Learner-Centered Education Grants

2 0 0 4 Final Report

1. Project Name and Project Director's Name. Include mailing address, phone and e-mail address.

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1.0 Brief Description of Project:

For the VELS project, we proposed to build a Virtual Electronic Learning Space (VELS) that would greatly enhance ecological science education at NAU by creating an engaging online learning environment that explores a novel integration of research and learning communities and promotes the development of interdisciplinary course content. Our goal has been to create an ecological "explore-atory", an interactive on-line system that weaves together course curricular modules, actual data from ongoing ecological research projects, and novel "virtual explorations" of different climatic zones to create engaging and highly relevant learning experiences. Some VELS components are tailored to specific courses, guiding students' explorations and investigations with structured laboratory modules; other components promote more free-form exploration, enabling students to make connections among fields and courses.

To accomplish this, we proposed to build on our successful pilot efforts (funded under an NAU E-learning grant in 2002-2003), by developing new course modules, prototyping additional data visualization tools, and integrating all VELS components into the nascent Southwest Ecological Research Forum (SERF), an on-line research forum which is being constructed in parallel under NSF funding, and which will form the informatics cornerstone for ecological research on the Colorado Plateau. Leveraging this complementary development (i.e., the construction of SERF) has provided us with an unprecedented opportunity to explore a novel concept in integration of research and teaching, by allowing students to inspect, analyze, and learn from ongoing research projects. Our ultimate motivating vision has been to allow students to electronically "look over the shoulder" of active researchers to observe how science works.

Our proposal was funded, but with a 50% reduction in the funds requested. In response, we submitted a revised proposal which maintained the core elements of the original, but reduced other tasks to match the revised budget. Specifically, our overall goal in revising our tasks in response to the smaller budget has been to cut non-essential tasks, and reduce the overall number of VELS instructional modules that we will be able to produce. We have continued to pursue additional funding to re-activate the curtailed extensions and activities, as we work to bring the VELS vision to full potential.

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2.0 Goals, Outcomes and Assessments

In this section, we describe the specific VELS development goals we promised to meet under this funding; in the following section, we then report on progress and outcomes for each task. In general, progress has been more than satisfactory; we have completed all promised tasks, as well as improving the overall architecture to promote robust future development.

Task 1: *Develop three additional VELS instructional modules for various courses; with existing modules, this will bring VELS-supported lab modules 5, which will cover several core natural science courses.

This represents the core content creation task for this phase of the VELS project. In the previous (first) phase of the VELS project, we had explored a variety of techniques for creating and deploying laboratory experiences in an online context. Our goal under this task has been to leverage this experience to create at least 3 new instructional modules (corresponding roughly to discrete laboratory exercises) for VELS, and deploy them within the existing ORF framework created in building the SERF forum for research scientists. In this way, the VELS modules would not merely be standalone websites, but could be embedded within the rich context of a research database, allowing module exercises to draw on the large amount of research data and other resources already available in SERF. Practically speaking, our approach was to recruit faculty teaching a number of courses spanning the curriculum willing to participate in the VELS project. For a modest amount of involvement in content creation, faculty were rewarded with functional instructional modules that they used to enhance their courses.

Task 2: Extend the core SERF database schema to integrate data entities to represent "students", "faculty", "courses", and to represent and enforce the relationships between them.

The existing SERF system was designed specifically to support a working community of widely-distributed researchers. Accordingly, the entities in the core SERF database are tailored to match the needs of this scientific enterprise. To implement a functioning VELS site, it was necessary to develop new data schema elements to represent relevant VELS entities, and then integrate these extensions with the existing SERF schema. As it turns out, the relationships between VELS entities (e.g. courses, students) are actually *more* complex than those in SERF. For instance, students are often in multiple courses; in each course, they may take part in several student workgroups. Implementing this task required us to generalize our underlying approach to managing group membership in both VELS and SERF.

Task 3: Integrate all VELS lab modules into the SERF system, allowing modules to draw on archived data, and to cross-link module contents to SERF resources like publication data, and data on labs, researchers, and studies.

This task speaks to the main philosophical goal of the VELS project, namely, that learning experiences should be situated within real, meaningful context. In particular, experimentation, data collection, and data analysis in student labs should draw on and be integrated with real data being produced by real research projects. In this way, students can juxtapose their own data with that collected by ongoing research projects; and students can draw on the research resources (information on labs, publications, etc) already available to research scientists to become "junior members" of a real, functioning scientific community. Accomplishing this task involved integrating the instructional modules developed for VELS (Task 1) into the existing SERF research forum infrastructure.

