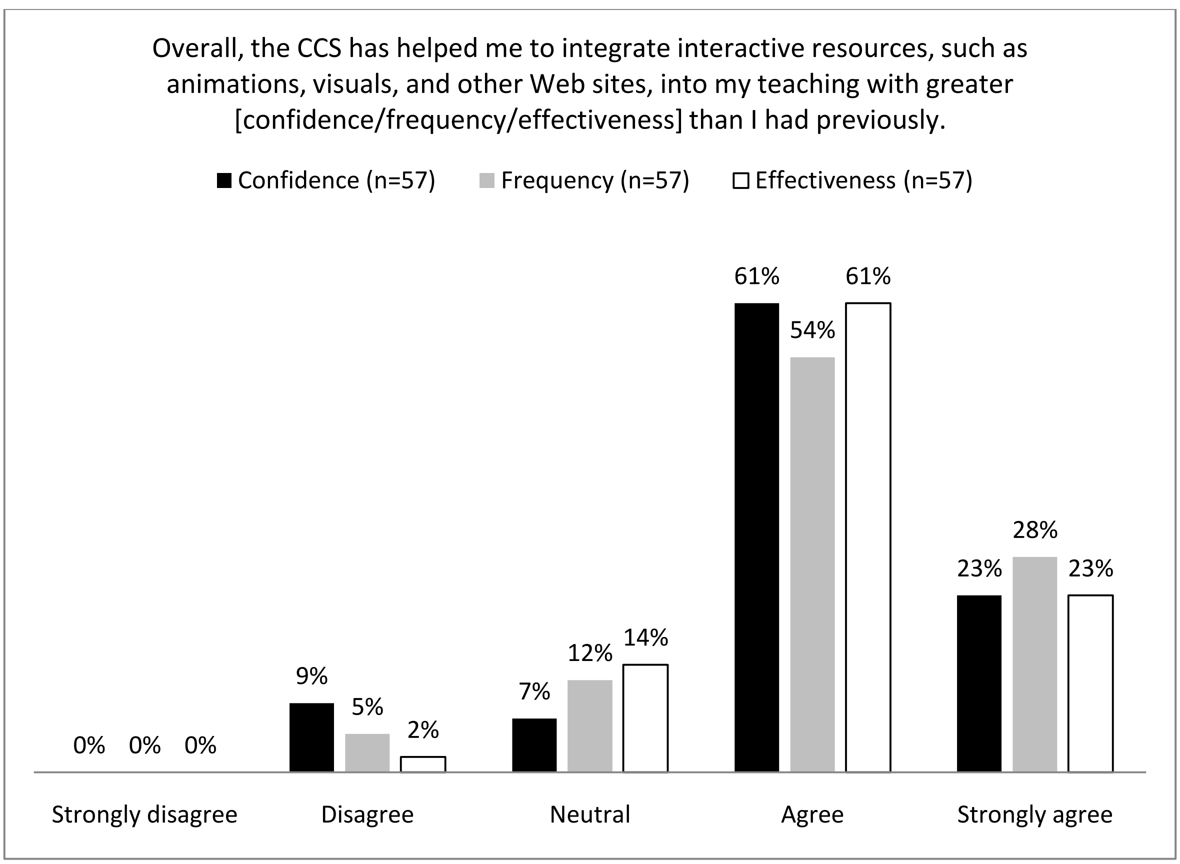


These data indicate that before the CCS even was made available DPS Earth science teachers valued digital resources' place in their instructional practices and saw digital resources as contributing to student learning outcomes. The post-survey responses show that those positive perceptions did not waver during the course of the field trial.

Given the positive perception of digital resources that already existed among DPS Earth science teachers before the CCS was made available to them, we specifically asked teachers in our post-survey about the role the CCS played in their teaching vis-à-vis digital resources during the course of the field trial. Because the cohort of Earth science teachers already was so positively inclined towards digital resources, it could have been the case that these strongly pro-digital resource educators would not see the CCS as a value-add to their practices. This was not what we found.

When presented with the statement "Overall, the CCS has helped me to integrate interactive resources, such as animations, visuals, and other Web sites, into my teaching with greater CONFIDENCE than I had previously," 84% of respondents agreed or strongly agreed (see Figure 7). Nearly the same number of respondents agreed or strongly agreed with the statements "Overall, the CCS has helped me to integrate interactive resources, such as animations, visuals, and other Web sites, into my teaching with greater FREQUENCY than I had previously" and "Overall, the CCS has helped me to integrate interactive resources, such as animations, visuals, and other Web sites, into my teaching with greater EFFECTIVENESS than I had previously."

Figure 7



The CCS was introduced to a cohort of teachers who already viewed digital resources in a positive light. Nonetheless, as the data in the preceding three figures show, this same cohort of teachers reported that the CCS still helped them integrate digital resources into their practices with greater confidence, frequency, and effectiveness. In interviews, teachers offered us illustrative examples.

