

Electronic Lab Notebook Pilot at the University of Wisconsin-Madison

Study Findings

November 10, 2012

Executive Summary

Participants and Tools

A three-month pilot of Electronic Lab Notebooks (ELNs) was conducted during the spring of 2012 using two software products, eCAT (ResearchSpace¹) and CERF (ELN Technologies²). Both systems were hosted on campus servers.

Fifty-five researchers, from the College of Agriculture and Life Sciences (CALs), the School of Engineering, the School of Medicine and Public Health, and the College of Letters and Sciences (Chemistry), participated in the pilot. Participants were mostly graduate students but also included scientists, post-docs, PIs, and research staff. The pilot was sponsored by the Office of the CIO, Wisconsin Alumni Research Foundation (WARF), the College of Agriculture and Life Sciences (CALs), and the Division of Information Technology (DoIT).

Findings

- Overall, eCAT was the preferred ELN. Users found it easy to use and most found the quality of research records they kept in it was better than records kept using prior methods. Most also said that it would be a good method for keeping data over a number of years.
- CERF was rated as more difficult to use. While generally satisfied with its features for record keeping, most users felt the quality of research records they kept in it was either worse or about the same as records kept using previous methods and that it did not offer an improved way of managing data.
- The majority (75% or more) of eCAT respondents found that the ability to add data files and links, view data files in the ELN, search, and access the ELN outside of the lab were useful features, in addition to the interface and templates. In contrast, the same proportion of CERF users only agreed that adding data files and links to the ELN were useful. Pilot participants using either ELN generally did not find simple drawing tools or the ability to use their ELN offline or on mobile devices to be useful during the pilot. In the case of use on mobile devices, several participants attempted to load and/or use both ELNs on mobile devices but did not find the mobile version useful.
- Pilot participants agreed both at the start and end of the pilot that the ideal ELN interface is one that provides basic functionality and is easy to customize. There is little evidence that researchers in the disciplines represented in this pilot want an ELN that is designed specifically for their research domain, although the availability of tools for viewing chemical files and searching against chemical structures was important to chemists in this pilot.
- Most participants indicated they spent less than 12 hours learning to use the ELN software and found live training sessions and trial and error to be the best methods for learning.

Future Prospects

At the end of the pilot, 91% of users said they wanted to continue using an ELN to record their research. 83% of eCAT users wanted to continue using it as their ELN while 60% of CERF users wanted to try another ELN.

¹ ResearchSpace changed its name from Axiope after our pilot was completed.

² ELN Technologies changed its name from Rescentris after our pilot was completed.

Given the high level of interest in the continued use of an ELN by participants plus frequent interest expressed by nonparticipants, we are planning a campus ELN service. A business model for this service that includes technical infrastructure, administration and support, and cost estimates is under development.

Introduction

ELNs are widely adopted by labs in the private sector but currently are not widespread in academic research settings (Rudolfi and Gossen, 2011). Barriers to adoption of ELNs in higher education include the cost of ELN software, the need for high level IT support for hosting and administration, and the need for custom ELN designs that suit the wide array of research approaches found in academic settings. (Carpenter, 2012)

Paper lab notebooks have a number of advantages such as readability, low cost, and support for hand-drawing that make them a valuable tool for many types of research (Mackay *et al*, 2002). Researchers can maintain a complete and continuous record even when their data are in digital formats by printing out data files and taping them into paper notebooks, cross referencing file names in notebook entries, and replicating information that was hand-written in paper notebooks into their digital data files

(<http://www.warf.org/inventors/index.jsp?cid=18>). However, increasingly researchers point to the difficulties of tying together paper documentation of the work performed and its conclusions with the countless types of digital files that constitute data and with the results/analyses, protocols, designs, calculations, and presentations/publications that often exist in electronic form (Carpenter, 2012). Many researchers today, particularly graduate students, increasingly find that hand writing in paper notebooks slows down the process of recording their research. (Giles, 2012). In addition, ELNs may facilitate sharing of data in collaborative research compared to the inherent constraints of sharing data via paper notebooks (Butler, 2005).

The goal of the ELN pilot was to determine if ELNs are useful to researchers in a variety of disciplines and across the variable IT environments found in in academic settings. The pilot included two ELNs (CERF by ELN Technologies and eCAT by ResearchSpace) to allow us to determine if some ELN features and designs were more valuable to researchers.

In order to understand whether ELNs offer researchers advantages over their current lab notebook practices as well as what level of technical work would be required to provide a large scale ELN implementation, we sought to investigate the following broad questions:

1. Are ELNs easy for researchers to use? What is the learning curve for working with them?
2. Do they offer flexibility to researchers for keeping track of their work? Do they get in the way of research or of documenting research?
3. Do they make it easier to find things? Improve data management? Make record keeping more efficient?
4. Do they make it easier to share findings with collaborators, where appropriate?
5. On the technical side, do they integrate with campus identity management architectures? Scale to accommodate large numbers of users? Store data in a manner that protects intellectual property of researchers and keeps private data secure?

In addition, we were interested in learning whether ELNs would allow researchers to improve their data management and meet the requirements of the UW-Madison Data Stewardship, Access, and Preservation Policies (<http://www.grad.wisc.edu/research/policyrp/rpac/documents/PolicyDataStewardship.pdf>) and the requirements of funding agencies, research sponsors, and contractors. Notebook entries are often important evidence of the discovery process and may be critical for patent and scientific misconduct challenges. ELNs have features that make them acceptable electronic records for research (Robson, 2007) that must comply with the FDA's Code for Federal Regulations Title 21.

(<http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcr/CFRSearch.cfm?CFRPart=11&showFR=1>).

