Data Tools: Weaving Data Analysis into the Science Curriculum

Spring 2010 Sustainability Evaluation Report

Executive Summary

DataTools, a four-year NSF ITEST project led by TERC, a nonprofit education research and development organization based in Cambridge, Massachusetts was a professional development program for middle school science, math, and technology teachers that was implemented in three different Massachusetts communities from 2006-2009. Teachers learned how to use and integrate spreadsheet data analysis, image analysis, and GIS technologies into science education lessons. The program, completed after the 2008-09 school year, met its original goal to work directly with at least 75 middle school teachers and 150 middle school students.

This report concludes a sustainability use study of the DataTools program, the purpose of which was to ascertain the extent to which former program participants continued to use DataTools technologies and methods in the years following their funded participation year, providing an informed sense of sustained program impact upon teaching.

This evaluation report includes findings based on data and analyses from an online survey, sample site visits and interviews with former DataTools participants. 28 teachers from each of the three cohorts completed the online survey. Individual interviews were conducted with a sample of 26 teachers which included 8 in-person site visits and 18 telephone interviews.

Overall, while classroom use continues to a lesser extent than during the program, more than 90% of the respondents continue to demonstrate some extent of DataTools use. Excel was used the most, GIS the least. Barriers included technology and support challenges, time constraints, teacher isolation, leadership issues, and school demands. While the barriers were evident in nearly every school, teachers were able to not only continue using DataTools resources, but continue developing ways in which to use them. This is testimony to the program design, and more importantly, the relevance of the professional development to teachers, and in turn, the successes they have had implementing these technologies in their classrooms.

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DataTools: Weaving Data Analysis into the Science Curriculum

Sustainability Study

1.1 Background

DataTools, a four-year NSF ITEST project led by TERC, a nonprofit education research and development organization based in Cambridge, Massachusetts was a professional development program for middle school science, math, and technology teachers that was implemented in three different Massachusetts communities from 2006-2009. The project provided professional development on using freely accessible Web-based scientific data and data analysis software to support standards-based science curriculum in the classroom.

Focusing on spreadsheet data analysis, image analysis, and GIS technologies, teachers learned to locate and download data from sites such as the USGS, NOAA, NASA, and the National Science Digital Library, and develop appropriate instructional plans and strategies to analyze these data as part of standard grade level units. The program, completed after the 2008-09 school year, met its original goal to work directly with at least 75 middle school teachers and 150 middle school students.

At the end of the final fully supported (third) year, it became evident that many teachers would continue using the tools and methods attained as part of their regular instruction beyond involvement with TERC or outside support agencies. This report concludes a sustainability use study of the DataTools program that began late fall, 2009 and concluded late spring, 2010. The purpose of this "extension" study was solely to ascertain the extent to which former program participants continued to use DataTools technologies and methods in the years following their participation, providing an informed sense of sustained program impact upon teaching.

This evaluation report includes findings based on data and analyses from three main data collection sources:

- Online survey of DataTools technologies use and skill acquisition (to compare with same instrument administered during program participation)
- Sample site visits and in-person interviews with participants from each cohort, each interview administering a "talking survey" instrument
- Telephone interviews with sample teachers from each cohort

1.2 population

28 teachers responded to the online survey, administered during December, 2009. Of these, 21% were from the first year's group, Cohort 1, 25% were from Cohort 2, and 54% represented Cohort 3, the most recent, having officially finished the program the previous summer (accounting for the largest response rate). These 28 teachers account for 41% of all participants over the three years. Individual interviews were conducted with a sample of 26 teachers; 8 in-person site visits, 18 telephone interviews.

1.3 Evaluation Design

The December, 2009 survey was designed as a ~post instrument to compare growth over a variety of dimensions with similar items presented in surveys participants completed at the start of their active DataTools year. Additional follow-up questions added to the survey collected ~post program usage data. A specific protocol was used for all interviews with an additional "talk survey" instrument administered during site visits. Instruments are included in the appendix.

1.4 Research Questions Addressed:

The purpose of this evaluation report is to describe findings related to longer-term impact and outcomes as a result of the DataTools program to determine the viability of the model for future innovations that might support or improve STEM-based instruction in schools.

While the main investigative strand of the evaluation is program impact and sustainability, we also report on Student Outcomes, Teacher Outcomes, Program Design, and Barriers. Some of the following research questions helped frame the evaluation:

- To what extent have DataTools activities and strategies continued beyond the project's funded period?
- To what extent have students acquired the technology skills and use of those skills in learning science?
- To what extent have teachers acquired the technology skills and use of those skills in teaching science?
- Do teachers perceive the DataTools program to have been relevant to their teaching situation?
- How effective was the program design, specifically each component: choice of tools, workshops, online course, EET materials)
- What barriers to continued implementation have teachers experienced?

2. Findings

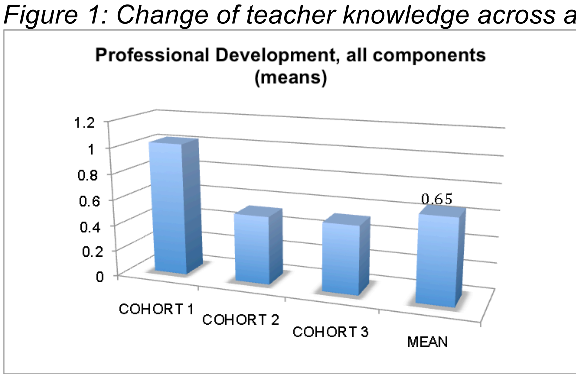
2.1 Online Survey Data

Professional development was at the core of DataTools and included two primary methods: two-week summer institute, and eight online conferences during the year forming a course based on Earth Exploration Toolkit materials. The online survey asked self-rating questions about a range of technical skills and abilities, and was administered at different points during the program for each cohort. For this analysis, ratings from the first administration of each cohort were compared with those from the December, 2009 administration. In each of the charts, rating points are either a four-point scale and correspond to varying scale criteria appropriate to use, frequency, or awareness (none, a little, some, a lot). Occasionally there is a five-point scale with a "no change" option at the mid-point. In all charts, Cohort 1 refers to the 2006-07 group; Cohort 2, 2007-08, Cohort 3, 2008-09.

Overall usage gains

Overall, means from all items across all cohorts show a .65 point gain from the beginning of the program through December, 2009. From the time they participated in DataTools to the present, their average skills and usage increased significantly:

Figure 1: Change of teacher knowledge across allcomponents, all cohorts (means)



This is significant in that over a half-point improvement (e.g. one whole point might be the gain in confidence in using a type of software from "a little confident" to "some confidence") shows from the intervention as long as three years back. More significant is that the first cohort (longest time since the intervention) gained slightly more than 1 point, suggesting both that they may have come to the program with less skills than other cohorts, and that continued skill use seems to strenghten retention.