Task 4:*Provide a mechanism to allow the SERF forum to continually upload new data, providing up-to-the-minute research result sets for VELS students to analyze.

A central goal of the VELS concept is that students should have accept to real, complete, up-to-date research data – just like the scientists using the SERF forum – in order to conduct their experiments. A major deficiency is this regard has been that the data accessible to VELS users is generally incomplete and out-of-date, simply because uploading new datasets is a tedious manual process. The aim of this task is to simplify and automate this process, making it possible for a technologically-naïve research staff member to upload new datasets in minimal time, using a simple but powerful web interface. .

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* Aspects of this task were altered/curtailed in response to the 50% funding reduction.

Task 5:*Design and implement a proof-of-concept model for student discussion forums; explore mechanisms for allowing forums to span and be cross-indexed by multiple classes across the disciplinary spectrum.

The purpose of this module is to support intra- and inter-course discussion among students. In "virtual discussion spaces", that is, restricted-access, threaded discussions attached to particular topics, lessons, or datasets. For example, a forum attached to the description of data collection techniques in some laboratory module might contain exchanges (both student-instructor and student-student) focused around questions about these techniques, problems encountered along with their solutions, and so on. A forum attached to the topic of regression analysis might be cross-linked to several courses, allowing all students interested in this topic to learn from each other and various instructors, regardless of the actual course they are enrolled in.

Task 6:*Design and implement a sophisticated data uploader/downloader module to allow VELS student users to easily upload their own data to VELS, and to download "virtual data sets" resulting from cross-dataset searches in VELS.

This is a new task that was not foreseen in our original proposal. During our pilot classroom deployment of our module prototypes in Fall2004, it quickly became clear that manual techniques for getting students' own experimental data into VELS were completely impractical. Students are unable to consistently provide their data in a concisely detailed file format, and there is no staff support for entering these datasets into the database. What is required is a flexible, automated mechanism for allowing students to upload their experimental data for analysis in VELS.

Similarly, it turned out that our initial thoughts on how students would access the experimental data in VELS were unrealistic. Rather than downloading entire existing datasets, students need the ability to search across datasets (i.e. extracting relevant data from each), and then a way to download the new "virtual dataset" for analysis.

2b. Outcomes and Assessment for each Goal:

Task 1: *Develop three additional VELS instructional modules

We developed 5 new lab/instructional modules to support interactive VELS experimentation in three core natural science courses. The modules were deployed for a pilot offering in the three courses in Fall 2004. In order to minimize faculty load (funds to compensate faculty were requested but cut from the award), we hired an instructional specialist to act as a liaison between faculty and our programmers; this liaison met with faculty and produced module content, which was then implemented within our pre-existing online research forum infrastructure. The following sections describe the modules in more detail.

ENV110 (3 Instructional Modules). Content: Provides a series of exercises in which students explore how pressure, temperature and wind change with increasing elevation. The basis for this exploration is provided by weather data for the Merriam-Powell Center for Environmental Research elevational gradient, which includes 5 sites, Desert (1500 m), Grassland (1700 m), Pinyon-Juniper Woodland (2000 m), Ponderosa Pine Forest (2200 m), and Mixed Conifer Woodland (3000 m). These data are posted to the SERF scientific forum used by research scientists; VELS allows students to interact with this same data, satisfying a major goal of the VELS project.

1. Module 1: Changing Pressure with Elevation - students examine pressure data extracted form the Gradient Weather database, construct graphs and do linear regressions of atmospheric pressure vs. elevation. The object is for student to understand how pressure decreases with elevation.
2. Module 2: Changing Temperature with Elevation - students examine temperature data extracted from the Gradient Weather database, construct graphs and do linear regressions of air temperature vs. elevation. The object is for students to understand how temperature usually decreases with elevation and also how temperature inversions can form.
3. Module 3: Initiation of Mountain / Valley Winds - The objective of this module is to plot the wind speed and direction for a single diurnal cycle for one of the gradient sites. The student will identify times when mountain and valley winds become evident and verify this with temperature data. This module is a hands-on project in which students are expected to explore data with little *a priori* knowledge of the exercise's outcome.

