

CyberTracker in BioKIDS: Customization of a PDA-based scientific data collection application for inquiry learning

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Introduction

This paper documents our efforts to customize CyberTracker--a PDA application originally designed for conservation biology data collection--for use within an inquiry learning environment: the BioKIDS curriculum. We provide background for our approach and describe both the initial and current versions of the customized application. We focus on three design choices we made and how they represent multidisciplinary tradeoffs. Finally, we reflect on how this tool meets the needs of the overall curriculum and how it may be helpful more broadly.

Handheld technology in education

Handheld computers, or personal digital assistants (PDAs) are rapidly finding a place in the classroom. In a recent study, 102 teachers received PDAs from Palm, Inc (Crawford, et al., 2002). Students used the PDA as an organizational tool, for quizzes or writing activities, or for collecting data in field activities or lab settings. Teachers who used handhelds for inquiry-based instructional activities were more positive about the benefits of handhelds than the group as a whole (Crawford et al., 2002, p 18). These general findings on the pioneering efforts of these teachers are exciting, but little detail is available on any one project or the learning that ensued. Very little research exists so far on the effectiveness of PDA for specific educational practices, and even less on how to custom-design PDA applications for an education audience.

Advantages of handheld data collection for inquiry learning

One promising use of PDAs is handheld data collection by students. User interface research suggests selecting from menus and icons can be more efficient than text entry, because users only need to recognize the item they want instead of remembering it (Preece et al., 1994). Furthermore, data collection using handheld computers has been shown to be a faster and most accurate method for transferring data than paper-based methods, including scantron forms (Hecht, 1997; Spain et al., 2002). Data entry via a pen-based PDA can even reduce technology anxiety compared to other forms of computer-aided data collection (Tsenge et al., 1998). Recognizing these advantages, professionals in a variety of settings are using handheld computers for efficient and accurate data collection (e.g., Weber & Roberts, 2000; Greene, 2001; Hampshire, 2001).

We propose that handheld data collection using customized PDA software can foster inquiry learning. When students are allowed to focus on content instead of logistics, they develop stronger understandings of the content (Thornton & Sokoloff, 1990; Brasell, 1987). If students do not have to worry about the format of the data they collect, they may be able to focus instead on what those data represent. PDAs should allow students to “employ simple equipment and tools to gather data and extend the senses” and “use appropriate tools and techniques to gather, analyze, and interpret data” (National Research Council, 1996). This use of PDAs highlights how “technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations” (National Research Council, 2000).

BioKIDS: Kids' Inquiry of Diverse Species

Now in its second year, the BioKIDS project explores how best to provide technology-rich, inquiry-focused life science instruction in urban elementary schools (<http://www.onesky.umich.edu/site/biokids.html>). It is vital to our inquiry goals that students collect authentic data using authentic methods, and then analyze and interpret their data. As such, the eight-week fifth and sixth grade curriculum includes collecting field data on animals in schoolyards, examining species patterns and distribution, and developing individual species accounts. Through these engaging

activities students will gain a clearer understanding of how organisms meet their basic needs and the role the environment plays in supporting a variety of organisms. A second goal of our project involves addressing how interdisciplinary teams can transform scientific resources in order to foster student questioning, collaboration, and reflection; CyberTracker is one such resource. A third goal is to consider how our technology fosters scalability.

Multidisciplinary tradeoffs

The following scenario illustrates the multidisciplinary nature of the BioKIDS project. A teacher takes her class out to her schoolyard to gather biological data – wildlife observations – using cutting-edge technology in a way that should foster their inquiry skills. Her students may later become involved in NatureMapping (<http://www.fish.washington.edu/naturemapping/>), a citizen science effort where non-scientists collect valuable data on natural resources that will later be used by scientists. Thus, we are concerned with real-world biological data (biology), using technology that must be usable by non-scientists (information technology), in a classroom context paying particular attention to inquiry-learning techniques (education). Furthermore, we must meet challenges in all three disciplines in a way that is scalable.