Study Methods

Pilot Personnel

Executive Committee

Phillip Barak, Professor, Soil Science and Director, Information Technology and Computing, CALS; Sarah Castello, Senior Disclosure Specialist, Office of Research Services, Graduate School; Irwin Goldman, Professor, Horticulture; Stephen Harsy, Assistant Dean, School of Medicine and Public Health; James Muehlenberg, Assistant Director, DoIT Academic Technology

Sponsor Group

Michael Falk, General Counsel, WARF; Linda Jorn, Director, DoIT Academic Technology and Associate Vice Provost for Learning Technologies; John Krogman, Chief Operating Officer, DoIT; Bruce Maas, CIO and Vice Provost for Information Technology

Work Team

Alan Wolf, DoIT and Office of the CIO; Jason Pursian, CALS IT; Victoria Sutton and Cheryl Scadlock, WARF; Jan Cheetham, Dan Voeks, Scott Fullerton, DoIT

Pre-pilot Interviews

To better understand current practices used by researchers to record their research, we conducted interviews during the winter of 2011 with 6 faculty PIs, 5 graduate students, 2 postdoc/scientists, and 6 research/IT staff from the agricultural, basic medical, and physical sciences. Nearly all those interviewed were using paper lab notebooks and/or log books to record at least some aspects of their research. At that time, nearly all expressed the opinion that their current methods were satisfactory but many felt ELNs had the potential to improve record keeping. For example, most felt ELNs would make it easier to find things in notebooks (by allowing text searches), could reduce redundancies in recording research (some were entering information about data both in their paper notebook and again in the digital data files), and to keep records of dates, people, and versions of notebook entries. A summary of the results of these interviews is on the ELN pilot website at <http://academictech.doit.wisc.edu/ideas/electronic-lab-notebooks>.

Software Selection

Given the interest in ELNs evident from interviews, we began a process of software selection. Because scant information was available from ELN vendor websites about their products, pricing of licenses, and technical requirements, we conducted a formal request for information and proposals from vendors (See <https://academictech.doit.wisc.edu/files/115349rfi.pdf> and <https://academictech.doit.wisc.edu/files/ELN125349.pdf>), in compliance with state laws governing purchases over a baseline amount. Fourteen ELN vendors responded and their proposals were evaluated. From this process, we obtained a non-exclusive contract with the Rescentris Corporation (now known as ELN Technologies) for the use of their product, CERF, both during the pilot and for subsequent purchases by interested parties on campus after the pilot. At the same time, the IT unit in the College of Agriculture and Life Sciences (CALS) set up an installation of eCAT for a few labs in their college. They expanded their installation to include 25 additional seats for researchers from CALS who were interested in participating in the ELN pilot. The CERF software was hosted on the DoIT Enterprise Storage platform and was administered by staff in the Systems Engineering and Operations and Academic Technology groups at DoIT.

Recruitment and Selection of Participants

We provided information about the pilot and an online form for researchers to indicate their interest in participating in the pilot on the ELN pilot website during the summer of 2011. We emailed a list of several thousand researchers to invite them to demos by ELN vendors and some of the attendees decided to participate

in the pilot. Stories about the ELN pilot which included an invitation to participate also appeared in the September issue of the WARF Discovery Bulletin (<http://www.warf.org/news/index.jsp?cid=52&scid=111>) and in the August 31 TechNews bulletin from DoIT, both emailed to thousands of researchers on campus. Additional participants were recruited from the list of interviewees in the environmental scan and from personal contacts of CALS IT and WARF staff. A total of 137 researchers indicated an interest in participating in the pilot. From these, 55 were selected. Participants who used eCAT were all associated with the College of Agricultural and Life Sciences (CALS). Participants using CERF were from Engineering, Letters and Sciences, and the School of Medicine and Public Health. For both groups, participants were selected to maximize the breadth of fields and project types from the pool of volunteers.

Participant Consent, Obligations, and Risks

All participants signed a statement agreeing to the terms/expectations of the study³. Those participants who were trainees also obtained their PI's signature to ensure that the PI understood the risks and expectations and supported their trainee's involvement. Expectations included using the ELN as the primary method for recording research during the three month pilot, participation in evaluations and feedback sessions, and maintaining dual records in hard copy format as well as in the ELN to protect against loss of data during the pilot. Risks included additional time needed to learn the ELN software and to maintain dual records and the possibility that the ELN assigned each participant would not be their top choice or the software selected for future campus support.

Participant Training and Support

Training was provided to all participants in one or more live sessions with vendor trainers. Short videos demonstrating features of each ELN were also available on the vendor websites. The DoIT HelpDesk provided Level 1 support for the CERF ELN, which included referral to the vendor's contact information for support and notification of outages on local servers hosting the CERF system. Participants corresponded directly with the vendor for support issues, in general. However, the ELN pilot team provided some support with installing the software and troubleshooting connections to the CERF server. In the case of eCAT, CALS IT staff provided support for some issues and forwarded other issues from users to the vendor. The pilot work team also set up listserves and online user forums in Piazza (<https://piazza.com/>) for both eCAT and CALS users to share stories and issues relating to use of the ELNs.

Evaluation Instruments

We administered a pre-survey to capture participants' expectations about the usefulness of ELN features and their potential for data management and record-keeping (n=52). During the pilot, we convened several focus groups of participants and checked in with individuals from time to time via email and phone. Both of these methods were useful for troubleshooting problems with the software, learning which features participants were using, and gathering feature requests to improve the ELNs. At the end of the pilot, participants were asked to complete a second survey to evaluate the ELN product they used and assess the usefulness of various features of their ELN (n=32). Because of the small sample size for both surveys, means are not stable; therefore we are reporting percentages. Further analysis (i.e., cross tabs, correlations, etc.) could not be done; and confidence intervals around findings/margins of error are high. The administered surveys allowed us to capture the perception of our users. Our indication of how important each of the features or functionalities were to their research is limited to anecdotal information from focus groups, support cases, and interviews as well as responses to open-ended questions on the surveys.

³ The study process was reviewed by UW's Institutional Review Board, which approved the study methods and consent process.

Study Results

Demographics and Characteristics of Participants

Research Role and Disciplinary areas

At the end of the pilot period, a total of 32 responses to the Electronic Lab Notebook (ELN) survey were collected: 20 CERF users and 12 eCAT users. The majority of respondents were graduate students (56%, $n=18$). Five post docs (16%), one faculty (3%), and two scientists (6.3%) also responded. Nearly 19 percent of the respondents reported that they were “other,” with the majority having research in their title. See Figure 1 for more details.

Because the College of Agriculture and Life Sciences (CAL S) was hosting an eCAT service already, all pilot participants whose primary departments were within that college were assigned to use the eCAT product. Respondents who used the CERF product were comprised of researchers from: Chemistry, Engineering, Medicine and Public Health, and Pharmacy. See Figure 1 for more details.