Confidence

Vernon stated: [The CCS] *gives me direction as to where to look for a resource… I know that the CCS is a site where, instead of vainly searching the Internet and not finding* [anything pertinent]*, I'd be more likely* [to find] *something* [pertinent]*. So I'm more likely to have more interactive-type resources in more classes. I'd probably be more likely to use interactive resources in a lesson because I know a place where it'd be easier to find them.*

Henrietta told us: *When* [another Earth science] *teacher from across town might have found a great website or a video clip or something that really does bring the point home and makes it more relevant to the students, that's what I'm looking for, and so far, I have found some things like that on* [the CCS]*.* Later in the same interview, Henrietta added that she and the other Earth science teachers at her school – all CCS users – often discussed useful resources that they had found using the CCS: *We certainly confer on* [resources we discover]… [We tell each other] *"This was great,"* [and] *"This is something you need to* [use] *when you get to this* [certain] *point in your book."*

The boost in confidence for Dustin came from the CCS' computer-based interface. Dustin told us: [Using the CCS] *you can go through and look at all the chapters of a unit, and it gives you information on each one,* [such as] *big ideas, a guiding question, materials necessary, and stuff. You can find that in the teacher's manual, too, but I find that I use the computer more than the teacher's manual…* [The CCS] *is very simple, very easy to use. I mean it's right there...* [At the moment] *I'm in astronomy... I'm going to be doing the chapter on the sun. I'll go click on investigation five, and I'll have all that information right there for me. I'll read it all.*

Vernon, Henrietta and Dustin were all experienced Earth science teachers and each had taught using the DPS curriculum in prior years. Teacher Rafaela, although certified to teach science, first taught the DPS Earth science curriculum during the year of our field trial. Her needs differed somewhat from Vernon and Henrietta, yet the CCS still gave Rafaela increased confidence. Rafaela stated: *It's been really hard for* me [during the current school year]. *I've been teaching mostly math* [in prior years] *and this year I have to* [teach] *science, and it's been a real struggle for me. I have to really break* [the course material] *down… The CCS would help me present the* [course] *information* [to students].

Frequency

Vernon's explanation for why he began to use digital resources more frequently was straightforward but illustrative of the reasoning described by many of his colleagues. Vernon told us: *I really try to bring in a lot of good visuals because I know interactive* [resources such as] *engaging visuals* [are] *a powerful learning tool for so many students.*

Dustin gave us a detailed description of how and why he has integrated digital resources into his teaching practices: [I have incorporated] *technology* [such as digital resources] *as much as possible into the* [lesson] *plans because it's so readily accessible... When you have a 90-minute block of time with these kids, you've got to do at least four transitions. You maybe* [start with] *a little quiz, then videos, and* [then] *some discussion,* [then] *some reading,* [and] *a PowerPoint* [slideshow]. *You've got to break it up and keep them interested, because they're sixth graders, and they're very easily distracted… Their attention spans are short. So,* [the CCS] *is just a better way to give you more activities to keep the kids interested and keep them on task.*

Liz made a comment that echoed remarks we had heard from other teachers – she used the CCS at least in part because the computer projector she received as part of the CCS project gave her, for the first time at DPS, the ability to project digital content in class. Liz stated: *I didn't used to try and incorporate visuals* [into class], *and part of it is the fact that we got projectors with this* [CCS project]. *We have* [had projectors] *at our school, but our technology person hasn't been very helpful in allowing us to use them or find ways to connect them to our computer... The projector that you guys provided* [is] i*n my classroom at all times. And then, on top of* [the availability of the projector], *the* [CCS] *provides me with resources that I can actually project. So I use them* [digital resources] *a lot. I never used to use online stuff like that.* Liz's comment is an important reminder that although the Web-based CCS tool is the most public 'face' of the Curriculum Customization Service, in reality, the tool is part of an ecology that includes hardware (such as computer projectors) as well as software (the tool) and high-quality digital content.

<u>Effectiveness</u>

When discussing the increased effectiveness that they felt in integrating digital resources, teachers frequently cited the opportunity to access content developed and shared by other Earth science educators. In response to a question about why she used the CCS, Olivia stated: *The first reason would be to see the shared resources,* [the] *things that people* [have] *uploaded*. Olivia told us that she assumed shared materials represented successful instruction: *I figure if they took the time to put it* [a shared resource] *on there* [uploaded to CCS], *it must've been something that really works for them*.

Other teachers valued materials shared by their colleagues because they had previously used such resources in their own teaching and received positive feedback from students. Henrietta provided one example: *Those things that the other teachers have posted, like some of the websites to go* [visit], *and the short video clips* [are resources I liked]. *There was one* [interactive resource] *on rocks that the kids really, really got into, and* [they] *actually asked to see it again.*

Octavio found that his effectiveness increased because he could leverage digital resources shared by his colleagues to teach key concepts in an impactful but efficient way when compared to instructional approaches that did not incorporate digital resources. Octavio shared this anecdote: *We were about to start the lesson that has students analyzing the scale of the solar system, and, before having CCS, there was a really, really nice lab* [activity] *that I've had the students do every year* [which required them to make] *scale models* [of the solar system]. *Walking down through the hallway* [where models are set up], *they get a sense of the scale, but it doesn't really strike home. I don't think it hits home how really far away things are* [from one another].

Octavio continued, *So one of the things that I found on the CCS was a resource that somebody had saved. It was a little QuickTime movie…* [The viewer] *traveled through space and it was timed at so many times the speed of light. I projected that and used it kind of as a class starter, and the students were really, really engaged with guessing when the next planet was going to come. There was enough time in between the further planets to* [ask students in class] *"Oh, when's the next one?"* [and] *"How far away, really, is that?" To me, having that impact on the students with a visual, with something that I'm able to project up on the board – I feel like it really drove home what I wanted to get out of that lab* [I used in prior years] *in about five or ten minutes that it took to play that little video clip.*

In summary, we found that DPS Earth science teachers, as a group, already had very positive attitudes towards educational technology; most teachers reported that they considered digital resources to be a vital part of their teaching practices. Nonetheless, the CCS appears to have been useful to this already technology-friendly cohort of teachers because a majority of teachers reported that the CCS helped them integrate digital resources into their teaching practices with more confidence, frequency, and effectiveness than was the case prior to the introduction of the CCS.