The major biological design issue is what data to collect. Some variables will be too difficult or time-consuming for students to measure, or may not be useful for classroom activities. At the same time, certain variables will be essential to support understanding of basic ecological principles, such as relationships between habitat and species distributions or diversity. Classrooms may contribute their observations to other monitoring efforts, so variables chosen should be consistent with real-world requirements.

The major design issue relating to education is how to foster inquiry. Unlike biological data collection by scientists, the methods by which the data are collected may influence what students learn about biology. We need software designs that encourage students to focus their observations, to question what they are seeing and how they know what they are seeing, to begin to make connections between kinds of data, to share their observations with other and knit them together into larger understandings of how things work.

Ideally, technology supports the needs of both accurate biology and effective inquiry learning. The major technology design issue is usability. How can we make the technology engaging, authentic, and powerful (meeting goals of biology and education), yet easy to learn and use (meeting goals of usability)? Obviously trade-offs will be necessary, as the complexities of biology and inquiry tasks may be at odds with ease of learning and usability.

Initial Design

CyberTracker software

South African conservation biologists created CyberTracker so that highly skilled but illiterate native trackers could systematically record field observations on wildlife preserves (<http://www.cybertracker.co.za/>). This application is available under a “Greenware” policy; software may be downloaded and used without charge by projects that benefit conservation.

The CyberTracker application includes a Windows-compatible desktop environment that, among other things, is used to customize and install a sequence of data entry screens onto handheld computers running Palm OS. In this paper we refer to the “CT desktop” as those parts of the application running in the Windows environment and the “sequence” as the program loaded onto the PDAs. We used version 2.5 of the CT desktop. Some icons and lists come from the Shikari sequence distributed by the North American group, Wilderness Awareness School (<http://www.natureoutlet.com/cybertracker>) though our sequence differs substantially.

The CT desktop provides all the tools necessary to construct custom-made sequences for recording field observations. Observation data to be queried and visualized in table or map form (using built-in GIS capability). Data can also be exported in a wide variety of formats for use in other programs.

A CT sequence consists of the interface on a handheld computer, or Personal Digital Assistant (PDA), such as a Palm Pilot or Handspring Visor. CT does not rely on text entry, but allows users to choose among preset options, usually indicated by icons. However, text can be displayed and entered if desired.

We chose CyberTracker for our handheld data collection software for three main reasons. First, we could maximize our own programming resources by customizing a product already known to work. Second, CyberTracker’s icon-based approach seemed well suited to our end users, fifth and sixth graders. Third, we believed our pilot audience,

at-risk children in Detroit and their teachers, would be motivated by the knowledge that they were using the same software as trackers and conservation biologists in Africa.

Exporting and uploading data

Transferring sightings data from the PDA to the CT desktop environment simply involves hot-syncing the PDA (placing it in the cradle and pressing the sync button). Data are permanently removed from the PDA.

The CT desktop provides a rich set of tools for data analysis, but we judged this environment unnecessarily complex for our purposes. Currently, the CT desktop dangerously combines the ability to alter the sequence and data structures with the ability to view and manipulate data. Therefore, we set up a single query of the collected data. Teachers follow simple instructions to export the data to a comma-delimited text file. Then, a web page guides teachers to upload these comma-delimited files to our server where they are processed for display (details below).

Initial Sequence Design: All you need and more!

Our first round of development produced a sequence that offered much flexibility to teachers. We included three screens for recording weather data, several ways to enter location information (including latitude and longitude) and two ways to enter habitat codes – entering a three digit code or choosing from a series of nested menus covering 28 habitat codes. After screens to record an animal identification, we offered four optional screens from a single branching menu: population data (number of males, females, juveniles), behaviors (feeding, drinking, etc), microhabitats (a list of 21 choices), and sign data (for users to indicate what animal signs they observed, such as webs, feathers, hairs, nests, or scratches). We wanted to allow a class to collect data for any specialized interest they might develop over the course of the curriculum. For example, if they wanted to explore where spiders build webs, they'd be able to by examining sign data in the context of microhabitat.

Preliminary User Testing

The preliminary BioKIDS CT sequence was used by approximately 100 students in three southeastern Michigan elementary schools in Fall 2001, during a four-week pilot test of the partially completed BioKIDS curriculum. Students used the handhelds only during specific BioKIDS curricular activities and did not take the devices home.