Level of Completion:

Introduction: Implementation is 100% complete, content is ~75% complete. Addition of the remaining content is merely awaiting the return of the faculty member working on this course, which will be in Fall 2005. The content

* Aspects of this task were altered/curtailed in response to the 50% funding reduction.

will be completed with the next offering of this VELS-supported course. Methods: Complete, but interface and interaction needs to be refined as students work with the new data uploader/downloader tool.

ENV230 (1 Module). Content: In this series of laboratories, student measure abiotic and biotic parameters at permanent research transects that have been established across an elevational gradient. Data collected during a two all-day field trips is made available to students through the Virtual Environmental Learning Space (VELS) web site. In future offerings, this will allow student to compare their results with the results of previous classes and examine whether any change has occurred, which will greatly enhance the utility of student field studies by bringing the variable of time into their studies.
Level of Completion: Introduction: Complete. Methods: Complete, but will need refinement to integrate new data uploader/downloader tool.

BIO326 (1 Module). Content: This course focuses on the experimentally-based investigation of ecological questions. Via this module, we aim to develop long-term student-collected data sets from experimental manipulations along the C. Hart Merriam Elevational Gradient, to allow students to develop skill in recognizing and investigating ecological relationships in the field. Two major experiments are performed: one on grazing and one on nitrogen deposition. Using the VELS infrastructure, observations on these two experiments are archived by students each semester; over time as more data accumulates, students will be able to ask more sophisticated questions about these studies.

Level of Completion: Introduction: Complete. Methods: Complete, but will need to be edited once data uploading/downloading is available.

Task 2: Extend the core SERF database schema

In order to support “courses” within VELS as components that interact with the existing SERF research data forum developed for scientists (see original grant proposal), the following extensions were added to the SERF infrastructure: (1) The "course" and “student workgroup” group types were added; (2) The prototype VELS schema was extended to add extra information for courses: course name, section, year, and semester. (3) The person types "professor", "student", and "teaching assistant" were added. (4) The VELS data schema was extended to add extra information for students: university ID. (5) Administrative functions were added to allow professors and teaching assistants to create course rosters for each semester utilizing existing NAU online roster downloads, and then create student workgroups from that roster.
To complete this task, a reorganization of the database schema for all forums was performed. The benefits of this include:

1. Once a person is a member of any forum, they have one record. This person can be a member of any number of student workgroups or courses if they are of type "student". This allows a student (a) to be in multiple student workgroups within the same semester (i.e., to participate in multiple experiments, or to be in multiple workgroups within the same experiment); and (b) to take a VELS course later, and to use the same person record, making it possible for us to determine what groups a student has ever been in, or what data they have ever collected.
2. Faculty positions are implemented as person types "professor" and "teaching assistant". Utilizing the existing security infrastructure within the SERF forum, these two groups of people are allowed to perform maintenance activities such as: editing student records, emailing passwords, editing virtual datasheets, etc. Note however, that students are only allowed to edit their own records, and the data within a virtual datasheet that their student workgroup owns.

Level of Completion: This task is 100% complete.

Task 3: Integrate all VELS lab modules into the SERF system

Implementing this task to create the Integration between the SERF and VELS forums involved three aspects:

1. SERF Person Module was abstracted to create a common code base for person records. A VELS person module was created which implements the necessary extensions to support the needs of a VELS course.
2. The module infrastructure was completely rewritten to allow the VELS website to use existing SERF weather data modules.
3. Researcher person records were extended in the case where an existing SERF researcher was also a professor for a VELS course.

During development of the VELS person module, it was realized that many tasks needed by the VELS forum either already existed in the SERF module, or were needed by the SERF module. This functionality (such as resetting passwords, for example) was implemented in the ORF infrastructure and is leveraged by VELS. However, certain functions (such as adding students by course roster) are by their nature VELS specific. An object hierarchy was created allowing the new VELS person module to utilize the existing person functionality provided by the SERF person module.

Extensive work had already been done to create the weather data module for the SERF forum. By creating the concept of a "forum" with the database, we were able to allow the same code to be used (with some modifications) to provide the weather data functionality simultaneously to the SERF forum and the VELS site.

Level of Completion: This task is 100% complete.

Task 4:*Provide a mechanism to allow the SERF forum to continually upload new data

To address this task, we developed a simple but powerful dataset uploader for use by the research assistant responsible for collecting research datasets from weather data collection sites spanning the research gradient. Manual data entry is no longer required. Once reviewed for quality, datasets are passed through an automated software tool that formats them into a data input file. This file is that uploaded via a secure web page to the VELS forum, adding the latest dataset to the database. The new dataset is immediately visible and accessible by VELS courses.