Research Question 5: What types of resources did teachers seek, use, and value?

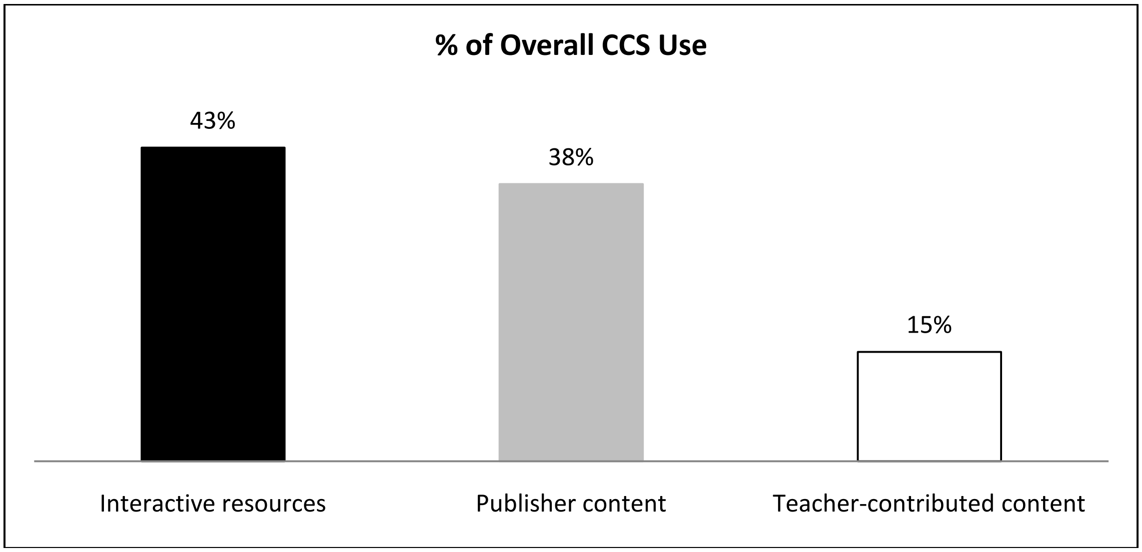
Recall that the three major components of the CCS are:

1. The publisher content from DPS's Earth science curricula (Investigating Earth Systems in Grade 6 and EarthComm in Grade 9)
2. Digital resources from the Digital Library for Earth System Education ("DLESE"), which includes both digitized traditional resources such as lesson plans and interactive digital resources such as animations and video clips
3. Digital resources uploaded to the system by CCS users themselves to Shared Stuff, which include both digitized traditional resources and interactive digital resources

Based on an analysis of Web server logs that recorded various aspects of CCS users' behaviors within the system, we found that, overall, CCS users spent approximately 43% of their time accessing the interactive resources (see Figure 8). About 38% of their time was spent in the publisher content component, and the remaining 15% of CCS use was in the teacher-contributed content component. These usage data appear to reflect the utility teachers found in incorporating non-publisher resources into their teaching practices, as we have described above.

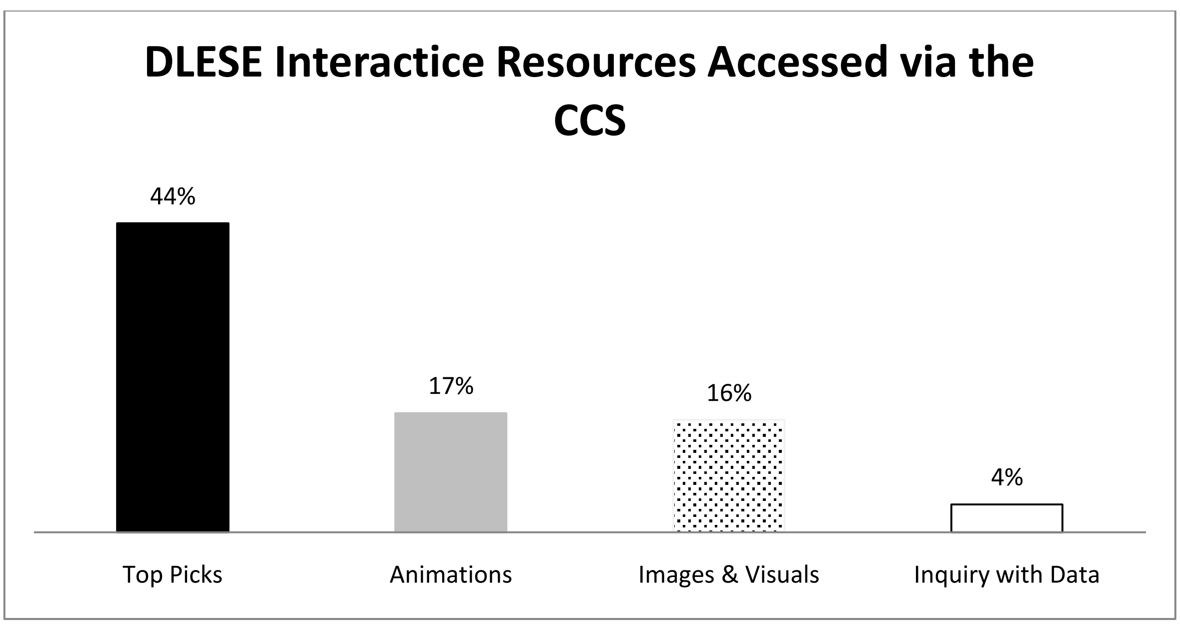
The publisher content is a digital analog to curricular materials already available to DPS Earth science teachers before the introduction of the CCS. Teacher-contributed materials were uploaded during the course of the field trial by users. (Some content was loaded into Shared Stuff by the district's professional development trainer as well as by pilot users during the 2008-2009 school year.) The materials in the interactive resources component, however, all came from DLESE.