Ad hoc observations suggested that this sequence, while very flexible, presented too many optional and usually unnecessary screens to users. Users had difficulty navigating optional branches – choosing OK was intended to bring a user back to the branch point so they could choose another option, while choosing STOP would end a record for a particular animal and allow the start of a new observation. Users were not sure which choice to make, and in some cases avoided STOP and instead backed up through the sequence to record a new observation. This resulted in lost data. Three digit number entry screens posed a problem for users—they often entered 100 rather than 001 when recording that they saw one animal.

Current Design

Current Sequence Design: Streamlined

Our second round of development focused on streamlining the sequence to make it as linear as possible. We pruned away options that were not used within the curriculum but included limited flexibility by allowing users to skip two screens they may not need to use. We added more icons and modified others.

The sequence begins with a start screen shown in Figure 1. The four icons along the top row lead to “state” screens. Data entered here are expected to remain unchanged throughout a field session.

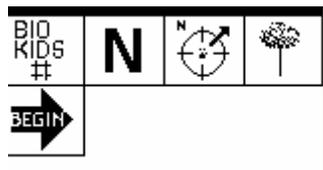


Figure 1. Start screen. Within the BioKIDS sequence, four kinds of information are requested at the start of each data collection session. From left to right, BioKIDS# icon: identifying number for the class. N icon: a tracker name (from a pre-set list). Compass icon: zone in the schoolyard. Tree icon: habitat classification. To select each screen, the user taps on the icon and taps on a right arrow cursor at the bottom of the PDA screen.

Next, users begin recording an animal observation by tapping the BEGIN arrow icon on the start screen. Figure 2 illustrates the linear sequence of screens a user sees as they step through the sequence.