Level of completion: This task is 100% complete; the mechanism is used regularly to update VELS data.

Task 5:*Design and implement a proof-of-concept model for student discussion forums.

Early in the PhaseII work funded by this grant, it became clear that our instructor-collaborators did not feel that this capability was as crucial as the other tasks we proposed to address; it was therefore made a low-priority task. Then, as a major outcome of our initial pilot offering in Fall2004, it became clear that what was truly needed was a more powerful,streamlined upload/download mechanism for VELS data that would be easy for students to use. Thus, we decided to shelve this task entirely, and instead posed and completed a new task (see Task 6).

Level of completion: 0% complete. Task shelved in favor of higher priority features.

Task 6:*Design and implement a sophisticated data uploader/downloader module.

As described in the previous section, this task came about in mid-project in response to pressing needs revealed in our trial offering of our new VELS modules, and replaced a task (Task 5) that we had originally proposed. A Data Uploader/Downloader Module was developed to allow students using various course modules to upload their datasets to the VELS forum, as well as later downloading arbitrary datasets to their PCs for analysis. There are two goals of the Data Uploader/Downloader Module:

1. Upload of VELS experimental data. A key feature of VELS is that it allows students to upload their own experimental datasets to the forum, sharing it with other students, and allowing them to juxtapose and analyze their data with respect to actual scientific data. To support this capability, the module allows instructors to easily design and deploy “virtual datasheets” on VELS, which allow students to enter their experimental data directly in a form-based online interface. Alternatively, students may save their data in a simple spreadsheet format and then upload the whole dataset at once

2. Provide a mechanism for downloading portions of the existing extensive weather data collection in a custom format. To address this goal, the downloader module works with an extended search module to allow students to specify global search criteria, and then apply them across multiple datasets of interest, thus creating a “virtual” result set containing data from several actual datasets. The uploader/downloader module allows students to compose such virtual datasets, and then to download them to their PCs for further analysis.

Level of Completion: This prototype module is 100% complete. Because it has not been deployed in the classroom, we expect to make many refinements to the interface and the underlying module based on feedback from our second pilot offering in Fall2005.

3.0 Problems or Issues Encountered:

The challenges we encountered in this second phase of the VELS project can be divided into the **logistical challenges** and **technical challenges**.

Logistical Challenges.

Whereas we anticipated many of the technical challenges associated with deploying this phase of the VELS project, we were somewhat surprised by the challenges associated with coordinating the interaction between the various course instructors involved (for whose courses we were designing the five new VELS modules) and the technical personnel implementing those projects. In a general sense, difficulties encountered here can be seen to arise from the interdisciplinary nature of the project: how to educate the biologist educators and content providers about the possibilities and constraints of implementing a virtual learning forum like VELS, while at the same time providing the computer scientist implementers of the system with enough background on the biological content and pedagogical strategy used in the laboratory experiments embodied in the various VELS modules they were tasked with implementing.

The solution we devised was to rely heavily on a "facilitator", a technology-savvy staff member trained in biology; it was this person's task to act as a liaison between the faculty and the implementers, interviewing faculty members regarding content and procedures, and then re-formulating this information as specific prose for VELS module pages, and process diagrams that could be easily mapped to implemented VELS interfaces. In this way, we minimized the demand on instructor time, while at the same time ensuring high-quality module content.

Despite our use of a facilitator to streamline extraction of module content from faculty, a second logistical problem we encountered was frequent delays in our access to participating faculty. Faculty are simply too busy to allot substantial amounts of time --- especially frequent requests for feedback on module design or content – on short notice, especially given the voluntary nature of their participation. The resulting delays significantly impacted our development timeline, particularly during the critical first deployment of the modules during Fall 2004. In our follow-on proposal to further develop VELS (PhaseIII), we proposed, for each new module developed, to include a faculty stipend for the instructor. We felt that even a token stipend would increase the commitment level of the collaborating faculty member. Because the follow-up proposal was funded at a reduced level, however, we elected to remove development of further course modules from the project goals, and thus have been unable to assess the efficacy of faculty stipends in increasing participation.

Technical Challenges

Because both VELS and the SERF forum which VELS complements/extends are based on a novel informatics architecture, we expected to encounter significant technical challenges during VELS implementation. In all cases, we have developed satisfactory solutions to these challenges; the development goals for this phase of the VELS project been substantially met. An additional benefit is that these challenges have exposed certain weaknesses in our overall SERF/VELS architecture. Wherever possible, we have addressed these weaknesses with comprehensive redesign (rather than small "fixes"), which has greatly improved the generic utility and robustness of the system. We feel this approach will pay tremendous dividends in future development.