We can further support these generalizations with some teacher comments about using data and data analysis in the classroom in ways DataTools helped them grow:

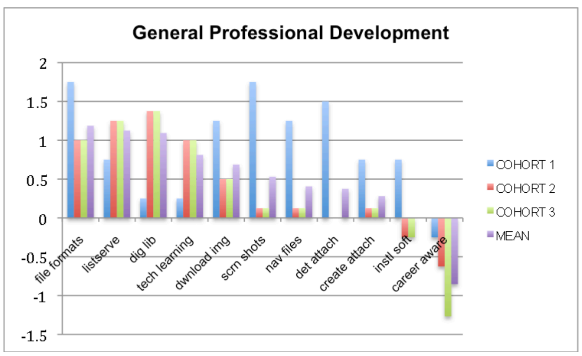
"The program showed me how data is the cornerstone of science - without data I might as well be teaching fiction. This has helped [the students] have a more authentic, relevant learning experience... to engage students in doing the work that scientists do."

"Data analysis through your [DataTools program] software helps us get away from the idea that there is only one correct answer and that it always comes out as a nice round integer."

"What I learned I use as a "hook" to build students' interest by showing how math is used to address important questions."

When we separate the different skills and knowledge components of the survey responses, we get a more detailed picture. First, let's look at the fundamental technical skills and knowledge areas that we matched ~pre/~post, which included understanding file formats, listserve experience, use of digital libraries, technology learning, ability to download images, take screen shots, navigate folders and files, use attachments, install software, and STEM career awareness and opportunities. These are the changes in *non-DataTools* computer skills as a result of participation in the program, or technology skills ancillary to the core DataTools skills.

Figure 2: Change of teacher's basic computing skills and knowledge



These discreet skills, here sorted by means across all cohorts show the greatest gains were in understanding how to use/save/open files in different formats, followed by listserve and digital library use. The lowest gains (and in some cases, decreases) were in email attachment use and installing software, with the lowest in STEM career awareness. Perhaps the low changes in basic skills such as these suggest teachers were already comfortable with them in the beginning, hence little change, however the significant decrease in STEM career awareness might mean that while this component was introduced during DataTools meetings and activities, it played a lesser role than that of technology learning.

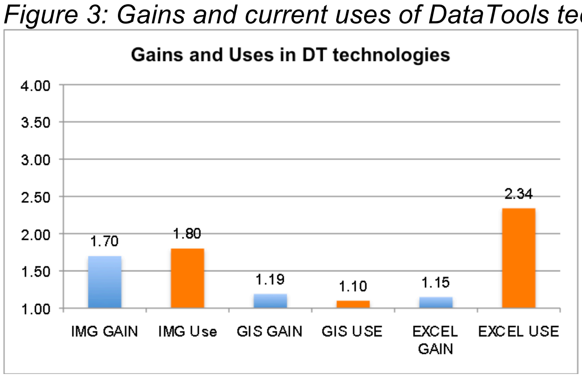
This is consistent with what we saw during Year 3, where we commented that one of the weaker findings was the level and extent of knowledge gained in career opportunities related to the tools and strategies informed by DataTools. It stands to follow that years after the intervention, while teachers may have been continuing technology use, without a strong basis and continued support in career development or awareness, it would decrease accordingly.

One other note of interest is that Cohort 1 showed the most gains in computer fundamentals (file formats, downloading files, taking screenshots, navigating folders and detaching attachments) and the fewest in more advanced computer use (listserves, use of digital libraries, general technology learning) as compared with the other cohorts, suggesting they came to the program with the least collective technology experiences.

Individual DataTools technologies

We break down usage characteristics and changes related to each of the three primary DataTools technologies: Image analysis software (ImageJ), Excel, and GIS. We saw the most overall gains since the program ended in ImageJ, followed by GIS, then Excel. This is somewhat counterintuitive to usage by teachers (orange bars):

Figure 3: Gains and current uses of DataTools technologies, all cohorts



We have two concurrent scales here, both using a four-point scale of 1.0: none/low to 4.0: much/high; blue bars represent degree of change from beginning of program to present; orange bars represent absolute current ratings (non-comparative) of current tool use, e.g. for imaging technology use (IMG), teachers are using to some degree (1.8, but their gain is 1.7 points over from where they began. Teachers used Excel the most, GIS the least, but experienced gains in imaging software the most. We suspect the Excel gains (least) are due to teachers being most familiar with the tool when they joined the program; ImageJ gains as the highest suggest that teachers used it a lot (reported in Year 3 evaluation) but were unfamiliar with it in the beginning; GIS gains in the middle suggests many teachers used it only briefly (Year 3 evaluation) and never achieved high-level use.

Sub-skills of each DataTool technology show significant technology skills were acquired as a result of the program and since:

Figure 4: Gains in image analysis as a result of PD

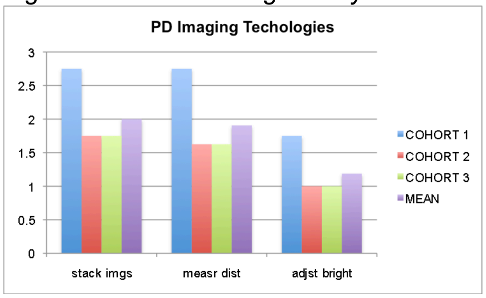


Figure 5: Gains in GIS as a result of PD

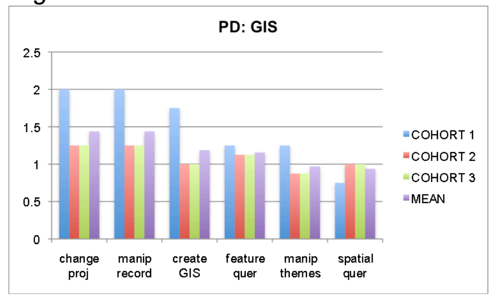
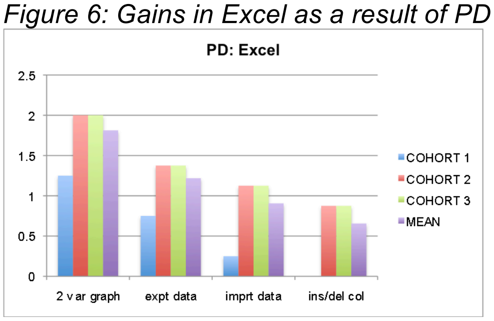
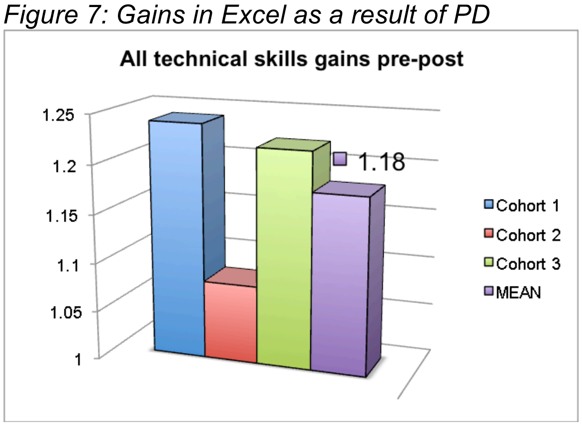


Figure 6: Gains in Excel as a result of PD



If we were to generalize over all cohorts, over *all technology skills* gained since the beginning of the program to the present, we see a 1.18 mean gain (as compared with the .65 gain above for all survey items, technology skills, usage, attitudes, awareness):

Figure 7: Gains in Excel as a result of PD



Interesting to note is how Cohort 2 seemed to gain significantly less that the other two groups in technical skills, however above in the analysis of all program components (figure 1), Cohort 2 and 3 are similar while Cohort 1 responded the most.