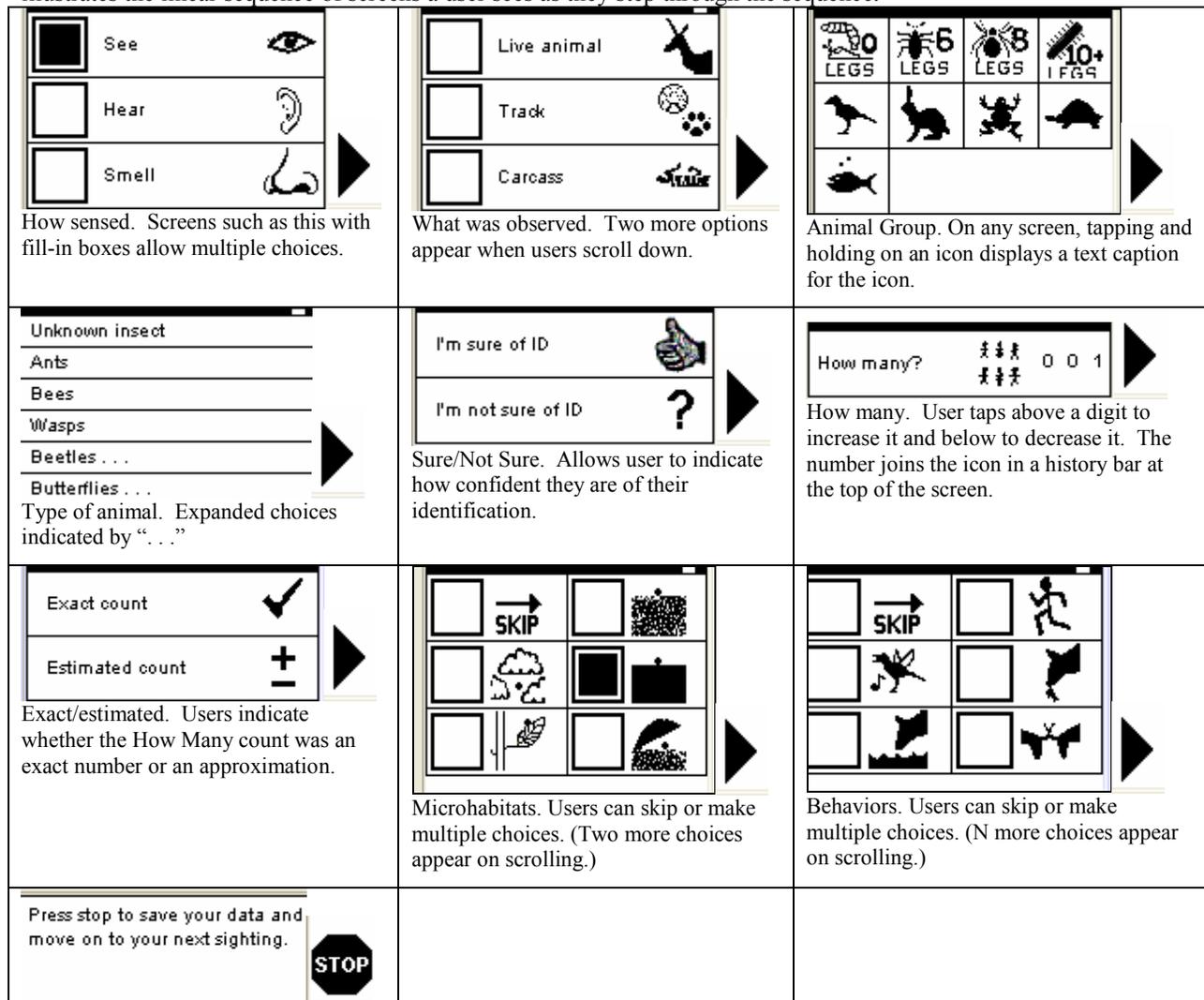


Figure 2. Sequence of screens for recording an animal observation. In each screen, the choice is made by tapping on the icon, then tapping on a right cursor arrow at the bottom of the PDA screen. Some screens have both text and icons, others have simply icons, other screens have only text (e.g. lists of animal common names). Screens with fill-in boxes allow multiple choices, other screens require a single choice.

Displaying data

After data are synchronized and uploaded (described above) we provide two ways for students and teachers to view their collected data. First, we display a simple table of observation data so that students can immediately recognize their own data (Figure 3a). This is close to the raw data. Students can feel some ownership of their data, while students and teachers can spot obvious data entry errors. We eventually hope to allow editing of the data via this web interface. Second, we summarize the data for a class so that it may be used for specific exercises (Figure 3b). We chose to generate this summary for the students in order to maximize the time students spend trying to understand and further analyze the concepts.

Figure 3: Web-based data displays. The display on the left is the observation report showing individual CyberTracker entries. The display on the right is the class summary table. Note use of icons from the CyberTracker sequence.

	08:08AM		with trees	7	robin	ID	count				- Moving		
253	Isoko	05/07/02 - 08:09AM	Zone A	Park: with trees		Unknown bird	I'm sure of ID	0	Exact count	- Live Animal	- Saw	- On plant	- Fighting
253	Isoko	05/07/02 - 08:11AM	Zone A	Park: with trees		Mourning dove	I'm sure of ID	3	Exact count	- Live Animal	- Heard	- On plant	- Fighting
253	Isoko	05/07/02 - 08:13AM	Zone A	Park: with trees		Unknown bird	I'm sure of ID	3	Exact count	- Live Animal	- Heard	- On plant	- Moving
253	Isoko	05/07/02 - 08:21AM	Zone A	Park: with trees		Black tern	I'm sure of ID	200	Exact count	- Live Animal	- Heard	- On plant	- Drinking
											- Saw	- On something hard	- Feeding

CyberTracker Zone Summary
Go to: [Observation Report](#)

Animal Name	Zone A	Zone C	Zone E	Micro Habitat	Total Abundance for Each Animal
Earthworms	2	0	2		4
Ants	2	239	75	- On something hard	306
Other insects	0	0	2	- On plant - Other insect	2
Unknown beetle	0	3	0	- On plant	3
Unknown insect	0	2	0		2
Other leggy inverteb	1	0	0	- On plant	1
American robin	6	1	3	- On plant - Other macrohabitat	10
Black tern	200	0	0	- On plant - On something hard	200
House sparrow	0	0	1		1
Mourning dove	3	0	0	- On plant	3
Unknown bird	7	5	2	- On plant	14
other birds	0	1	2	- On plant	3
E. fox squirrel	1	1	0	- On something hard	2
Human	10	21	1	- On plant - On something hard - Other macrohabitat	32
Other mammal	3	0	16	- On plant - On something hard	19
Red squirrel	2	0	0	- On plant	2
Total Animal Abundance	237	263	104		604
Total Animal Richness	11	8	9		16

3b.