Figure 8



We analyzed the types of DLESE resources accessed by CCS users via the interactive resource component of the system and collapsed them down to four categories. Figure 9 shows that about 44% of the digital resources accessed were in the ‘Top Picks’ category. These resources were selected manually by subject matter experts on the CCS development team as well as by Earth science teachers on our teacher advisory board because the resources were exemplars – top picks – of high-quality digital resources pertaining to a given key concept. Given the value that teachers placed on resources uploaded by their fellow educators, it follows that the interactive resources category purposefully selected by a human expert – Top Picks – would be the most popular.

Figure 9



The digital resources in the remaining three categories were selected automatically by the system using computer algorithms that matched the DLESE resources to the key concepts in a given curricular unit. Thus, when a teacher accessed interactive resources within the key concept of 'volcanoes,' the CCS would retrieve from DLESE a listing of volcano-related resources. Again, these data are unsurprising - we have seen that teachers value digital resources that present graphic representations of key concepts, and together the Animations and Images & Visuals categories account for about one-third of all the interactive resources CCS users accessed. The Inquiry with Data category represents resources that call for students to analyze existing data sets; this category saw very little activity. Although a number of science education researchers and policymakers have called for more inquiry with data at the K-12 level, it appears that DPS teachers are not incorporating this activity into their instructional practices.

Having discussed what resources CCS users accessed, we now turn to the question of why they accessed them. What purposes did these resources serve pedagogically? We raised this issue in surveys and found that more than half of survey respondents reported that they searched at least a few times per month, if not more frequently, for digital resources that accomplish the following instructional objectives:

- Improve student engagement and capture student interest
- Introduce new ideas/concepts and address misconceptions about key concepts
- Offer alternative representations of scientific concepts or phenomena
- Address differences in abilities (e.g., ESL, gifted and talented, quantitative skills)

The teachers' own descriptions of their digital resource use, recounted to us in interviews, illustrate these four objectives.

<u>Improve student engagement</u>

Like many of her colleagues, Liz found that the mere presence of digital resources caught her students' attention: *In general, my students are really interested in seeing any kind of thing online. I've shown them the* [CCS in class] *and I've shown them the video clips or PowerPoints that I get off of the* [CCS]... *I showed them, "Oh, look at this, what I have online. I have all our chapters* [online]…*" It's just engaging for them to see it in a different format than in print.*

Octavio had a similar perspective; in his case, he explicitly cites his campus' pedagogical philosophy: *One of the big pushes here at* [my campus] *is we're trying to put on stuff for the '21st century learners' and trying to incorporate that into our instruction. One of those things happens to be video clips* [from the CCS], *and it's so nice to have the animations and the video clips* [available] *right there. I could save them right to my lesson plans. I don't have to go to the library or go to Blockbuster or whatever and try and find something that might fit the lesson.*

As we have noted above, many teachers reported projecting resources onto a screen or smartboard in their classrooms so that students could refer to a central instructional artifact. Olivia described her approach: *I really appreciate that the* [textbook] *is digital and online. If it's referring to a diagram in their book, I'll cut it and paste it into my flipchart for my Promethean* *board so then I can refer to it on the board. If there are directions in the book and… You want to refer to* [them], *you can point to it on the whiteboard and say, "Okay, look at* [this], *find this*…"

Introduce new ideas/concepts and address misconceptions

The following anecdote was recounted to us by Trudy: [A certain Earth science exam question stated that] *mountains are located on the west coast of the South American plate, so they* [the students] *would have to know west from east* and [have] *an understanding of geography… At first glance you don't really think that the student has to know that* [geographic knowledge] *but they do* [to answer the test question]. *They have to be able to decode that first sentence to understand, just to begin this part* [of the exam], *where that location is that they're being asked about.*

Trudy's anecdote refers not to digital resources but to an underlying pedagogical challenge that motivates many teachers to seek out digital resources – a lack of prior knowledge (sometimes coupled with misconceptions about scientific phenomena) that must be addressed before a teacher can begin to address a key concept from the curriculum. When the curriculum – in Trudy's example, an exam that is part of the curriculum – does not adequately address a concept or topic, teachers often turn to digital resources to bridge their students' knowledge gaps, and to help them think about phenomena in new and different ways.

Olivia described her approach: *In my initial planning, or if I come across a misconception or a snag in learning, then I'll go there* [to the CCS] *and say* [to myself], *"Well, did anybody address this* [concept/topic]*? Is there something better?" There were some websites that I found helpful that illustrated certain things, like velocity in a stream and how the bigger particles fall out first… It just illustrated that in this little video clip. So, when we're talking about that in class and wrapping up a lesson on erosion, I would say, "Oh, well, this is what happens. See how the bigger ones* [particles] *fall out first?" And so then you expect, later on, the smaller particles are falling out, and so… It illustrated that so well, and I would never have found the time to look that up and find it. It's nice that* [resource] *was already found, bookmarked there* [in the CCS] *and attached to the lesson. I like that.*

Carlie has also found that accessing one digital resource can actually lead her to other resources that help her students' understanding of key concepts: *We were working on the theory of continental drift, and I actually used a CCS link for a video on Alfred Wagner, and then that link led me to two other really good videos, short two-minute clips that I show the kids to kind of solidify their understanding of pieces of evidence that scientists use to piece together Pangaea.*

Offer alternative representations

A number of teachers commented that the sometimes abstract nature of key Earth science concepts could be daunting to students without a 'hands on' element to engage them and make the course material personally relevant. Digital resources were often able to help.