Use of Information Technology

Pilot users were asked to rate their attitude towards information technology adoption in their research. Unequivocally, these researchers adopt technology cautiously, but do not actively resist. When benefits of a technology are clear, the majority of the ELN users will try the technology (CERF 80% and eCAT 67%). This attitude towards technology is consistent with the pre-pilot survey results (not shown) where 75% of respondents claimed they would try a new technology for their research as long as the benefits were clear.

Figure 1.
Pilot User Demographics (Frequencies)

		Total	CERF	eCAT
Respondents		32	20	12
Used ELN Before?	Yes	3	1	2
	No	28	18	10
Primary Role	Faculty	1	1	--
	Scientist	2	1	1
	Postdoc	5	2	3
	Graduate Student	18	14	4
	Other	6	2	4
Primary College/School/Department	Agriculture and Life Sciences	12	--	12
	Chemistry	6	6	
	Engineering	6	6	--
	Medicine and Public Health	7	7	--
	Pharmacy	1	1	--
Previous mode of Record	Paper Lab Notebook	27	18	9
	Digital Data Files	26	16	10
	Printouts of Data Files	17	10	7
	Software Tools	10	3	7

The majority of CERF respondents (90%) had never used ELNs before the pilot. (See Figure 1 for more details.) Similarly, only two of the eCAT users (17%) had ever used ELNs before the pilot. Overall, researchers more often used paper lab notebooks (84%) and digital data files (81%) compared to printouts (53%) and software tools (31%) for recording their research prior to the pilot--See Figure 1 for details. When asked what software they used, users named a range including Excel, Evernote, Google Docs and DropBox.

Research Modes

During the ELN pilot, the majority of CERF users (50%) spent more than 15 hours a week on the computer. Additional research modes for these users included: in the field (88% less than two hours per week); at the bench (62% less than ten hours a week); and at instrument facilities (83% less than 5 hours a week). During the pilot period, all eCAT respondents reported spending less than two hours per week doing research in the field and at instrument facilities (73%), while spending more than 10 hours per week at the bench (58%) and on the computer (58.3%). The most notable differences in research mode between CERF and eCAT users are more time spent at instrument facilities in the case of CERF users and more time spent at the bench by eCAT users during the pilot. See Figure 2 and Figure 3 for further detail about which modes of research users of CERF and eCAT used.

Figure 2.
Time Spent in Research Modes during Pilot by CERF Users

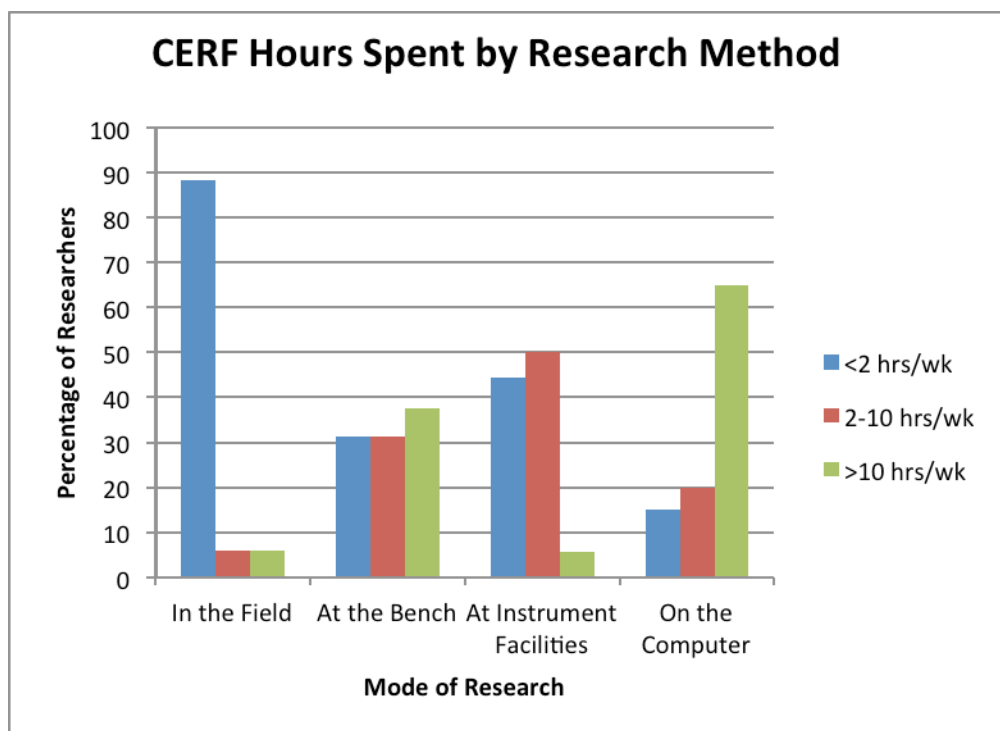
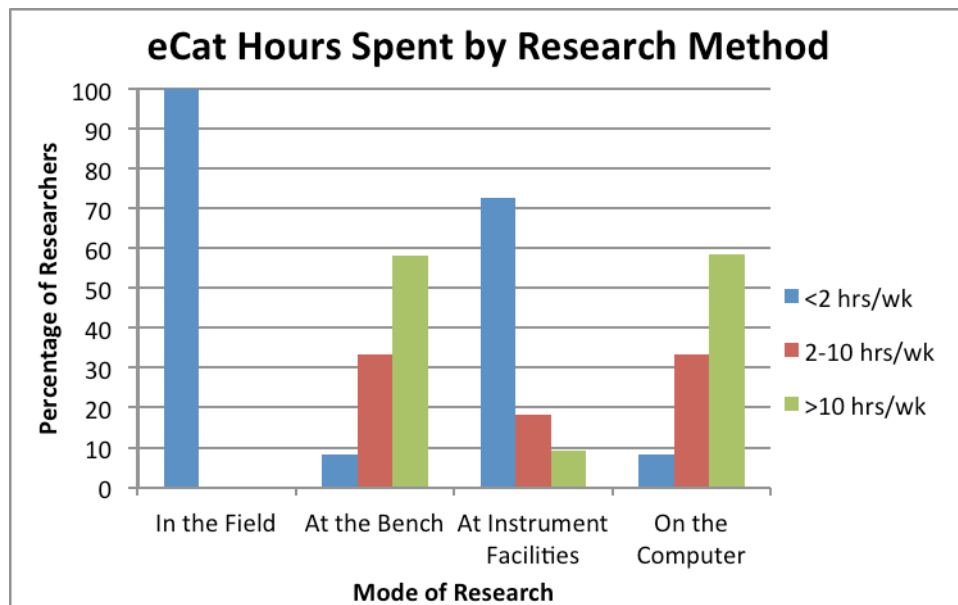