Discussion

In this section, we discuss three important design choices we made and how these were informed by biology, education, and technology considerations. We summarize how CyberTracker helps us meet our overall project goals and how we resolved multidisciplinary tradeoffs. Finally, we comment on the larger potential of this work.

Design choice 1: Aim for linearity and limited flexibility

The final version of the data collection sequence is largely linear. Curriculum considerations drove which screens remained; for example, we eliminated weather data entry and latitude and longitude entry. The first round of user testing had indicated that students were confused with a richer set of choices. We hypothesize that: (a) start screens had different interaction methods so users were unable to develop expectations or a consistent mental model; (b) some of the screens had options within them; (c) these data were not used again and thus did not seem important.

There were two exceptions to curriculum-driven pruning. First, we retained a screen to collect behavior data to allow some flexibility. Students were excited about and motivated by entering animal behaviors. Though the current curriculum does not include it, teachers and students could plan a behavior experiment and use CyberTracker to collect data. Second, we retained screens reminding students to use all their senses (how sensed, what was observed), to report their confidence in their identification (sure/unsure) and to indicate whether they are providing an exact or estimated count of individuals (exact/estimated). These variables are not explicitly used in the curriculum, but support our inquiry goals by guiding students to be better observers and to question the source of their knowledge. In addition, these four variables are among the minimum required by the citizen science program, NatureMapping.

While pruning has led to simplification, it has potentially negative implications. Students will not have weather data to use as evidence when arguing about relative abundance on different days, even though it has considerable influence on animal activity. Lack of this evidence may also be a limitation when we ask students to make comparisons across schools. However, for this age group it is reasonable to constrain inquiry to carefully selected variables – open-ended opportunities are more appropriate for advanced students (National Research Council, 2001)

Once we finalized a set of screens, we simplified each one to improve usability. For example, users choose from only four habitat types we expect them to encounter at or near their schoolyards. We collapsed microhabitat categories from more than twenty in the preliminary design to seven. Each is now illustrated with an icon for ease of use. We also made the screens more consistent with one another: three of the four start screens require the user to choose an item from a set of icons, while the fourth screen requires input of an ID number. No knowledge of Graffiti (the specialized character set for entering text with a stylus) is necessary.

Design choice 2: Use “taxonomic common sense”

“Taxonomic common sense” refers to our efforts to adhere reasonably to accepted animal classification at important levels (most often Linnean classes) while using ease of use criteria to organize at lower levels. Our vertebrates are organized into classes (Aves, Mammalia, Lissamphibia, Reptilia, Actinopterygii). Invertebrates at the highest level include two biologically meaningful groups (Classes Insecta and Arachnida) and two less meaningful groups: (0 legs=Annelida and Mollusca, unrelated phyla whose individuals lack legs, and 10+ legs= Centipedes, Millipedes, and Crustacea, unrelated classes whose individuals have many legs). As invertebrate biology is less likely to be familiar to the students, we use leg number to guide them towards the right lists. The drawback is that students may erroneously conclude that, for example, crayfish (crustaceans) are more closely related to millipedes than to insects. Usability dictated limiting the number of invertebrate options.

Below these highest animal groupings we limit the depth of menus to no more than two (except for birds) and organized lists of names by how likely they animals were to be seen on schoolyards. To limit the menu depth, we provide a quick list of most commonly encountered animals in the area as the first screen after the animal group was chosen. Items on the quick list that are followed by “...” expand to a final level of detail. To reduce the amount of scrolling necessary we include only local animals and display the choices most likely to be used towards the top of the list. We also did not use icons here, which take more space and are unlikely to be useful at such fine detail. While these quicklists should be easy to use, they may promote misconceptions (e.g. European Starlings are not related to House Sparrows though they are listed sequentially in the list). Also, students familiar with traditional field guides may have problems with our lists and we may lose the ability to scale to more sophisticated users. This organization has multidisciplinary advantages. Scientifically and educationally, the resulting taxonomic hierarchy follows accepted high-level classification (except for 0 legs and 10+ legs) and we hope it will encourage students to think about how and why these animals are grouped. Technologically, higher taxonomy is simple and fixed and quicklists will be customizable for other geographic locations – making scaling easier.