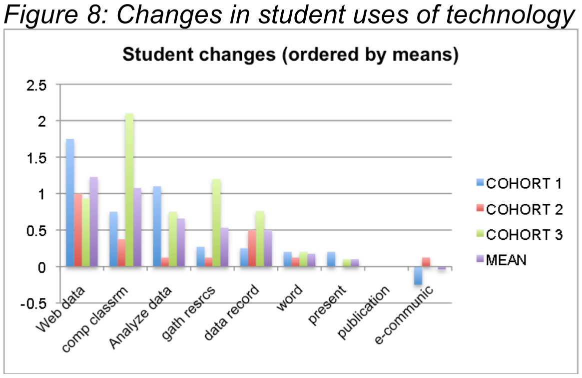
Student and classroom uses

Teachers reported on student learning changes as a result of engaging with DataTools technologies. The following graph depicts changes in how often, or to what extent students use computers in each of the dimensions. The frequency five-point scale consists of seldom (1), occasionally (2), once a month (3), once a week (4), daily (5). The largest gains were in the categories of using web data, general computer use in the classroom, and using technology to analyze data; the least were for publication, and e-communication,

As a teacher commented,

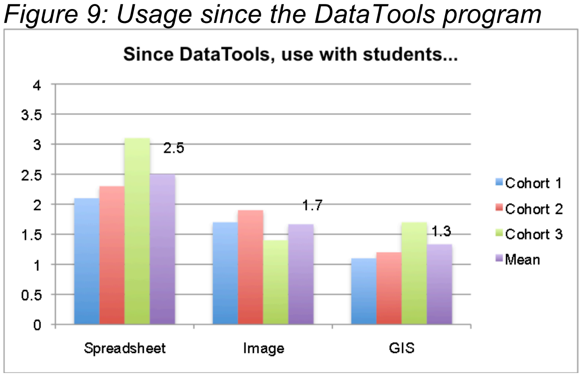
> "I love using data in the classroom because it incorporates useful technology along with daily information. Students can really appreciate observations made when they are using hand held technologies AND inputting this data into computer technology, but you know they are not allowed to collaborate online because of school privacy issues, the ports are all blocked."

Figure 8: Changes in student uses of technology



Teachers were asked to describe tool use since their DataTools participation year. These figures are not comparative, but come solely from December, 2009 as recollections of extent of use.

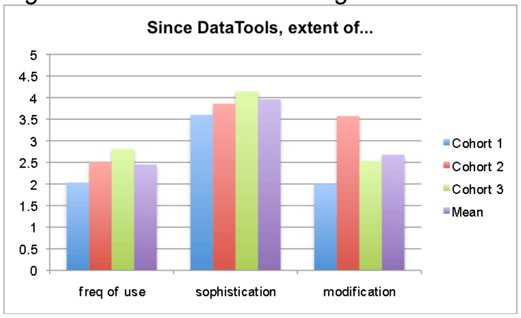
Figure 9: Usage since the DataTools program



This uses a four-point scale: none (1), a little, (2), some (3), a lot (4) and correlates with Figure 3 above in terms of degree of tool use: spreadsheet (Excel) the highest, GIS, the lowest. Anything 2.9 or less is considered to be used less than during the DataTools program year; while all categories show decreased use, GIS and ImageJ are used with students considerably less than spreadsheets. It should be noted that usage during Year 3 (usage during Years 1 and 2 was not calibrated) was approximately 0.5 point higher in all tools.

Also, when examining how the tools are used, it's interesting to note that frequency and modification of lesson plans have decreased, but sophistication overall increased.

Figure 10: How DT technologies are used



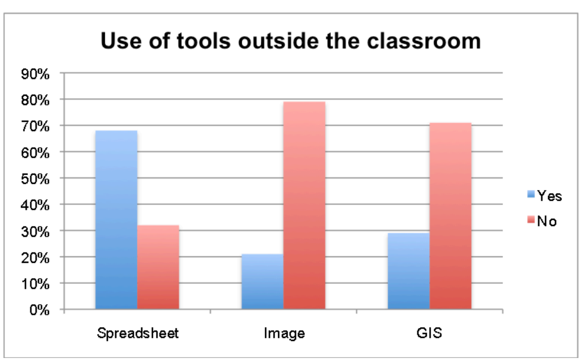
This five-point scale comprises much less (1), a bit less (2), no change (3), more (4), a lot more (5). Increasingly sophisticated uses of these tools may be attributed to a range of factors, including familiarity with the technologies, comfort with working with students and the tools, getting past data entry to data analysis, using lessons that have been tested, and downloading real time and relevant data (NOSS, USGS). Teachers report,

> "I am able to use the technology with more sophistication because I learned more ways while taking DataTools and now I am able to bring this knowledge into my classroom."

> "When students are comfortable with the tools they explore with ease since they are used to technology. I learned things from my students and have acquired more experience which leads to more use of technology in my lessons."

Another indicator of sustainability and impact is the extent to which teachers use these tools outside the classroom; a personal connection will always transfer back to the classroom as increased interest, use, and motivation. Nearly 70% of respondents reported using Excel, while 20% used imaging software. Nearly 30% claimed to use GIS, but upon reading of uses, it was actually GPS units related to geocaching and travel-related activities.

Figure 11: Use of DT tehcnologies outside the classroom

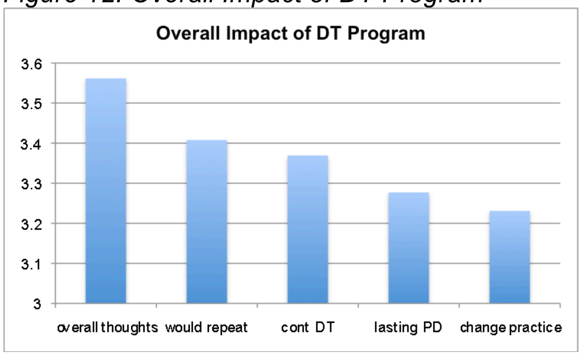


Spreadsheet use was the highest. Uses included analyzing student data to improve test preparation, household budgeting and finance, and list-making. GIS use was the next highest, with one teacher reporting a GIS data-collection project, the others citing travel and GPS navigation uses. Image manipulation uses included personal research projects and photography.

2.2 Teacher Interviews

Interviews were conducted with 26 teachers, 8 in person, 18 by telephone. Responses fell into two general categories: Overall impact of the program, and barriers to continued and developing use. Overall impact dimensions included general thoughts about the program, likelihood they would participate in a similar program, continued DataTools use, extent of lasting professional development, and the extent DT changed their teaching.