Figure 3.
Time Spent in Research Modes during Pilot by eCAT Users



Analysis of ELNs

Ease of Use

Researchers were asked to rate the ease of use of their ELN. All eCAT users reported that the pilot software was easy or somewhat easy to use. Ease of use for CERF users was more variable, with eight users (40%) reporting that the pilot software was somewhat easy and seven (35%) users reporting the pilot software as somewhat difficult or very difficult to use.

Learning how to Use the ELNs

Before the pilot, perspective participants were asked how much time they were willing to spend learning about the operation of the ELNs. The majority of respondents (88%) agreed that they would be willing to dedicate between one to twelve hours to learn the ELN. In reality, the majority of CERF and eCAT users spent less than 12 hours learning to use their respective ELNs (CERF 95%; eCAT 80%). Overall, most ELN users thought that was the right amount of time to dedicate to learning (66%), but 9% did say that that was not enough time.

Pilot participants were asked how useful they anticipated various learning methods would be before the pilot began. Respondents believed that training sessions (84%), online tutorials and documents (82%) and learning by trial and error on their own (82%) would be the most useful learning activities. At the conclusion of the pilot, participants rated training sessions (85%) and learning by trial and error (87%) as the most effective resources for learning to use an ELN. Online tutorials and documents, anticipated by researchers to be helpful, were reported as being useful by less than 60 percent of users. User reception of email/phone support and online user forums was lukewarm at best. Figure 4 details the breakdown.

Figure 4.

Pilot User Perception of Usefulness of ELN Learning Resources

		Anticipated	Post
Training Sessions	Useful	84%	85%
	Neutral	16%	9%
	Useless	--	6%
Online Tutorials and Documents	Useful	82%	56%
	Neutral	16%	34%
	Useless	2%	9%
Email and Phone Support	Useful	54%	28%
	Neutral	30%	69%
	Useless	16%	3%

		Anticipated	Post
Online User Forums	Useful	44%	13%
	Neutral	42%	78%
	Useless	14%	9%
Trial and Error	Useful	82%	87%
	Neutral	14%	9%
	Useless	4%	3%

Participants were also asked what would make learning an ELN easier on the post-pilot survey. Thirteen percent of respondents thought that the training process was just right and didn't think any changes needed to be made. The biggest suggestion (42%) from users was that the design/interface of the ELNs be changed before training is undertaken again (further information can be seen about this in the disadvantages section). Further, 21% of respondents suggested that the example be more "real-world" to the users so that applicability was clearer. Other recommendations from pilot users included adding group work (13%) and hands-on training (8%).

Flexibility and Customization

Before taking part in the pilot, users were asked to anticipate which type of ELN best fits their research needs in terms of flexibility and customization. This was important since a goal of the pilot was to learn if a single ELN would be useful to researchers across the wide range of scientific disciplines on campus and if they could customize the interface to suit their needs. At the time we began the pilot, studies indicated that uptake of ELNs in the private sector was often dependent on a custom ELN interface that fit with the sub-disciplinary area of the researcher (Elliott, 2010). Most participants anticipated that a generic user interface that allows features and tools to be added as needed would best fit their research needs (45%). A quarter (25%) of respondents anticipated that a user interface that they could customize themselves before use would work better in their research context. Very few researchers anticipated that an ELN already customized to their research type would be the best fit for them (14%). At the end of the pilot, participants were asked the same question. These researchers found, in agreement with their predictions, that a generic interface that allowed tool and features to be added as needed was the best fit (44%). Twenty-two percent of users reported that an interface they could customize before use was ideal and few (16%) thought that a pre-customized ELN was what they needed. There is no evidence that researchers in our study held any expectations that they would be using ELNs designed for a given domain of scientific research. There is consensus, though, that customization—whether done before use or in an ad hoc manner—is important to these researchers.

Pilot users were asked to consider their needs for flexibility and customization and then rate their ELN. Users of CERF and eCAT agreed that the basic functionality of their respective ELNs were about right (CERF 60% and eCAT 75%). eCAT users were happier with the amount of additional features (50%) than were CERF users

(30%), though a significant number of researchers believed there were not enough (CERF 40%; eCAT 25%). Overwhelmingly, eCAT users were happier with their ability to customize (58%) than CERF users (15%). Forty percent of CERF users did not believe that there was enough ability to customize whereas only 17% of eCAT pilot users thought there was not enough customization. Fifty percent of eCAT users but only 17% of users found that their ELN fit their research without customization. Overall, eCAT seemed to be the preferred ELN for flexibility and customization. Further details can be seen in Figure 5.

Figure 5.
Pilot User Perception of ELN Flexibility and Customization

		CERF	eCAT
Basic Functionality	Too Much	15%	--
	Right Amount	60%	75%
	Not Enough	15%	17%
	Neutral	10%	8%
Additional Features	Too Much	10%	8%
	Right Amount	30%	50%
	Not Enough	40%	25%
	Neutral	20%	17%

		CERF	eCAT
Ability to Customize	Too Much	10%	8%
	Right Amount	15%	58%
	Not Enough	40%	17%
	Neutral	35%	17%
Fits Research Without Customization	Too Much	--	--
	Right Amount	17%	50%
	Not Enough	44%	42%
	Neutral	39%	8%

Disadvantages

Users were asked to predict what disadvantages they would face during the pilot. Many of those responding were concerned that the ELN would not handle data types important to them or generate types of data necessary for their research (28%). Some respondents (17%) also questioned the ELN’s ability to draw representations correctly, generally because of a lack of sophisticated drawing tools. Finally, some respondents (15%) were concerned about possible technical issues such as compatibility, software updates, or glitches.