Some of the significant technical challenges included:

1. Creating appropriate database schema for complex SERF weather data configuration. During development of the Data Download module, it was realized that the configuration of the weather data database was not correct. The schema was completely rewritten to support the complex relationships between datasets, weather stations, sensors, and data types presented.
2. Getting complex configuration data from SERF scientists. Although the SERF system (on whose scientific data VELS draws) already contained much data, some datasets specifically needed for the supported VELS courses had not been entered yet, and still existed in a multitude of formats in various file systems maintained by individual scientists. In working to upload this data to SERF/VELS, a significant challenge turned out to be getting accurate meta-data (information about the configuration/content) on these existing datasets from these scientists. This greatly slowed our uploading of these data into VELS.
3. Creating an appropriate database schema to support the extremely heterogeneous needs of VELS Virtual Datasheets Module. Implementing the Virtual Datasheets Module required modifying our underlying database schema created for the SERF scientific forum to handle the addition data categories needed to support VELS courses, while at the same time keeping the table structure simple enough to allow us to create a usable web-based interface for selecting/uploading datasets. In short, this required coming up with a modified data schema

that would support both SERF and VELS data. Our first attempt at meeting this challenge met the immediate needs for VELS, but was not suitably robust and flexible to support future goals, particularly the creation of a completely generic upload mechanism to support all of the methods (e.g. via excel, via notepad and direct entry, etc.) students might use to collect and upload their data.

4. Creating usable interfaces in a web-based environment. In principle, there is almost no limit to the complexity of searches that can be supported by the VELS system: users may search across datasets containing partially overlapping data types which span any conceivable timeframe for which data is available. The "virtual target datasets" comprised of all target data from across all searched datasets, can then be downloaded by VELS participants for further analysis. Creating a usable interface for managing this complex data indexing process would be challenging in a traditional software design context; creating such an interface given the constrained interfaces and interaction techniques available in a browser-based interface was extremely difficult. A key issue here was how to visually "compile" the various search criteria (selected using various screens) into a cohesive overall query, and then to somehow label the result set with these criteria. Our solution hinges on heavy use of session information in PHP, with integration of auto-generated javascript to control local interface behavior.

5. Creating a highly extensible architecture for VELS and future VELS-like systems. One of the issues which soon emerged was that, due to the complexity of each VELS screen, writing the PHP scripts to generate those screens becomes very time-consuming. Progress was slow. At the same time, many pages contain similar elements, color schemas, and controls. Thus, our solution was to abstract (factor) out the common functionality into a "VELS toolkit", a comprehensive set of PHP functions kept in a common space, that are called repeatedly across all of the pages in the VELS forum. This abstract approach not only saves time coding pages, it is highly maintainable (a change to one function changes all pages that call it), and is also makes extended VELS to support new datatypes and pedagogic modules very simple; existing functions can be re-used, leaving only the truly unique elements to be developed in order to extend VELS.

4.0 Conclusions, Recommendations and Future Directions:

Overall, this second phase of the VELS projects has been very successful. Starting with a handful of techniques and insights gained from Phase 1 of the VELS projects, we were able to produce a fully functioning system, a Virtual Electronic Learning Space very much like the one that we envisioned in making this proposal. Moreover, we were able to make fast enough progress (leveraging experience gained in constructing the SERF research forum) to actually pilot prototype version of several modules in Fall 2004, resulting in valuable feedback. We summarize our conclusions as follows:

1) The concept behind VELS, namely, the creation of a virtual online laboratory – one that it tightly integrated with a real online research forum used by a functioning, active scientific community – is a viable and valuable concept. Our surveys (albeit based on rough prototypes) show that both students and instructors see the potential in this approach to augmenting conventional courses.
2) The approach taken in VELS, namely, leveraging the existing SERF forum, has both pedagogical and practical advantages: practically, it allows fast progress in implementing modules because, although modules involves creation of content and extension to database schemas, they may also draw on the tremendous amount of core infrastructure (e.g. for security, fast database access, interface look and feel) that has already been created for SERF. This allowed us to, in fact, develop five instructional modules, rather than the three we had proposed to achieve. Pedagogically, integration with SERF allows learners access to a real research context in which they can view research datasets, upload their own datasets, and analyze their data with respect to research data and datasets uploaded by other students and courses.
3) The ultimate usability of VELS will depend crucially on refining our initial prototype, adding features that were requested by instructors and/or students during our pilot deployment. Although our users (both faculty and students) were willing to put up with clunky functionality in a trial context, it is very clear that this goodwill is limited. If VELS does not deliver (a) educational experiences and insights that can't easily be gained by conventional means and (b) reduce the "hassle overhead" to a point where it's actually easier to use VELS than to work through a conventional lab experience, then VELS – and similar attempts at bringing laboratory experiences online – will not succeed.