Figure 12: Overall Impact of DT Program



Ratings are on a four-point scale (1.0:lowest, 4.0: highest). Note that all of these impact dimensions score from 3.2 to 3.55, in other words, they are uniformly positive as a group, and the range is relatively narrow. You see near 3.4 that respondents report that to some extent they are continuing DataTools use and intend to continue into the future, as well as a change of practice (3.2) as a result of the program. One teacher explains,

> "It made me aware of all the ways these technologies can actually make teaching science easier and deeper… I need to make the investment, but it's worth it to the kids… they need to understand data, be data literate for their own lives, this is it."

Barriers

Teachers certainly spoke of various barriers preventing the continued or expanded use of DataTools technologies. These fell into specific areas: school pressures, time, hardware and software issues, curricular, support, leadership, time, and other assorted obstacles. In summary, school pressures presented the highest rated reason, namely test preparation, and the narrowing of curriculum; time proved an ongoing obstacle: time to plan, to learn or revisit the technologies, time to collaborate if possible. Many also claimed leadership was unsupportive and did not value their work with the program, providing overloaded teachers with little incentive to argue for including DataTools lessons as part of their course work. There were also several instances of leadership changes. In most schools, there was very little support for the technology, for example, GIS was difficult to use simply because it either was never installed, or was removed during the summer after the program and not reinstalled again (several schools). Teachers usually did not have installation privileges in labs but conducted most computer activities in labs. Schools' change of focus was another reason some teachers didn't continue DataTools to a greater extent, there were new programs, new projects, new directions that required teachers' commitments.

Given the prevalence of these barriers, most endemic to schools everywhere, it is quite a surprise to learn of continuing use situations of any type, let alone the kinds we've seen during this study. We detail the barriers in the following section.

3. Uses

3.1 Sample Usage Scenarios

Teachers continued to use technology in many of the same ways they had during the program, but most often to a lesser extent. As mentioned, Excel experienced the highest usage, due to several factors:

- Familiarity with the software. Several teachers reported having at least some familiarity with spreadsheet software prior to entering the program. Teachers learned how to graph, sort, perform manipulations with data, importing, and a range of other skills they found useful both for science and in other subject areas. In all cases this familiarity lent itself toward more advanced learning and use, and led toward retention of skills.
- Installed at school. Excel was often installed on the schools' computers, in labs, and in classrooms. Existing as a regular part of a school's technology offering also allowed teachers to seek support from school technology personnel, something that occurred to a much lesser extent with GIS or imaging software. Further, this common software was familiar to many individuals, not only DataTools teachers, providing another layer of informal support.
- Applicable across multiple subjects. Excel was used to collect and sort data, import tables, analyze patterns and create graphs. It was used equally effectively in both science and mathematics projects.
- Students expected to know it. In several schools, Excel was software students were expected to know and use by the end of middle school, yet many schools did not provide adequate instruction. In some DataTools classrooms, Excel projects provided this instruction. Further, by being part of expected knowledge, there were fewer opportunities for detractors to limit its use (e.g. technology personnel, IT, etc.)
- Useful outside of class. Many teachers claimed to use Excel outside of class. While the use was primarily for non-science purposes (budgets, list-making, inventory analysis), continued use led toward comfort, which significantly diminishes excuses and barriers in the classroom.

Teachers reported using Excel for graphing, fundamental data analysis, mostly working in groups in the computer lab. One teacher was using it to map resources for an urban planning unit; another was using it to teach analysis in a biology class, while still another used it for students to create launch windows for space flights based on planetary movement. A teacher is now using Excel to work with exponential functions and linear regression models; that has made a permanent impact and contribution to her course. Some teacher comments included:

> "I still don't use it a lot, we used it for cataloguing kids, use it for graphing, not a lot, but I'm a little more comfortable than I was prior to the workshop."

> "I'm using it every year in my math class, the kids get to do graphing; it's so much better because they spend less time plotting and drawing lines, and more on understanding how to interpret a graph…"

> "It's [Excel] already on the computers, they'll always upgrade it and I know I can find help if I get lost using it. Plus the kids are required to know how to make tables, graphs, use the spreadsheets a little…"

ImageJ use was less than Excel due to the following factors:

- Not loaded on computers. Several teachers could not load it properly on the lab computers; ports not always open for downloading web-accessible software. While it was installed in many schools during the program, labs are often reconfigured during the summer, and were not reloaded with software that is particular to a single project or class.
- Time investment not warranted. Some found that while it was useful in certain applications, the time invested proved too much for the return in terms of students understanding science. Teachers often only had a few days per year to devote to new technologies, and many opted not to use that time with ImageJ. Where the tool worked well, it was used as part of a larger unit over a longer period of time.
- Computers not adequate. School computers were too slow or had insufficient memory to adequately present the images and stacks.
- Curricular connections. Teachers did not find enough curricular connections to the tool.

Participants reported using ImageJ for understanding the ozone layer, measuring school buildings and trees to understand scale, developing ratio units, measuring cells, and studying global warming trends through measurement of NOAA maps and data. Several teachers only were able to present the software without using it in class, they conducted the Mona Lisa introductory activity. About ImageJ, teachers commented,

> "I'm finding paired photos of the atmosphere for my class to study glacial change, we're using it [ImageJ] for that."

> "We had only a few days to learn it, which we did with the Mona Lisa lesson we did during the summer… but then we returned after the [MCAS] tests, about four months later and they forgot everything, so we had to re-learn it and ran out of time"

> "I really like it, it gives the kids a great sense of scale, both large, like the atmosphere, and at the cell level. I only wish we had more places to use it."

GIS (ArcView) was used the least. Many of these reasons are the same as they were for ImageJ:

- Not loaded on computers. Teachers were unable to load software on lab or classroom computers.
- Time investment. It proved a big time investment to get kids proficient with it, then the need to develop curriculum
- Computers not adequate. School computers were too slow or had insufficient memory to adequately present the images and stacks

- Comfort with software. Many teachers never felt comfortable with GIS during their DataTools year; they were unlikely to develop its use after the program.

GIS use included an animal tracking project using NOAA datasets, mapping the Earth, looking at birds as they travel through the Garbage Patch, studying Katrina damage, and earthquake study. Several teachers give a short presentation on GIS each year, promoting its use as a scientific analysis tool, but did not use it with their students. Teachers who used GIS did think it was a valuable contribution,

> "I really found GIS useful. I learned it during your program [DataTools]… the kids have no problem with the technology, it has proven a great asset to get them to understand patterns about earthquakes and plate tectonics by visualizing the areas and land masses"

> "a problem is getting the data sets into ArcView; the raw data is too noisy, one year I tried having the kids clean it up, but it took all three days I put aside for the project… now I clean up the data, they just do the analysis, but they love using it."

3.2 Sample Usage Vignettes

Each teacher interview contained a story or profile of how DataTools currently were used (or not used) in the classroom. From the 26 interviews, we've selected some vignettes to highlight situations of interest that help us understand the program impact some time after the intervention. While not every story is presented here, the collection fairly represents the array of conditions teachers currently experience.