When users were asked after the pilot to list the disadvantages of the ELNs, a quarter of the respondents, mostly CERF users, reported technical glitches/bugs as the biggest issue. Time was also a concern for a quarter of the respondents. Some reported this in terms of time to learn the software while others said keeping duplicate notes (paper and electronic) to ensure archival of notes was very time consuming. As in the pre-survey, respondents to the post-survey reported that interface issues such as navigation, layout, and lack of flexibility were a disadvantage (21%) for both ELNs.

Features and Functionality

In the pre survey, researchers were asked to think about the features and functionality of their ELN. Across the board, the anticipated usefulness of features and functionality was very high. In fact, eleven of the fourteen components (see Figure 6 for breakdown) were ranked as “somewhat useful,” “useful,” or “very useful” by 86% or more of the respondents. Overall, it appears that mobile use (63%) was perceived as the least useful component while simple drawing tools (77%) seemed moderately useful. After the completion of the pilot, researchers were far less enthusiastic about the usefulness of many of these features. In the post-pilot survey only two features scored above 70% for usefulness: adding data files (80%) and adding links (86%). The remainder of the features dropped significantly in the post survey, some as much as 70% (see Figure 6 for details).

Figure 6.
Pilot User Perception of ELN Features and Functionality

		Anticipated	Post*
Interface	Useful	96%	70%
	Neutral	2%	13%
	Useless	2%	17%
Templates	Useful	96%	69%
	Neutral	--	14%
	Useless	4%	17%
Simple Drawing Tools	Useful	77%	12%
	Neutral	14%	48%
	Useless	10%	40%
Add Data Files	Useful	98%	80%
	Neutral	--	10%
	Useless	2%	10%
Add Links	Useful	94%	86%
	Neutral	2%	14%
	Useless	4%	--
View Data Files	Useful	92%	68%
	Neutral	6%	16%
	Useless	2%	16%
Ability to Annotate	Useful	90%	45%
	Neutral	6%	31%
	Useless	4%	24%

		Anticipated	Post
Ability to Search	Useful	98%	71%
	Neutral	--	23%
	Useless	2%	6%
Use on Mobile Device	Useful	63%	36%
	Neutral	12%	50%
	Useless	25%	14%
Ability to Print	Useful	92%	54%
	Neutral	8%	32%
	Useless	--	14%
Ability to Collaborate	Useful	86%	53%
	Neutral	10%	29%
	Useless	4%	18%
Access ELN Outside Lab	Useful	94%	66%
	Neutral	4%	30%
	Useless	2%	4%
Use ELN Offline	Useful	92%	33%
	Neutral	6%	43%
	Useless	2%	24%

However, there was some demarcation between the post-pilot respondents. At least three-quarters (75%) of eCAT respondents found that templates, ability to view data files in the ELN, search, the interface, access the ELN outside of the lab, and ability to add data files and links were useful features. In contrast, the same proportion of CERF users only agreed that adding data files and links to the ELN were useful. Figure 7 shows the rank order of various features usefulness, by ELN. CERF and eCAT users agreed that drawing tools and using the ELNs offline were not useful. What remains to be seen is whether some of these features would improve in perceived usefulness for these users over a longer period of use and among researchers in other disciplinary areas where drawing and offline access, for example, are more important —this may be an area for further study. For the most part, we do not know whether the features were rated as less useful because they didn't work as desired or if they were not relevant to users' research during the pilot. However, because we had fairly close contact with the participants during the pilot we do know that mobile versions of both eCAT and CERF were tested or testing was attempted but found lacking. In addition, two CERF users indicated in an open-ended question on the post-pilot survey that the ability to have it loaded and usable on a tablet would have made it easier to learn. Also, we heard from several chemists who attempted to use chemistry tools included in CERF for drawing, viewing, annotating, and searching chemistry data files and did not find them satisfactory. In general it appears that neither ELN met the needs for use on a mobile device or drawing tools, but when considering features and functionality overall, eCAT has a more favorable rating by pilot researchers.

Figure 7.
User Perception of Usefulness of ELN Feature and Functionality

CERF		eCAT	
Add Links	94%	Templates	92%
Add Data Files	84%	View Data Files	92%
Interface	61%	Ability to Search	92%
Ability to Search	58%	Interface	83%
View Data Files	53%	Access ELN Outside Lab	83%
Templates	53%	Add Data Files	75%
Access ELN Outside Lab	53%	Add Links	75%
Ability to Print	47%	Ability to Collaborate	72%
Ability to Annotate	44%	Ability to Print	64%
Ability to Collaborate	41%	Use on Mobile Device	50%
Use on Mobile Device	25%	Ability to Annotate	45%
Use ELN Offline	20%	Use ELN Offline	25%
Simple Drawing Tools	12%	Simple Drawing Tools	13%

Data Management

Compared to the evident enthusiasm about the usefulness of features and functionalities of the ELNs, users were more cautious about the potential of an ELN for improving data management on the pre-pilot survey. The majority of respondents stated they were confident that the ELN could: make it easier to search for data (84%), easily retrace research flow (77%), keep track of data for several years (75%), and annotate and tag data easily (73%). Fewer were confident about the potential for an ELN to: track what was done to create different versions of data (68%), keep all research records and data in one place (66%); improve data management (64%); control versions of data (66%), or capture metadata (64%). Participants were somewhat uncertain/neutral about the potential for ELNs to: make it easier to share data with collaborators (61%) or track contributions by collaborators (39%). Uncertainty about the potential of ELNs as data management tools was also a theme in responses to an open-ended question about possible disadvantages of using an ELN to record research in the pre-pilot survey. Nineteen percent of respondents expressed concern about retention of data they would be entering in the ELN and questioned the reliance of the system to record everything properly and then safely maintain the data for an undetermined period of time.

At completion of the pilot, users were asked to reflect on how well their ELN provided data management in the same categories. As was seen with ELN features, user perceptions generally shifted down in this area (see Figure 8 for break down). Two of the data management items anticipated to be most useful had large drops in user ratings. These included the ELN's ability to easily retrace research flow, which received a 77% pre-pilot confidence rating but declined to 44% at the end of the pilot. The second item in this category was confidence in the ELN's ability to tag and annotate, which dropped from 73% to 44%, a nearly thirty percent drop for both eCAT and CERF users. In both of these items, the drop was due to an increase in neutral and negative opinions, suggesting that some users were disappointed in the ELN's support for these activities while others may not have tried or needed to use these features during the pilot.