Norma told us: [Students] *needed to be able to play with it* [a key concept], *mess with it, move things around… I have a Promethean board, which really helps the interactivity part of* [a lesson], *and they were able to actually experience it in smaller group settings. It* [Promethean board] *was a richer resource… Our second-language learners need that extra hands-on part that a traditional paper and book does not provide, and the resources that other teachers are posting on* [the CCS] *really helped. We are just finishing up our dynamic planet unit, and we're going to be getting into our solar system part of the curriculum, and those concepts are so, no pun intended, out in space… They* [solar system key concepts] *are really detached* [from students' daily life], *but the interactivity and especially the resources provided by other teachers* [via the CCS] *really helped bring it* [key concepts] *home and make it come alive for kids. They need to be able to play with that kind of stuff, and I think* [the CCS] *really will provide what we need*.

A growing body of research argues that classroom assessment can serve an instructional, as well as an evaluative, function. Norma offered an interesting example of how the CCS has become part of her assessment practices. Note how Norma appears to have incorporated her students' need for alternative representations of key concepts into the assessments administered to them: *Depending on the group of kids, I try to gear* [assessments] *toward the particular group of kids. Let's say, for one group, I have a really small group of about six, so I might use a different assessment with them as compared to my A group, which would be more rigorous, and so being able to use the* [CCS] *system makes it a lot easier. They* [students] *might even just take it online, like looking at the Promethean board instead of paper and pencil… It might a more oral piece* [assessment], *or more activity-based, project-based piece.*

<u>Address differences in abilities</u>

As is the case with many large urban school districts, the student body in DPS is very diverse. During the CCS field trial year, 70% of the Earth science students qualified for free and reduced lunch, 19% were designated English-language learners, and 14% were designated as having special education needs. Differences in academic ability among students are one consequence of this diversity that teachers must face as a salient part of their jobs.

Trudy told us about a time when a test question called for students to refer to a diagram of a subduction zone and, in their own words, write a narrative description of what the diagram showed: [Answering the test question] *it's really a vocabulary thing, because the arrows* [on the diagram showing plate movement] *are pointing towards each other, so they* [students] *would need to know the vocabulary that would describe when the plates move towards each other… That might present some challenges for language learners or kids who have trouble with language acquisition… And, you know, regardless of language ability, if it's hard for them to acquire new vocabulary,* [it] *would be hard for them to describe it* [a key concept] *with a scientific word*.

Henrietta told us about what she did to help students with reading comprehension challenges: *I like the ability to project the* [student text] *book* [in class] *for the* [students to read]. *I have one class that I do need to go and explain what certain words mean in their text, and that ability just to highlight it* [the digital version of the text projected in class] *and go to Dictionary.com* [to show students definitions of words], *I think that's where it* [the CCS] *has been priceless*.

Statistics provided to us by DPS indicate that, across the entire district, less than one-third of DPS students are native English speakers. Thus, second-language learners are a particularly large part of the student population that Earth science educators teach. Digital resources accessed via the CCS have helped many teachers meet the needs of these students.

Shanna stated: *I do look* [to the CCS] *as a guidance and tool*… [I ask myself] *okay, what is there to help explain the concepts? Because I know sometimes, with the second-language students here at this school, the concepts are really difficult to understand from the book. It's been helpful to have those additional visuals for the kids.*

Like Shanna, Norma found that the CCS helped her access digital resources that were an important supplement to curricular materials. Norma told us: *I tried to use it* [the CCS] *with almost every lesson that I could… We have so many second-language learners, that they needed the visuals… The resources provided in the* [CCS] *system really helps, because a lot of times when you look at the teacher's guide, the traditional paper teacher guide, the assessments that they provide and the visuals didn't exactly do the trick and give the second-language learners what they needed. But the visuals and the interactivity of the resources provided on your site do.*

In summary, we found that, when aggregated together, interactive resources from DLESE and resources uploaded by CCS users were the most frequently accessed components of the CCS. Teachers integrated digital resources in order to, among other reasons, improve student engagement, address misconceptions about key concepts, offer alternative representations of scientific concepts or phenomena, and differentiate instruction according to student differences such as reading ability and language proficiency.

Research Question 6: What is the relationship between digital resource use and student outcomes, such as academic achievement and student engagement?

As we have described, the cohort of DPS Earth science teachers overall reported very positive attitudes towards computer technology and digital resources. When asked specifically about the value that such technology provided vis-à-vis student learning, the teachers were similarly positive. In response to the statement "Using computer technology in the classroom enables me to better meet the learning needs of students in my classroom," 85% of pre-survey respondents agreed or strongly agreed (see Figure 10). 81% of post-survey respondents agreed or strongly agreed with that statement. Thus, DPS teachers tended to value the role of computer technology in their students' learning, and that view persisted throughout the period of the field trial.

Our findings were similar when teachers were presented with the statement, "Using interactive resources in the classroom enables me to better meet the learning needs of students in my classroom" (see Figure 11). 82% of pre-survey respondents agreed or strongly agreed, while 81% of post-survey respondents agreed or strongly agreed. Again, DPS teaches reported valuing the part digital resources had to play in their students' learning at both the beginning and the end of the field trial.