Unintended career shift

One teacher, a technology novice upon entering the DataTools program, loved the potential so much she committed to learning the software programs and general computer skills simultaneously. Failing to install the software on her school's computer labs using the traditional IT support channels (no one paid her attention, too many school policy, firewall, etc. issues), she asked her principal if she could become the computer lab director part-time; she learned everything necessary (fundamental hardware troubleshooting, disc installation, mirroring, network, etc.) and now, as a result of efforts begun during DataTools, she teaches computers and runs the lab part-time, and uses DataTools technologies in the courses she teaches.

> "The program caused me to rethink my role here, and the only way I was going to get things going with the technology was to figure out how to do it myself. It was a very good program for me, especially for me as professional development, now I have a new job title"

This is an example not only of sustainability and continuation, but of career focus shifts and professional development as an unintended result of the intervention.

Importance of site-based team

One school had a team of four teachers: three science teachers as part of a grade-level team and the IT/Computer Lab teacher. Today, more than a year after DataTools, they not only have continued their program activities to the same extent as they did during the supported year, but have institutionalized the use of the technologies at their school. In fact, since the tools were installed in three computer labs in the school (and maintained by the IT/Computer Lab teacher), some additional teachers are beginning to use them (ImageJ). This is a case of how a critical mass of participants in one site provides ongoing support to use and continue learning about the technologies. Having a computer lab instructor as part of the team was an important element as well. This team has recently presented their DataTool work at regional technology education conferences and signed up for other technology-based professional development opportunities (as a team).

Sustainability in spite of poor resources

In one urban, resource-poor school, science students do not have computers in the class. Nevertheless, the teacher has demonstrated GIS and ImageJ to them each year (now four years later) and she provides assignments that require students to learn and use the technologies, expecting them not only to figure it out by themselves, but to find the technology as well.

> "those kids just know and love technology, what they don't know, they ask their friends or somehow figure out… if I didn't ask them to use technology, they wouldn't do the assignments at all…"

These students used computers at public libraries and other centers, a few have computers at home, and they sometimes gained access to the school's computer labs, which do have all the software loaded. While the teacher's self-proclaimed expertise with technology is low, she managed to inspire the students, and she reported that most students complete the assignments every year. They print out the computer files on paper and hand them in to her.

> "… as I told [you], I never got too proficient with the computers, but I did learn a lot from where I came that first day.. I know my kids would find this stuff really exciting, we have computers in the building, they got them at libraries, our kids can do something if they want to…"

> "It was one of the good science workshops I've attended… made science relevant and interesting for us teachers and the students."

Here we have a case of strong sustainability in spite of school conditions that directly oppose any continuity or support.

Alternative to traditional technology learning

In one middle school, students are expected to know some basic features of Excel by the time they graduate, yet the computer program does not address that software (exclusively teaches typing skills). The teacher brought Excel to a climate studies unit, something she developed during a DataTools workshop. Students investigated the climates of different cities around the world, including rainfall, temperature, population density, industrial impact, etc. They next created spreadsheets with collected data to produce graphs supporting their findings, and produced a report. This project allowed students to pass their school's Excel technology requirement.

> "At the end, students were able to visualize the data better, and see if they made a mistake with data entry as they looked at their graphs. They learned the Excel part, but also how to look at data. It was a great boost to them, not having been provided with computer instruction previously in the school."

Students retain skills

A DataTools teacher transferred from middle school to high school in the same district. During DataTools she developed an engineering project with Excel for her middle school students, but now converted it to a high school biology unit. She now sees some of the students she had during DataTools as middle schoolers; they are completely prepared for Excel with the new biology units. They are not surprised at all about collecting, inputting, analyzing and graphing data, as many of their classmates (who did not participate in DataTools) are.

> "I know it came from our work in DataTools, I didn't even need to ask them… one student came up to me and said [teacher name], this is what we did two years ago with the [engineering] project, right?.... I know they remember."

Inspiring new teachers with technology

During DataTools, this teacher had only taught in the classroom for three years, and had come to teaching mid-career without very much technology expertise. She completed some ImageJ exercises with her students but could not do any GIS activities due to software installation problem. However, she discovered Excel was perfect to teach students about how data can be analyzed and graphed, regardless of content area. She continues to flourish with students collecting and imputing data, conducting rudimentary analyses and graphing trend lines. This enables them to make conjectures in the scientific method, look at data, and try to figure out how things happen.

She has ArcView on her personal laptop and each year does a one-period demo on the tool and its abilities to help visualize scientific data, specifically how cities change over time and the environmental impact of such changes (environmental science class).

During DataTools, she built a single Excel lab unit, now there are three that she uses each year. As a result of DataTools, she joined NSTA, and has attended conferences, meeting some former DataTools colleagues. Additionally, also as a result of DataTools, she has joined and brought a National Geographic technology project to the school for herself and others.

> "… it helped me gain confidence in technology and thinking about how to use

> new tools not only for science, but for other subjects… it's been a real eye opener. It's too bad our school won't support GIS because I know the kids would love to use that, I know of so many possibilities."

Staffing shifts affect technology integration

In one middle school, two teachers co-taught the same students, one in math, the other in science. They were able to use DataTools technologies in both subjects since the students were familiar with the technologies from both teachers. They used ImageJ to study how crab eggs "morph" into creatures. In mathematics, they studied data analysis and graphing using Excel. They used ArcView to track animals across the world.

> "I was surprised about last year, this particular bird in California, the kids tracked this bird through the garbage patch, they found and used NOAA data. This year I have a lot of those kids. We were studying force and motion this year and one of the kids said, it was a physics things about force, and he said, "that's about what we did last year, you were talking about the forces on the garbage patch and that's why it moves… and he went into this huge thing about why it happened and all the DataTools kids went on and on, they were telling the others what they learned, why the garbage patch cant' move; because each student had their own identified bird, it became personal. They did their own data collection, their own analysis. It was a real impact, that program."

Unfortunately, this year the teachers were split to each teach a separate grade level and they no longer co-teach.

> "I feel that the kids who were really immersed had very strong computer skills; they had computer class in 7th grade, then with [other teacher] and I doing specific software skills, they were so deeply immersed; now it's no more. They hardly get computer skills in the computer class, let alone in science or math. When we worked together, the skills and concepts were reinforced and totally integrated into our teaching. Now it's no more."

GIS a strong model for visualization

One teacher remains committed to using GIS. Her students have had little problems with understanding how to use it, and the school responded well to supporting installation and updates. Her biggest problem is getting the raw data sets into ArcView,

> "… it just takes too much time for them to upload the data properly, and then that's the allotted time we have for the unit. I'm doing that work myself now to prepare for the lessons."

She sees two kinds of tasks for the students to learn: a) data gathering and cleaning, b) using GIS to discern patterns and make predictions. The first eludes middle school students and takes up more time than is merited by what they'll learn,

> "… it's very abstract to them anyway at this level; until they understand more

> advanced GIS use, it’s not worth it. I have some students do data cleaning and entry for extra credit.”
>
> “The kids have no problem with the technology, it has proven a great asset to get them to understand patterns about earthquakes and plate tectonics by visualizing the areas and land masses and how they have moved. They really see it!