Only 64% of respondents were confident the ELN would improve data management at the start of the pilot and this declined to only 34% at the end of the pilot. This was due primarily to a large decrease in agreement by

CERF users (20%); 58% of eCAT users agreed that their ELN improved data management after the pilot. (See figure 9.) It is likely that the term “data management” may not have resonated with the respondents in the intended way; i.e. anecdotal discussions with some researchers after the survey suggest that many may regard data files and lab notebook entries as distinct entities. We are investigating this possibility further.

The ELN’s ability to allow easier searching of past work was the highest rated item on the pre-survey (84%): it also decreased between pre- and post-pilot respondents using either product (60% for CERF and 58% for eCAT users). Again, an increase in neutral as well as negative ratings for this item may suggest both disappointment in the ELN as well as limited relevance of searching during the pilot. Searching may be relevant only once a researcher has accumulated enough material in the ELN to make it useful; three months may not have been an adequate time frame for this.

For some data management categories that were anticipated to be less useful at the start of the pilot, changes in user perceptions were more variable at the pilot’s end. For example, both CERF and eCAT users were less confident about their ELN’s ability to let them keep data all in one place (45% for CERF 50% for eCAT) compared to 66% of pre-pilot respondents. On the other hand, eCAT user ratings of their ELN as a way of keeping track of data for several years remained the same at the end of the pilot as the level of confidence at the start (75%) while CERF users’ confidence in this category decreased (55%) by the end of the pilot.

Only about half of both eCAT and CERF users indicated that they shared data with collaborators during the pilot (not shown). This explains, in some part, the relatively neutral ratings for data management activities such as sharing data (47%) and tracking the contributions of individuals (66%) by both types of users in the post-pilot survey, although eCAT users were more positive about their ELN as a tool for sharing data (58%). Anecdotally, we learned that some participants using eCAT were successfully sharing data during lab meetings while several CERF users were attempting to share data with mixed results. Finally, two additional data management functions of ELNS that were anticipated to be of low value at the start of the pilot; i.e., the ability to capture metadata and control versions of data, received more neutral to negative ratings at the end of the pilot, suggesting that for some users, as predicted, these features were not used or needed during the pilot and for others that the ELN did not provide satisfactory functionality in these areas.

Taken together, the user ratings of data management capabilities suggest some dissatisfaction with ELN capabilities, some uncertainty about the value of the data management activities as described in the survey questions, and may indicate that some of the data management activities detailed in the survey questions were not important or useful during the pilot but might be important to users over longer time periods. We are currently investigating these areas in more detail.

Figure 8.

Pilot User Rating of ELNs as Data Management Tool; Comparison of User Confidence (Pre) versus Conclusion (Post)

		Anticipated	Post
Improve Data Management	Confident/ Agree	64%	34%
	Not Sure/ Neutral	27%	22%
	Not Confident/ Disagree	9%	44%
Keep All Data in One Place	Confident/ Agree	66%	47%
	Not Sure/ Neutral	20%	22%
	Not Confident/ Disagree	14%	31%
Keep Data Over Several Years	Confident/ Agree	75%	63%
	Not Sure/ Neutral	16%	25%
	Not Confident/ Disagree	9%	13%
Easier Version Control	Confident/ Agree	66%	41%
	Not Sure/ Neutral	27%	34%
	Not Confident/ Disagree	7%	25%
Easier to Track Changes in Versions	Confident/ Agree	68%	37%
	Not Sure/ Neutral	27%	44%
	Not Confident/ Disagree	5%	19%
Annotate and Tag Data Easily	Confident/ Agree	73%	44%
	Not Sure/ Neutral	25%	34%
	Not Confident/ Disagree	2%	22%

Figure 8., Continued

		Anticipated	Post
Easier to Capture Metadata	Confident/ Agree	64%	37%
	Not Sure/ Neutral	36%	41%
	Not Confident/ Disagree	--	22%
Contribution Tracking	Confident/ Agree	39%	28%
	Not Sure/ Neutral	59%	66%
	Not Confident/ Disagree	2%	6%
Easier to Search for Data	Confident/ Agree	84%	59%
	Not Sure/ Neutral	16%	34%
	Not Confident/ Disagree	--	6%
Easier to Retrace Research Flow	Confident/ Agree	77%	44%
	Not Sure/ Neutral	23%	41%
	Not Confident/ Disagree	--	16%
Easier to Share Data	Confident/ Agree	61%	41%
	Not Sure/ Neutral	34%	47%
	Not Confident/ Disagree	5%	13%

Figure 9.

User Perception of ELN’s Data Management Ability

CERF		eCAT	
Easier to Search for Data	60%	Keep Data Over Many Years	75%
Keep Data Over Many Years	55%	Improve Data Management	58%
Annotate and Tag Data Easily	45%	Easier to Share Data	58%
Keep All Data in One Place	45%	Easier to Search for Data	58%
Easier to Retrace Research Flow	40%	Keep All Data in One Place	50%
Easier Version Control	35%	Easier Version Control	50%
Easier to Capture Metadata	35%	Easier to Retrace Research Flow	50%
Contribution Tracking	30%	Annotate and Tag Data Easily	42%
Easier to Share Data	30%	Easier to Capture Metadata	42%
Improve Data Management	20%	Contribution Tracking	25%

Record Keeping

Records kept in paper lab notebooks are important documents that serve as evidence of inventor-ship and authorship for patents and publications in many labs. ELNs offer features such as time stamping and versioning that can automate the capture of signatures, dates, and amendments, providing an audit trail. Before the pilot, ELN users were asked how useful they anticipated various record keeping functions would be. Generally speaking, the majority of users anticipated the ELN’s record keeping ability would be useful, especially the ability to store data in unaltered forms, keep alterations as new versions, time stamping, and the ability to tag corrections as changes (79% or more of respondents reported these features as useful). Fewer respondents (64%) agreed that the ability to electronically sign ELN records was useful. And only half the respondents (52%) saw the ELN’s ability to allow for electronic signatures of witnesses as a useful function, but only eighteen percent saw it as useless, demonstrating that there was a fairly ambivalent (30%) opinion about this functionality. See Figure 10 for detailed breakdown.