Figure 10

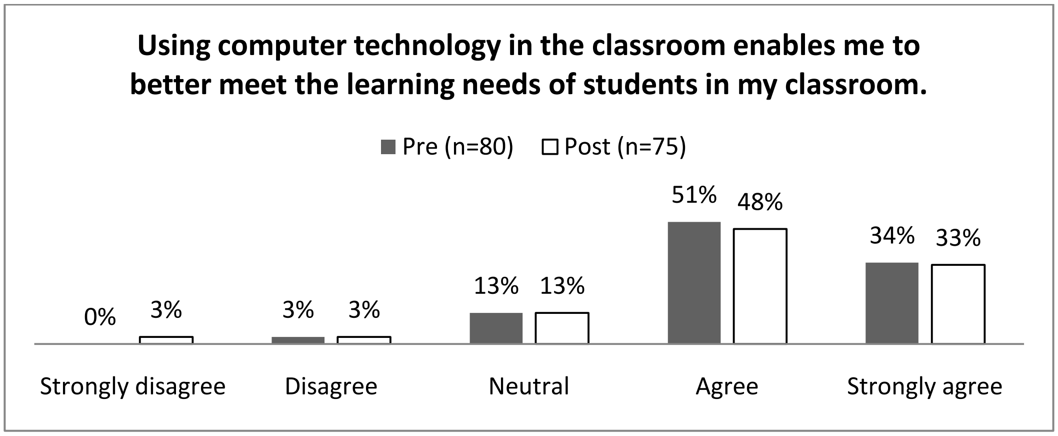
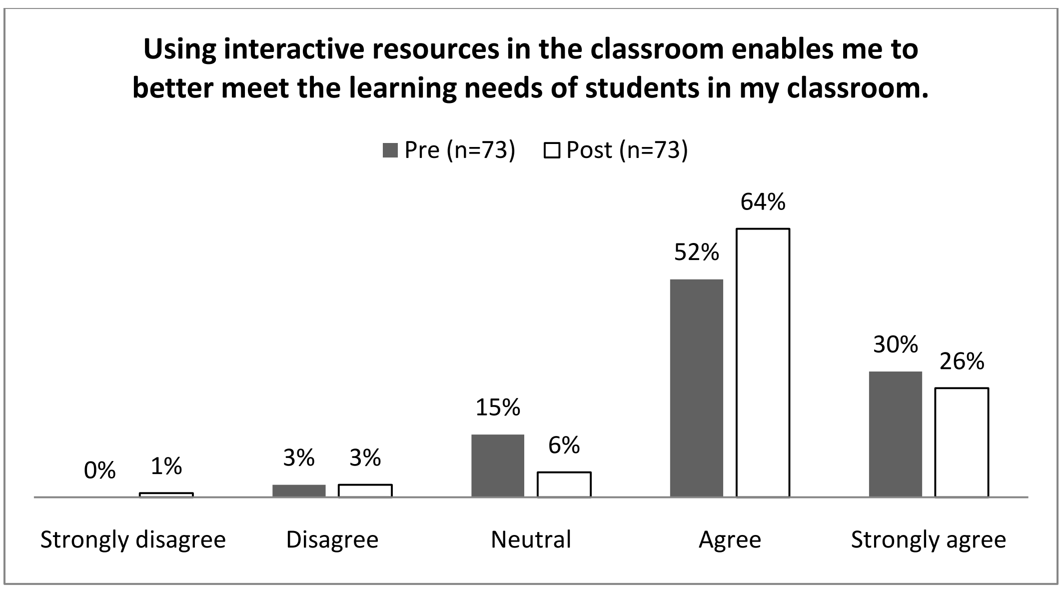