It is, however, clear to her the value of using GIS visualizations to help students discern data,

> “I really love GIS, it’s terrific.. kids have no problem with the technology, they love it, it really helps them see how earthquakes behave, move, the sub-quakes within larger quakes….”

3.3. Earth Exploration Toolkit

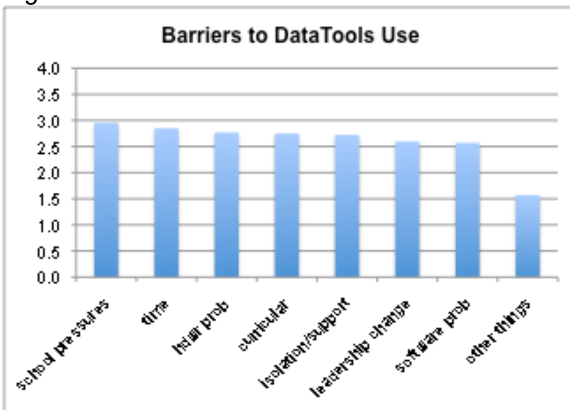
The Earth Exploration Toolkit, an online [http://serc.carleton.edu/eet/] collection of computer-based Earth science activities, was a cornerstone of the online DataTools course. Many teachers continue to use this online resource in their classes with or without additional DataTools technologies, simply as an Earth Science resource. Many teachers praised the EET and commented not only about the quality, but about its value as an ongoing resource, and its influence upon their teaching, suggesting continued and sustained use,

> “ I have successfully adapted several lessons from the Earth Exploration Toolkit in my sixth grade science and math classes. This resource has been highly influential in increasing my students’ ability to use Excel and ImageJ to display and analyze a variety of data.”
>
> “I have used the EET (Earth Exploration Toolkit) to both enhance my own understanding of technology tools and to provide enrichment for my accelerated students.”
>
> “It has now been several years since I completed the DataTools program. I have found the Earth Exploration Toolkit to be even more valuable as a resource for me to reteach myself some the skills I had previously learned. It is equally valuable to my students who have not enjoyed the full DataTools program. The availability of the Toolkit makes it a main resource available to me as I try to get students to look at real life data and to use geospatial thinking.”
>
> “As Science Department Chairman I am trying to get geo-spatial skills integrated in a 7-12 Science program, the Earth Exploration Toolkit is an excellent resource both to the teachers in my Department and their students (in multiple grade levels.”

4. Barriers

The barriers identified by participants toward continuing and developing uses of DataTools technologies, while many, fell into categories common with other technology education interventions: school pressures, time, hardware and software issues, curricular, support, leadership, time, and other assorted obstacles.

Figure 13: Barriers to DataTools use



Common Barriers

In conversations with teachers, the following barriers recurred often enough to qualify categorization as "common." We can see in the graph above, the highest ranking barrier was that of school pressures preventing teachers from more fully engaging with DataTools methods and applications, the lowest ranking barrier (aside from "other things") were those related to software problems. Note that in this four-point scale (0: not at all a barrier, 4.0: Absolute barrier), the top five obstacle fall between 2.9 (school pressures) and 2.6 (software), suggesting the impact of any one barrier might be considered more of less equivalent to that of any other as the variance is slim.

School Pressures. These consisted of academic, administrative, and managerial directives and initiatives, both formal and informal, that pulled focus from DataTools. Some examples included schools having a strong emphasis on test preparation with punitive action for non-compliance, teams and grade-level groups working together on curriculum that did not include DataTools, other programs in place and demanding of teacher's attention.

> "Our school is only concerned about test scores, test scores, test scores. If it doesn't have to do with the test, you may as well throw it out the window, because who knows what they'll do?"
>
> "My team wasn't using it, though I showed them ImageJ and they all know Excel. We plan together, so I'm not using it this year."

Time. Many teachers complained of not having time to plan or modify a previous DataTools lesson, time to re-learn or continue to learn the software, time to deploy computers and set up all the students, time to collect or investigate data sets, time to troubleshoot technology, and time to communicate with former DataTools colleagues,

> "Time in the curriculum to spend the time in both creation and analysis for the average 12 year old to get a clue of what I am doing… having the time to fit it all in."

Hardware Problems. These barriers included classrooms not having enough or access to enough computers, not having adequate time on the computers they did have access to, and computers not having enough power or memory (especially for ArcView)."

> "… there was definitely lack of access to technology… and unpredictable servers at school. The school only had one computer lab. Scheduling it sometimes was difficult."

Curricular. Teachers had problems finding the curricular connections and places to use DataTools in the sequence of course units. Many felt for some subjects (e.g. GIS with earth science) intersection was easier than for others (e.g. GIS with biology). In some cases, a tool may have been relevant for the subject, but not the grade level. In other cases teachers felt that they needed to spend too much time on the technology itself, which would compromise their time invested in the content. Much is related to the mandated content teachers are required to cover during the school year, none of which requires DataTools use.

> "Pedagogically I am challenged to think of ways to assess the students and to make sure that they are understanding the concepts in the way that they should be. It is sometimes hard to get them to the critically thinking level when they are analyzing the data."

> "Selecting a topic area that is within the grade level I am teaching that I can adapt across the curriculum."

Isolation and Support. Teachers who were the sole DataTools participants in their schools felt increasingly isolated from the program in the years after the program ended. During the program they felt they had a community; there were meetings and an ongoing network of users (to varying degrees of activity, both online and face-to-face). Currently, as the only teacher in their school, the loss of camaraderie around an innovative instructional approach seemed to diminish engagement with the program tools.

> "I am the only one in the school using this stuff, and it's terrific, but I've got no one to turn to for ideas or help."

Leadership Change. In many schools, the principal who had supported DataTools no longer was there; in others, the principal changed her mind about supporting the program, redirecting attention on other needs. Support by leadership is critical toward maintaining any degree of sustained and continued use.

> "My principal signed on to the program, but now we have a new principal, things are different, we are entirely focused on improved school scores [MCAS test], no technology."

> "We have a new principal and I'm not sure he even knows what I'm doing…"

<u>Software and other Technology Problems.</u> Teachers experienced many GIS and ImageJ software problems, mostly related to installation and the applications running smoothly. One teacher was able to install ImageJ, but it behaved erratically and unpredictably, so she didn't use it. Typically these cases occurred in schools without adequate technical support. Many cases involved incompatibility between software versions, operating systems, logon privileges, and internet access (many schools categorically block downloading sites, so teachers were unable to collect and install data tables).

> "Technological challenges occur when the websites do not work, certain programs are not installed or updates need to take place and I cannot do that because the school requires a password that they do not give teachers…"

> "My access to computers. Over the past two years, access to technology has decreased in my school. Our laptop carts are almost unusable."