Design choice 3: Script data collation and display

One of the most powerful aspects of handheld data collection is rapid and accurate data transfer and summary. We take advantage of this by scripting summary and display of class data on the World Wide Web. As a result, students are better able to focus on the scientific concepts these data represent.

Rather than have students summarize the records themselves – that is, to sum up sightings into totals, determine the total number of each species and the number of different species – we created a web-based summary table (Figure 3b). These pre-defined displays are coordinated with the curriculum to emphasize key concepts. Instead of conducting tedious calculations, students can focus on interpretation: what those values represent in terms of animal abundance, richness, and diversity. Furthermore, it enables students to use these values as evidence to support their claims about relative diversity across zones or schools.

Preliminary observations suggested that students wanted to be able to see *their* data. To this end, we also created an observation report showing individual CyberTracker entries (Figure 3a). The observation report reinforces student ownership of data, an important educational consideration given that data collection is intended to be a motivational component of the curriculum. It also provides validation that what they contributed is part of the summary. From the teacher’s perspective, individual entries help highlight the source of errors and anomalies. For example, the summary may show a total abundance of 306 robins. By looking at individual entries, the class may notice that one tracker entered 300 robins while another entered 6. The group entering 300 robins may realize it should have been 003, or the class may choose to eliminate the suspect entry altogether.

From a usability and scaling standpoint, the web-based summaries will expedite data sharing across numerous sites. Teachers can have ready access to summary tables for other schools.

Meeting multidisciplinary goals and resolving tradeoffs

Our customization of CyberTracker plays a large role in meeting three major goals of the BioKIDS project. Our first goal is to investigate how technological resources (including hand-held devices) can be used to facilitate individual student inquiry. We attempt to engage students in the curriculum content by establishing a connection with local biodiversity. They do this by using CyberTracker to collect field data in their schoolyards. Also, our CyberTracker data summary and displays allow students to more easily search for and interpret patterns in their observations.

Our second research goal is to investigate how scientific resources (in this case, the CyberTracker application) can

be transformed by a multidisciplinary team to meet these inquiry goals. Our development team of biologists, educators, and software designers resolved tradeoffs among their disciplines. The biologists helped us maintain proper taxonomic organization on the levels that are most important. Our science educators helped us produce a streamlined sequence, customized to reflect the particular content and inquiry goals of the curriculum. The sequence scaffolds student observations in terms of what to look for, and the web-based data summary and display scaffolds interpretation. Our software designers created a usable sequence, forgoing content flexibility for an interface that should be easy to learn and fast to use.

Our third goal is to explore techniques for scaling, including collaboration across hundreds of classrooms. When we expand to additional regions of the country, it will be easy to change our text lists of species or to add new habitat types. It may not be so easy to remotely guide teachers to sync and export their own data, but we have eliminated the need for them to learn how to use the CT Desktop. Consistently collected data can be summarized by our scripts and displayed on web pages to be viewed and discussed by a virtually limitless audience of classrooms.

Potential for other educational applications

CyberTracker could be customized for many educational uses at many levels of user sophistication. We are preparing students to participate in NatureMapping, but curriculum designers could create custom sequences for other citizen science efforts such as Journey North (<http://www.learner.org/jnorth/>) and BirdSource (<http://www.birdsource.org>). Our experience clearly shows that sequences can be made quite simple or they can be made more complex and intensive, appropriate for advanced students. Moreover, CyberTracker can support content areas outside biology; it could be used to collect observations or opinions on art collections or historical artifacts in museums. It could be used to scaffold students in evaluating their own writing or analyzing any text via screens prompting students for what to look for. Finally, we expect that our web-based approach to CyberTracker data summary and display can serve the needs of many educational projects requiring large-scale collaboration and sharing.

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