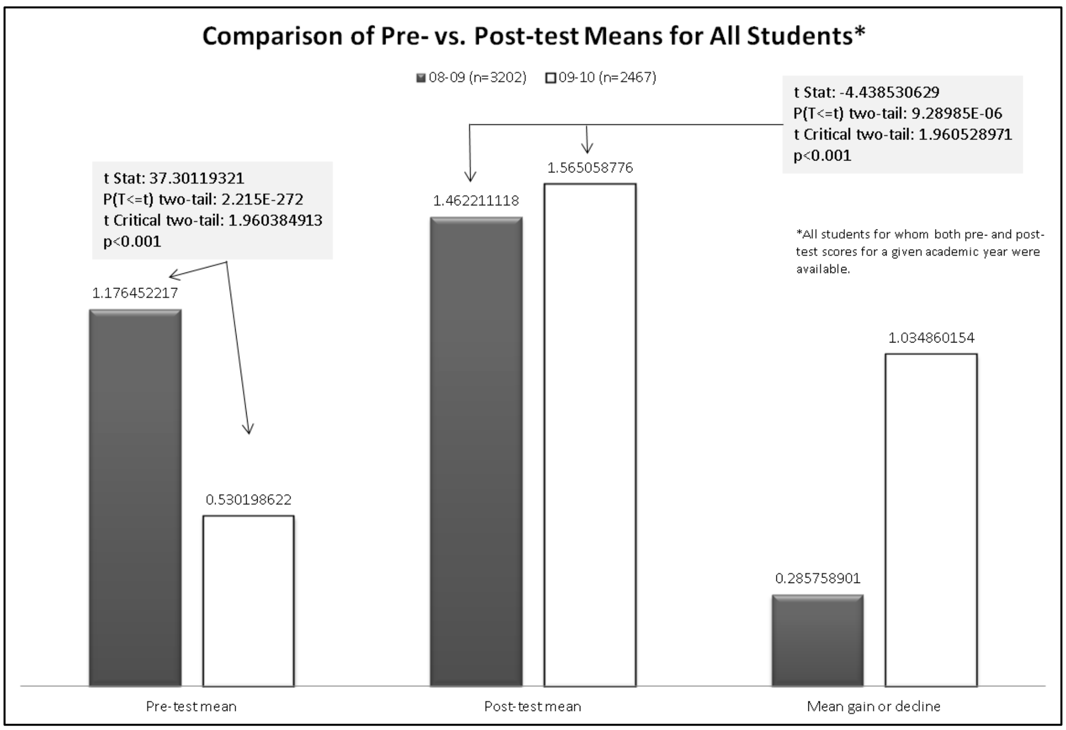
Figure 11



If teachers already saw computer technology and digital resources as central to their students' learning, it could have been the case that the CCS would not have a great impact on student learning because teachers already were incorporating digital resources into their instructional practices. Because the CCS evaluation project did not use an experimental design, we cannot make strong causal claims about the role the CCS had on the academic outcomes of Earth science students. There are, however, positive student outcomes that occurred during the field trial. We will present first a quantitative overview of student achievement on DPS benchmark exams and then several qualitative anecdotes vis-à-vis student outcomes that were recounted to us by Earth science teachers. Subsequent reports will delve more deeply into the issue of student outcomes.

DPS uses benchmark exams to gauge student progress during the course of a school year. These standardized multiple-choice exams are based on the official DPS Earth science curriculum and are administered to students at the beginning of the school year (as a pre-test) and at the end of the school year (as a post-test). Although DPS requires that students enroll in Earth science in Grade 6 and Grade 9, only Grade 9 students are administered the benchmark exam. Thus, the quantitative test score data we discuss below only pertain to high school Earth science students. Finally, note that during the 2008-2009 school year, the benchmark exams were required of all Earth science classes. During the 2009-2010 school year – the year of the CCS field trial at DPS – schools were allowed to opt out of the benchmark exams. Four out of thirteen schools did so, thus reducing the field trial year sample size available for analysis relative to the pre-field trial year sample. Although overall enrollments were comparable for both school years, 3,202 students took both the pre- and post-tests in 2008-2009 while 2,467 students took both pre- and post-tests in 2009-2010.[3] According to DPS, the exam items and scoring rubrics also were nearly identical across both years.

Figure 12



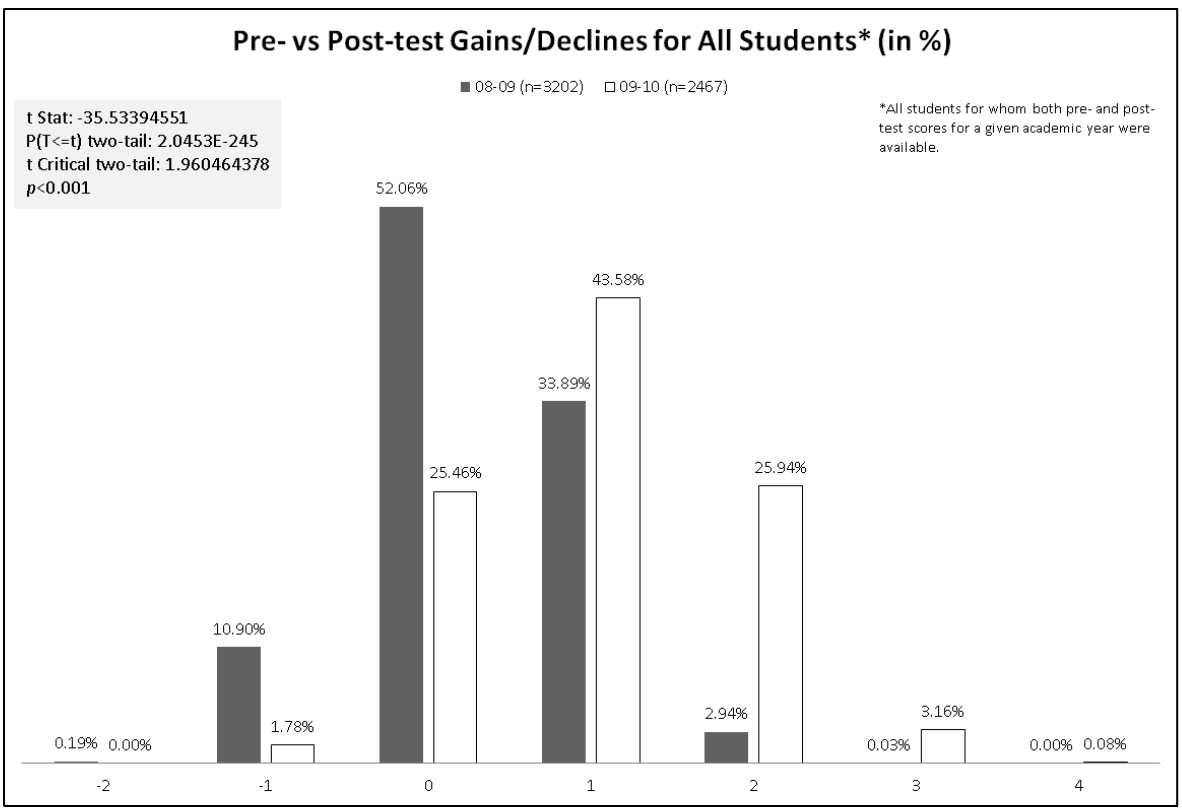
Benchmark exams were scored on a letter grade scale from ‘A’ (highest grade) to ‘F’ (lowest grade). For our analyses, we converted these letter grades to numerical values where A = 4, B = 3, C = 2, D = 1 and F = 0. When we compared the means for all pre- and post-test scores for both