<u>Other Barriers.</u> These included teachers losing interest in the program, difficulty with specific student populations and computer use (ELL, SPED), teachers getting interested in other things, teachers shifting positions—no longer teaching in the same school or same subject, and the technology learning differentiation among students.

> "I really like the program when we were doing it, but now I'm trying to focus this year on fundamentals, the kids need to know how to understand the math first…"

> "My greatest challenge is introducing a new technology - students pick it up at different rates and I often feel like I have kids waiting for the next step while some kids are struggling with the first steps."

5. Conclusion

This sustainability and usage study documents continued use of DataTools technologies and methods in the years following the participation period. While the use is to a lesser extent than during DataTools, it is nonetheless significant; more than 90% of study population (28 survey respondents, 26 interview respondents; 31 unique subjects including overlap between groups) continue to demonstrate some extent of DataTools use. We will respond to stated research questions within the proposed program dimensions:

5.1 Outcomes

Student Outcomes

Research Question:

- To what extent have students acquired the technology skills and use of those skills in learning science?

According to teachers (we did not interview students directly during this study), in every case where DataTools was used, students made connections between the scientific process and data collection and analysis, especially when data analysis was the central focus, e.g. while using Excel.

> "… my students really understand how to collect data and make predictions about the tides, it really gives them something relevant to connect to math and graphing…."

In using GIS, student excitement over mapping earthquakes, land masses, migration and travel patterns of animals, and urban growth provided a conceptualization teachers felt was otherwise missing.

> "They really saw how land masses shift over time, it was worth it, they're excited about this technology…"

> "…. the students you know love computers, and they're so good at picking up how to use them, I think our units with ImageJ when we looked at the [Aral] Sea shrinking, they really got it, but also they were enthused because of the computers."

These comments and general positive responses by teachers about student engagement learning with these technologies suggest that students were positively influenced in terms of attitudes toward science and science education. While there was no conclusive evidence of increased academic performance as a result of DataTools, we know of cases where students trained in DataTools from one year came better prepared to more advanced science classes, completed data analysis projects more readily than previously, collaborated among themselves, and asked more complex questions about the subject. These data, complementing those of significantly increased (>0.5 point gain ~pre/~post) student skill acquisition and use (Figure 8) in finding and using web-based data, classroom computing, analyzing data, gathering research resources, recording data all suggest positive student gains in technology use *as it directly pertains to* learning science and scientific processes.

Teacher Outcomes

Research Questions:

- To what extent have teachers acquired the technology skills and use of those skills in teaching science?
- Do teachers perceive the DataTools program to have been relevant to their teaching situation?

From both data sources, surveys and interviews, teachers reported significant gains in both technology skills and abilities to use those skills in the classroom, develop and enact lessons, and teach with DataTools. In previous sections we've seen that changes since the beginning of the program for technology skills among all cohorts rose more than one point (1.18) and general DataTools knowledge, use, and skills rose .65 across all cohorts.

Many teachers reported that teaching science using these technologies has helped reshape their own vision of science education,

> "… it helps me visualize the data, and then of course, when the students can do it, them visualizing the ideas, I think they understand it better [GIS use with earthquake project]"
>
> "I know that by avoiding manually plotting the graphs with chart paper and pencil, using Excel, the kids get to analysis faster, so we spend much more time on the part that matters. I think it makes a difference."

Program Design

Research Question:

- How effective was the program design, specifically each component: choice of tools, workshops, online course, EET materials)

Regarding program design, there was little to report on in a comparative manner, since the program had ended. In describing their recollections of the professional development activities, teachers were very enthusiastic about the program. As described in previous reports, the delivery method, sequence, and timing were good and addressed most teacher needs; the balance between face-to-face meetings and online instruction helped disseminate the program and served as a replicable training model.

Sustainability

Research Question:

- To what extent have DataTools activities and strategies continued beyond the project's funded period?

We have seen much evidence of how teachers continue to use and learn with DataTools. There is little doubt that teachers continue to use DataTools knowledge and technologies well beyond the project period. Our teacher sample accounted for approximately 40% of the entire DataTools participant population. Of the 28 teachers in our study, two no longer were teaching in K-12 environments, and one did not use DataTools in any way, resulting in approximately 89% of respondents demonstrating program sustainability in one way or another. While the technology use was lower than during the full participation year (approximately .05 point lower: spreadsheet 2.5, image analysis 1.7, GIS 1.3 on a scale where 1: none, 2: a little, 3: some, 4: a lot), demonstrated use was integrated into the curriculum, and barring unforeseen obstacles, teachers felt they would continue sustaining that level over the next years.

Barriers

Research Question:

- What barriers to continued implementation have teachers experienced?

Many barriers outlined above stem from school-related and system-wide issues of technology support and preparation time to continue studying the technologies, yet DataTools teachers were able to persevere despite these obstacles, testimony to their belief in how the program would help their students.

5.2 Lessons Learned

Lessons to be learned from the program, and this study in particular, are useful in that they may be considered in the design and preparation of future programs. In fact, the current Eyes in the Sky 2 (TERC, NASA funded, 2009) bases some of its professional development design on DataTools with modifications made as a result of some of these lessons. Some overall lessons to be learned might include:

- <u>Recruit teacher groups, not individuals.</u> Sites where more than one teacher participates often form stronger usage characteristics than those with single practitioners, simply because the teachers have local support and colleagues with whom to collaborate. Many teachers cited isolation as a cause for diminished continual use.
- <u>Technologies.</u> Use technologies that require a little external support and as little demand on current systems. While powerful technologies such as GIS and Image Analysis tools are becoming commonplace, many school computers still cannot fully support them. There's a delicate balance between advancing teachers' knowledge and recognizing the capacity of schools to respond to and support the technology needs. This balance needs to be carefully negotiated during project design and participant

recruitment.

- Content. Given the content demands many schools face, the closer project content is related to existing curriculum, the better chance it will have of being used, developed, and becoming an integral part of the course.
- Leadership. School leadership always needs to be a partner in innovative programs. Attendance to workshops or meetings, while not always possible, provides teachers with the message that they will be supported during the year (e.g. extra planning time, navigating technology hurdles, co-teaching, attending workshops or meetings, etc.)
- IT participation. Inviting members of the schools' IT or technology support staff will help alleviate many of the technology support challenges teachers experienced.
- Sustainability. There is, in fact, a high degree of continued use of the innovation in the years (in some cases three years after) after the program. If professional development is strong, if the content serves the learning goals of schools, if technology is available, then teachers will continue to engage with the innovation and lasting change may occur.

5.3 Conclusion

DataTools provided professional development opportunities for teachers to learn new technologies relevant to science learning, and presented a viable and scalable professional development hybrid model combining face-to-face instruction with intensive online coursework. We saw from previous reports the gains teachers made during each year of the program. During the final year (2008-2009), teachers commented about intent to refine and continue the work in successive, non-funded years, a strong indication of both program adaptability and sustainability. Program activities prompted teachers to think more deeply about science and mathematics instruction, how to make the learning more engaging, and how, after the first time through the program, to improve the experience the next time.