At the conclusion of the pilot, there were relatively small changes in user perceptions of the usefulness of records keeping features (all measures changed by no more than 9%), with three exceptions. Agreement with the usefulness of secure access, as implemented in the ELN, increased by 13%. On the other hand, users were more uncertain about the usefulness of electronic signatures and witness signature; both categories saw roughly a 25-27% jump in the neutral category in the post-pilot survey. After using the ELN for three months, users were more apt to have no strong opinion about these functions. This corresponds with anecdotal reports from users that signing and witnessing were not tested during the pilot. Overall, these differences in user perceptions of the usefulness of record keeping features between the start and end of the pilot may be attributable to the types of research undertaken during the pilot period, the degree to which compliance with records keeping practices were stressed in the user’s lab, or other reasons.

Figure 10.

Pilot User Perception of ELN Record Keeping Ability

		Anticipated	Post
Secure Access to Data	Useful	64%	77%
	Neutral	30%	16%
	Useless	7%	6%
Data Stored in Unaltered Form	Useful	86%	87%
	Neutral	11%	13%
	Useless	2%	--
Alterations Stored as New Versions	Useful	86%	81%
	Neutral	9%	16%
	Useless	5%	3%
All Entries are Time-Stamped	Useful	79%	74%
	Neutral	12%	19%
	Useless	9%	6%

		Anticipated	Post
Corrections are Tagged as Changes	Useful	80%	71%
	Neutral	11%	23%
	Useless	9%	6%
Records can be Electronically Signed	Useful	64%	48%
	Neutral	20%	45%
	Useless	16%	6%
Records can be Co-Signed by Witness	Useful	52%	37%
	Neutral	30%	57%
	Useless	18%	7%

A comparison between CERF and eCAT opinions of the usefulness of record keeping features as implemented in their ELN shows that both types of users saw record keeping as a strength of their respective ELN, rating the elements high in usefulness. The fact that data was stored in unaltered form was perceived as very useful (CERF, 80% and eCAT, 100%) as was the fact that data alterations were stored as new versions (CERF 80% and eCAT 100%). The secure access to data was also well regarded by researchers (CERF, 68% and eCAT 92%). As noted previously, both ELN's ability to allow for electronic signing and witness co-signing seemed to be viewed as less important. Overall it appears that there is a favorable opinion of both ELNs record keeping ability amongst the pilot researchers. Further details can be seen in Figure 11.

Figure 11.

User Perception of ELN Record Keeping Ability

CERF	
Alterations Stored as New Versions	80%
Data Stored in Unaltered Form	79%
All Entries are Time-Stamped	74%
Corrections are Tagged as Changes	74%
Secure Access to Data	68%
Records can be Electronically Signed	53%
Records can be Co-Signed by Witness	47%

eCAT	
Data Stored in Unaltered Form	100%
Secure Access to Data	92%
Alterations Stored as New Versions	90%
All Entries are Time-Stamped	75%
Corrections are Tagged as Changes	67%
Records can be Electronically Signed	42%
Records can be Co-Signed by Witness	18%

Overall Quality of ELN Records

Pilot users were asked to compare the quality of records they produced using the ELN to those using their previous method of recording their research. Across questions, CERF users believe that the quality of the records provided by the ELN was comparable to their traditional methods. eCAT users, on the other hand, believe that use of the ELN created better quality records overall than their previous method of record keeping, with the greatest improvements in the areas of recording methods and in the quality of record organization. Further details can be seen in Figure 12.

Figure 12.

Pilot User Perception of ELN Quality

		CERF	eCAT
Overall Quality of Records	Better	35%	75%
	Same	30%	17%
	Worse	20%	8%
Quality of Records Methods/Procedures	Better	20%	58%
	Same	50%	33%
	Worse	15%	8%
Quality of Records Results/Data	Better	15%	42%
	Same	45%	50%
	Worse	25%	8%
Quality of Records Analysis/Conclusions	Better	20%	50%
	Same	50%	42%
	Worse	15%	8%
Quality of Record Organization	Better	25%	75%
	Same	30%	8%
	Worse	20%	17%

*Response totals are < 100% for some categories because the survey had a “neutral” selection (not shown).

Continued Use of ELN

The exceptionally high anticipation scores participants gave features and functionality (see Figure 6) and record-keeping ability (see Figure 10) at the start of the pilot can be taken as evidence that the researchers see the potential value in ELNs. Although users appeared disappointed with some features and, potentially, with data management capabilities of the ELNs by the end of the pilot, the perceived value of ELNs to their research appeared to diminish only slightly by the end of the pilot, as shown in Figure 13. When users were asked to describe their ongoing interest in using an ELN at the end of the pilot, 91% of all users indicated they wanted to continue using an ELN for their research. Only three participants, all CERF users, replied that they no longer wanted to use an ELN. Most eCAT users (83%) said they would like to continue using that ELN while only 25% of CERF wanted to continue using their ELN now or in the future. Sixty percent of CERF users responded that they would like to use another ELN now or in the future.

Figure 13

Pilot User Interest in Using an ELN

	CERF	eCAT
I would like to continue using the same ELN	20%	83%
I would like to try a different ELN	45%	8%
I would like to use the same ELN sometime in the future	5%	8%
I would like to try a different ELN sometime in the future	15%	—
I do not want to use an ELN	15%	—

Time Spent Recording Research in the ELN

Pilot participants were asked how much time they spent per week, on average, recording and documenting their research in the ELN during the pilot. Figure 14 shows that most eCAT users (75%) spent between two to five hours with a smaller proportion (17%) reporting this time as between five to ten hours per week. CERF users generally spent less time recording in their ELN: Sixty-five percent said they spent less than two hours per week recording in the ELN, and fewer reported spending closer to two to five hours per week (25%) or five to ten hours per week (5%). No participants reported spending more than ten hours per week on this; however, a few individuals were not able to estimate the amount of time spent.