[3] During both the 08-09 and 09-10 school years, some students were administered only the pre- or only the post-test benchmark exams. These students were not included in any of our analyses since their exam performance could not be compared pre vs. post.

school years, we found that 08-09 students performed better on the pre-test than did 09-10 students (see Figure 12). However, 09-10 students showed greater improvement pre vs. post compared to 08-09 students; the average 08-09 student improved about one-third of a grade pre vs. post while the average 09-10 student improved by about one full grade. All differences in means were statistically significant; that is, calculations indicated with 95% certainty that differences in means between 08-09 and 09-10 were not due to chance.

To further explore differences in exam gains across the two years, we broke down the gains or declines for all students according to the number of grade levels students advanced or retreated pre vs. post to help us visualize the data in another way. Figure 13 shows that about two-tenths of one percent of 08-09 students declined two grade levels pre vs. post; that is, these students earned, for example, a ‘B’ on the pre-exam and an ‘F’ on the post-exam, while no 09-10 student declined by two grades. (Because the sample sizes are different from year to year, we report these gains/declines as a percentage of the total sample for each year to make comparisons between years easier.) In contrast, during 08-09, nearly 11% of students declined by one grade pre vs. post (e.g., from a ‘B’ to a ‘D’) while only about 2% of 09-10 students had a similar decline.

Figure 13



Overall, Figure 13 illustrates that the vast majority of 08-09 students – nearly 86% -- either did not improve pre vs. post or improved by one grade level. Given the 08-09 cohort's stronger performance on the pre-test, it is possible that this group of test-takers had a higher level of existing Earth science knowledge. Nonetheless, it is striking that among the 09-10 cohort (which performed more poorly on the pre-test), only one-fourth of test-takers failed to advance or decline at all pre vs. post, while about 44% improved by one grade level and almost 26% improved by two grade levels. The differences in gains/declines were statistically significant.

As we stated at the beginning of this section, we cannot make any causal claims about the impact of the CCS on student achievement; further, it is important to recall that Figures 12 through 13 show a comparison between two *different* groups of students (the 2008-2009 Earth science students and the 2009-2010 students). Nonetheless, we believe that the CCS played at least some part in the achievement of DPS Earth science students on the benchmark exams during the field trial. This assertion is based on the many statements teachers made to us regarding the impact on the CCS on their own students' classroom experiences.

Vernon, for example, told us about how digital resources accessed through the CCS impacted student understanding: *I think that just bringing the sort of resources* [available via the CCS into my classroom] *positively affects the learning experience of many of the students… Those students who are visual learners can benefit… When you* [a student] *are able to see things in such a way, engage in the prompt thought and discussion and questions, when I am using those visuals and interactives, I've noticed that the number of questions and the quality of questions often improves, and I feel like there is a connection there.* (Many teachers use the sophistication of students' questions as a way to gauge their level of understanding.)

Norma felt that digital resources spur student achievement by keeping them engaged. She stated: *It* [the CCS] *makes* [Earth science] *come alive. It piques their interest so that they'll start to ask more questions. They might not know how to ask questions, but it'll spur them on* [and] *give them the buy-in so that they're not so detached from the curriculum and the vocabulary, and they'll look forward to it* [Earth science class] *because of the interactivity… It's just cool to them.*

Trudy argued for a connection between student engagement and achievement: *I think* [incorporating digital resources make it] *more active for them* [and] *it also allows them to access the material in a way that doesn't depend solely on my instruction… I think before* [digital resources were incorporated], *they needed the book or they needed me to explain things, and I think now they can use these interactive resources and these tools to explain things kind of on their own and it just gives them another way of accessing content... I think it* [the use of digital resources] *does make it a bit more participatory for* [students]... *If they did read something and it* [science concept] *didn't make sense, they can see it* [represented in a digital resource], *and then it starts to make more sense to them.*

Conclusion

Liz remarked: *I think that I'm going to start using it* [the CCS] *more and more as time goes on. I just wish that they had it for all the grades, because it is really helpful, and I find myself a lot of times wasting time searching things on the Internet that end up* [being] *irrelevant, and it takes forever…*

A majority of DPS Earth science teachers reported that, like Liz, they found the Curriculum Customization Service to be a useful support for their instructional planning practices. By the conclusion of the field trial, these teachers integrated digital resources more frequently and more efficiently into their instructional practices. Despite the very positive attitudes DPS teachers had towards educational technology and digital resources, the CCS appears to have added value to the practices of this already technology-friendly cohort of teachers. We found that teachers integrated digital resources in order to, among other reasons, improve student engagement, address misconceptions about key concepts, offer alternative representations of scientific concepts or phenomena, and differentiate instruction according to student differences such as reading ability and language proficiency. Our non-experimental research design precluded us make strong causal claims about the impact of the CCS on student achievement but our examination of test score data indicates that, overall, student grade gains on Earth science benchmark exams showed more improvement during the 2009-2010 school year – the year the CCS was first made available to all Earth science teachers – than they did during the prior school year.

We are confident that, to quote Liz, "as time goes on" the CCS will continue to benefit Earth science teachers and students in Denver Public Schools, and in the other districts where it is used.