This study clearly shows indications of sustained use of at least one of the tools in 90% of the study participants, in some cases more than one. This is testimony to the program design, and more importantly, the relevance of the professional development to teachers, and in turn, the successes they have had implementing these technologies in their classrooms.

6. Appendix

A. Data Tools Teacher Interview Protocol (in-person and telephone)

(in-person and telephone)

1. Describe your DataTools usage today. [prompts: Excel, GIS, ImageJ) How has that changed since your DataTools participation year?
2. How have your students responded to those lessons?
3. How has the program impacted your overall teaching?
4. What have been the main barriers to more complete DataTools use?
5. How have your DataTools lessons changed during the time since your participation year?
6. How has your school climate (personnel, direction, focus) changed since that year?
7. Would you participate in similar programs in the future?

B. Online (SERC) Survey (December, 2009)

1. ID information:
    a. Last name
    b. First name
    c. Data Tools participation year: [select] 2006-07, 2007-08, 2008-09
    d. Current school
    e. Current email
    f. Phone where you can be most readily reached (cell or home)

DataTools Program

2. The DataTools program was designed around four main elements: a) spring online teleconference workshops, b) summer workshop, c) fall in-person meeting/workshop, d) fall online sharing and investigation events, Which one of these components did you find the most useful? Please describe why you selected that component: [open response]

3. Why are you interested in using data in the classroom? [open response or NA]

Student Use of DataTools Technologies

4. Approximately how often do you ask your students to analyze data? [every day, once a week, once a month, occasionally (every 3-6 months), seldom (once/year), never]

5. To what extent do you use Web-based scientific data (i.e. satellite weather data, earthquake data, etc.) with your students? [never, a little, some, a lot]

6. Since your DataTools participation year, to what extent have you used with your students the following technologies: [none, a little, some, a lot]
    a. GIS [none, a little, some, a lot]
    b. Spreadsheet [none, a little, some, a lot]
    c. Image analysis[none, a little, some, a lot]

7. Since your DataTools participation year, what have you used the following tools for? [open response or NA]
    a. GIS [open response]
    b. Spreadsheet [open response]
    c. Image analysis[open response]

8. Since your DataTools participation, to what extent has the usage changed when using DataTools technologies:
    a. Frequency of use in classroom: [much less frequent, a bit less, more frequent, a lot more frequent, no change]
        i. Reasons for this change? [open response]
    b. Sophistication of tool use (deeper and more complex problems to solve, tool used in multiple ways within a single problem or unit): [much less

sophisticated, a bit less, more sophisticated, a lot more sophisticated, no change]
    i. Reasons for this change? [open response]
  c. Modification of lesson plan developed during my first DataTools year: [slightly modified, somewhat modified, considerably modified, completely modified, no change]
    i. Reasons for this change? [open response]

9. How often do your students use computers as a part of your classroom teaching and learning activities?
   [every day, once a week, once a month, occasionally (every 3-6 months), seldom (once/year), never]

10. Check the boxes to indicate the ways in which your students have used computers as a part of your course. Check all that apply: [word processing, presentations, gathering research, electronic communication, data recording and analysis, publication]

My Own Use and Teaching

11. What is the greatest challenge you face when incorporating Web-accessible scientific datasets or analysis tools into your teaching? Consider both pedagogical and technological challenges. [open response or NA]

12. Do you currently use any of these tools outside the classroom for your own professional interest?
    a. Spreadsheet [yes/no]
       i. Example of use [open response or NA]
    b. Image Analysis [yes/no]
       i. Example of use [open response or NA]
    c. GIS [yes/no]
       i. Example of use [open response or NA]

13. How confident do you feel in your ability to facilitate technology-supported learning that improves the quality of students' education? [very confident, confident, not confident]

14. In my DataTools classes…
    a. I created the lessons that used DataTools technologies [never, a little, mostly, all the time, NA]
    b. I used lessons created by others that used DataTools technologies [never, a little, mostly, all the time, NA]

15. To what extent have you been using the following resources?
    a. Earth Exploration Toolkit resources [never, a little, mostly, all the time, NA]

b. Links and resources from the DataTools web site resource pages [never, a little, mostly, all the time, NA]
c. Lesson plans created by other teachers [never, a little, mostly, all the time, NA]

Self-assessment of Information Technology Skills

1. Email attachments
2. Opening attachments
3. Listserve use
4. Locate and download images
5. Using digital library
6. Open various file formats
7. Save screen shots
8. Install software
9. Navigate file systems

Image Analysis

10. Drawing and text tools to annotate
11. Make measurements on digital images
12. Adjust image brightness and contrast
13. Stack and animate images

GIS

14. Use point/line data to build GIS map
15. Add, on/off, change drawing order of themes
16. Change map scale
17. Find and manipulate records of an attribute table
18. Perform feature queries
19. Perform spatial queries

Spreadsheet

20. Import data
21. Insert rows/columns
22. Construct graph to compare variables
23. Export data

Career Awareness

24. Rate your awareness level of careers that use tools for data analysis (i.e. meteorologist using image analysis to understand weather patterns).
    [not very aware of these careers, know of a few careers, know of some careers, know of many careers, possess a high degree of awareness about these careers]

C. Data Tools Teacher Talking Survey

Administered only to on-site interviewees

Technology Skills. How would you have rated the general technology skills of your students at the beginning of this school year?

None				Average			Accelerated	
0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0

How would you rate the general technology skills of your students now?

None				Average			Accelerated	
0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0

To what extent would you attribute changes to Data Tools?

- ☐ None
- ☐ Some, but hard to attribute to DT
- ☐ Some, not attributable to DT
- ☐ Some, attributable to DT
- ☐ Much, but hard to attribute to DT
- ☐ Much, not attributable to DT
- ☐ Much, attributable to DT

Science concepts. How would you have rated the general science knowledge (as determined by grade level standards) of your students at the beginning of this school year?

Low				Average			Accelerated	
0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0

How would you rate the general science knowledge of your students now?

Low				Average			Accelerated	
0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0

To what extent would you attribute any changes to Data Tools?

- ☐ None
- ☐ Some, but hard to attribute to DT
- ☐ Some, not attributable to DT
- ☐ Some, attributable to DT
- ☐ Much, but hard to attribute to DT
- ☐ Much, not attributable to DT
- ☐ Much, attributable to DT

This (most recent) lesson encouraged students to seek and value using DataTools and data analysis to inform science learning…

False				Somewhat			True	
0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0

This (most recent) lesson encouraged students to seek and value alternative modes of investigation or of problem solving.

False				Somewhat			True	
0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0

This (most recent) lesson increased students' interest in and/or appreciation for science

False				Somewhat			True	
0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0

Your Overall Teaching. Did the program improve your overall teaching in any ways?

Not at all				Somewhat			Very Much	
0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0

Innovation. Do you consider the technologies innovative as teaching tools?

Not at all				Somewhat			Very Much	
0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0

Sustainability. Will you continue developing and implementing Data Tools activities in subsequent years?

None				Some			As Much As Possible	
0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0