Figure 14

Time Spent Recording Research in ELN During Pilot

	CERF	eCAT
Less than 2 hours/week	65%	—
2-5 hours/week	25%	75%
5-10 hours/week	5%	17%
10-15 hours/week	—	—
More than 15 hours/week	—	—
Not sure or can't estimate	10%	8%

Participants were asked to compare the amount of time recording their research in the ELN to the amount they spent recording their research using prior methods. Responses by both types of users shown in Figure 15 indicate a wide variance, suggesting that while some indicated the times were about the same, a nearly equal number of users indicated that recording in an ELN took more or less time than prior methods. This trend

suggests individual variation may exist in several areas: comfort with new technologies, type of research done during the pilot versus prior to the pilot, expectations about the appropriate amount of time to spend documenting research in different disciplinary areas, as well as each user’s overall satisfaction with the ELN used.

Figure 15
Comparison of Time Spent Recording Research in ELN Versus Prior Method

	CERF	eCAT
A lot more time	25%	17%
A bit more time	10%	17%
About the same	25%	33%
A bit less time	10%	17%
A lot less time	25%	17%
Not sure or can’t estimate	5%	—

Technical Evaluation

Both CERF and eCAT were hosted on campus servers in virtualized environments. Architecture for both included separate application, database, and file servers. The eCAT product was designed and run as a self-contained system (application, database, and data storage in one virtual machine) which was replicated to another “live” virtual machine for failover capability. Both systems backed up to secure servers to provide disaster recovery of data entered into the system. Users were urged to back up their data and keep dual records by either printing pages from the ELN or recording alongside in a paper notebook to protect against data loss during the pilot.

The CERF product is a Java client and integration with enterprise identity management was investigated but determined to be beyond the scope of the pilot. Since eCAT is a web based product, Shibboleth integration was achieved by redirecting all requests to a secure connection, and requiring a valid NetID login before allowing users through to the secondary eCAT authentication layer.

Because of the limited number of users in the pilot, we did not have an opportunity to test the scalability of the systems beyond 30-40 users. The eCAT 4 system is designed to accommodate 100 users per server and the CERF 4.5 system was designed to accommodate a larger number of users per server.

Future Prospects for ELNs

Interest in a Campus ELN Service

The pilot results demonstrate that at least one commercially available ELN was useful for researchers in CALS. Although all researchers in that group are life scientists, they represent somewhat diverse sub-disciplines within the domain: organismal (e.g., Animal Science), environmental (e.g. Soil Science), agricultural (e.g., Horticulture), and cellular/molecular (e.g. Biochemistry). It seems likely that this ELN, eCAT, is generic enough to be useful to many of the researchers from the School of Medicine, Pharmacy, and Engineering who used

CERF during the pilot. However, chemists may represent a unique population requiring a more specialized ELN and/or tools within the ELN. It will be important to track developments in the ELN market to find an affordable product that offers reliable chemistry tools. However, we note that the use of a separate product by chemists will likely limit the collaborative abilities with collaborators use different software.

The interest in ELNs on campus is substantial. At the time we were recruiting for the pilot, a large number (137) of individuals expressed an interest in participating. At the start of the pilot, participants expressed high levels of confidence about the usefulness of ELN for record keeping and the value of features and functionalities of ELNs. Although participants were disappointed with some of the features and experienced glitches with both tools, confidence in ELNs as tools for record keeping remained high at the end of the pilot, with users of both ELNs. The majority of all participants wanted to continue using an ELN at the end of the pilot. In addition, team members on this project have heard interest in ELNs from other researchers at events covering data management, lab notebooks, new faculty orientation, and other types of campus events.

Based on the ELN pilot results and the growing interest from other researchers, we are developing a business/funding model for a campus ELN service, in collaboration with the pilot sponsors and the executive advisory group.

Challenges

Both of the ELNs in the pilot fell short when participants tried to use them on mobile devices. Anecdotal comments and responses to open-ended survey questions indicate that this is an important feature to a subset of researchers and may become increasingly important for those who work in the field or need to record information at the bench where use of laptops is not feasible. To better serve researchers in higher education, commercial ELN offerings need to provide better mobile applications that allow data entry from various locations.

Paper lab notebooks are a centuries-old format for recording and documenting research data. However, in this pilot, some participants were fairly uncertain about the potential of an ELN for data management, with some voicing concerns in open-ended survey questions about the ability of an ELN to collect many data types and retain it for long periods. To be a reliable alternative to paper lab notebooks, a future ELN service will need to demonstrably meet the expectations of researchers for uptime, security, and long-term preservation and access to data, and establish itself as a way for researchers to satisfy both campus and funder requirements for data stewardship.

Costs represent a major challenge in a future ELN service. The cost of ELN software is highly variable and not insignificant, even for the most inexpensive software in our RFI/RFP evaluations. In addition the cost of infrastructure for hosting, backing up, archiving ELN records could be substantial. A lab may currently spend up to \$100/year/researcher buying paper lab notebooks (Carpenter, 2012); providing an electronic system to replace paper notebooks will almost certainly be more expensive, even if efficiencies can be achieved at scale. This disparity between the cost of paper and electronic systems may be better addressed by considering the risks of keeping valuable research data in fragile paper formats or in fragmented systems that inadequately meld digital files and paper records.

References

1. Butler, Declan. 2005. Electronic Notebooks: A New Leaf. *Nature*, 436 (7047), 20-21.
2. Carpenter, Siri. September 14, 2012. Must a Paper Trail Be Paper? *Science Careers*. http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2012_09_14/caredit.a1200103
3. Elliott, Michael H. December 2010. Fourth Electronic Laboratory Notebook Survey. Atrium Research & Consulting,
4. Giles, Jim. 2012. Going Paperless: The Digital Lab. *Nature*, 481 (7382), 430-431.
5. Mackay, Wendy et al. 2002. The Missing Link: Augmenting Biology Laboratory Notebooks. In *Proceedings of the 15th annual ACM symposium on User interface software and technology* (UIST '02). ACM, New York, NY, USA, 41-50. <http://doi.acm.org/10.1145/571985.571992>
6. Robson, David. December 2006/January 2007. ELNs in Action, *Scientific Computing World*. http://www.scientific-computing.com/features/feature.php?feature_id=52
7. Rudolphi, Felix and Gossen, Lukas J. 2012. Electronic Laboratory Notebook: The Academic Point of View. *Journal of Chemical Information and Modeling*, 52 (2), 293-301.