These observations – and the last one in particular – lead us to the following recommendations for future development:

1) Refinement. Although we have succeeded in developing a promising prototype, VELS must be comprehensively refined in order to streamline student interaction with the system. A significant obstacle in this respect is our commitment to a web-based interface (versus a dedicated client program). The constraints on interaction techniques available in a web interface (e.g. no drag-and-drop, limited ability to change/update layout, page-at-a-time model of browsing) make it difficult to create strong interfaces to some of the more complex VELS features, e.g., searching for and specifying multiple search criteria in constructing a complex, cross-dataset query. Fortunately, some recent cutting-edge extensions to web protocols promise to ameliorate these challenges somewhat.
2) More modules. The five modules developed under this funding support just three courses – and only partially: even within these three courses, there are many laboratory exercises that are not VELS-supported. In short, it is clear that there is a need to produce many more VELS modules in order to create a complete VELS-based curriculum. Although there is no reason why *every* lab exercise in a course has to be embodied in VELS, doing so would meet a long-term goal of the VELS project, namely, providing distance-learning access to lab-based courses for non-residential, non-traditional students.
3) More leaner-learner and instructor-learner interaction. Although we shelved the topical discussion groups planned for VELS due to more pressing development needs, we still believe that tools like this are important and can significantly enhance the VELS experience. Not only can discussion groups provide opportunities for learning, they also provide a means for *capturing* otherwise transient information exchanges; students faced with a quandary could scan archived discussions from previous terms or related courses for an answer.

At the time of this writing, we have applied for and have been awarded another round of support under the LCE funding initiative to develop Phase Three of the VELS project. Although, as with this proposal, the funding received was less than requested, we are confident that we will be able to make significant progress on the future goals outlined above, with particular focus on refinement of VELS interfaces and function, and on exploring additional mechanisms (e.g. the discussion forums) for enhancing conventional classroom instruction.

5.0 Has this project led to sustainable change in your department/college?

Yes. The VELS modules which have been deployed continue to be used by the courses named below, and will remain in service for the foreseeable future. The modules were designed to be configurable and maintainable by non-programmers; they can be updated in future (within limits, excluding computational elements) by staff with rudimentary HTML programming skills.

In addition, the VELS system is currently being refined and extended under a subsequent round of funding provided by this ABOR initiative. In sum, we see VELS as a proof-of-concept for the future of laboratory-science oriented biology/ecology education.

6.0 Impact:

a. Have other faculty been affected by this project? ☒ Yes ☐ No. If so, describe:

Four faculty members in biology have used the VELS online learning forum created under this funding to augment their courses: George Koch, Bruce Hungate, Nancy Johnson, Diana Anderson. VELS was leveraged in various ways depending on the course, but generally VELS was used to present laboratory techniques, allowed uploading of student data (for some courses), and access for analysis to extensive data in the SERF online research forum (which VELS is integrated with).

b. Number of courses affected/involved.

VELS modules for three courses were pioneered: BIO326, BIO230, ENV110

c. Number of students affected.

BIO326: ~100 students

BIO230: ~30 students
ENV110: ~50 students

7.0 Significant Outcome:

What was the most significant outcome based on learner-centered principles that occurred through your project?

One of our central goals in creating VELS was to allow students access to real ecological data that has been collected over the course of past and ongoing ecological monitoring projects on the Colorado plateau. The idea was that students could examine the scientific data and, in certain lab modules, upload data from their own field experiments for side-by-side analysis with the "real" data produced by scientific studies. In this way, students were allowed to "apprentice" in ecology, that is, to participate in the community of practicing scientists in a limited but realistic fashion. This succeeded and represents a significant learner-centered outcome for the project. An additional benefit that we did not anticipate was the synergistic effect of allowing student's to see each other's uploaded data sets. In several cases, the similarities and differences observed encouraged critical discussion in which students reflected on their data collection techniques, and were able to articulate and defend them successfully.