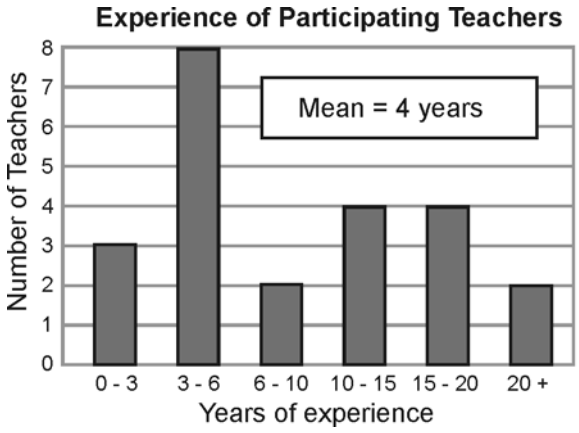
The primary goal of the Phase I research was to develop a commercially viable distance learning technology that would enable science teachers to take lab-based science courses. This goal was achieved however, the actual product evolved substantially during Phase I, becoming significantly different from our original proposal. The change was the result of market feedback, performance data from teachers, and economic analysis conducted during Phase I. As a result, we believe the phase II proposal we submitted has an excellent chance of self-sustaining market viability and also of achieving the educational mission. In light of what we learned in Phase I, this final report has two distinct and different sections. The first section covers the performance specific Phase I objectives and the second section covers the evolution of the technology based on what was learned in Phase I. More details can be found in Ergopedia's Phase II proposal, "*Phase II: Lab-Science Through Distance Learning: Certification for In-Service Teachers"*

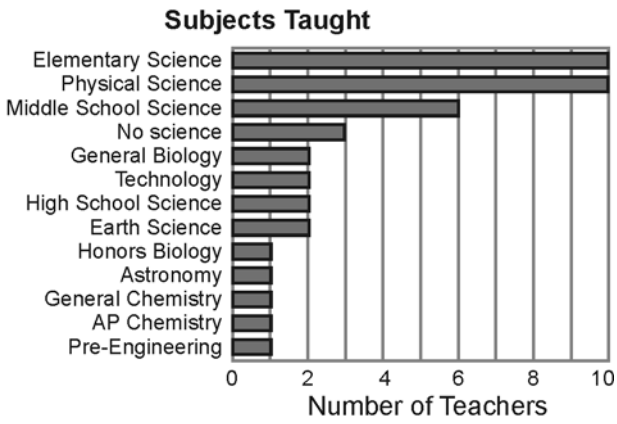
Our most important Phase I results were:

- The potential for interactive DVD as a learning tool is extraordinary. Interactive simulation is a powerful learning tool and we demonstrated that $40 DVD players can provide interactive capability essentially equal to a computer *for learning* but without the software, tech-support, compatibility, bandwidth, firewall, and cost problems.
- To be successful on a large scale a distance learning product must fit into the existing university instructional practice (i.e. professor + T.A.) in similar way as a textbook and for which $250 in curriculum or fees is the top end of what students pay (excluding tuition).
- The combination of interactive DVD with sensor technology makes a true, lab-based science course possible at a retail price of $250 that can be sold through a bookstore, including text, lab instrumentation, a specialized remote control, and DVD media in one unit. The synthesis of these elements is the Ergobook, which we proposed for Phase II.

Section I: Performance of Specific Phase I Objectives

Twenty six teachers from two school districts (Andover and Lowell, MA) participated in the field testing of lessons developed in Phase I. None were certified in physics and most were elementary or middle school teachers. Each teacher in the study completed a one-page, multiple-choice pre-test before doing the activities in each lesson. The test was designed to resemble a typical 10th grade assessment such as MCAS or TAKS. Each teacher then took the appropriate materials home and completed the lesson on their own, along with a matching number-coded post test.





On the recommendation of our advising teachers we changed the content of the lessons to include broader areas in science than originally proposed. Eight interactive lessons were created including approximately 2 hours of finished video and 30 pages of textual content. Six lessons were (or are) in field testing including 5 DVD discs. Lessons were constructed around the topics of sound, motion graphs, phase change, temperature, periodic motion, and genetics. Two lessons specifically designed for the MEbot have not been completed due to technical difficulties with the MEbot. The interactive DVD work was very successful and many DVD production techniques were evaluated, including interactive embedded questioning, interactive simulation, user interface design, representation of vocabulary, use of animation, stop-frame and slow-motion. The Phase I research pushed the envelope far beyond the capabilities of traditional video courses and opened up the potential for the Ergobook.

In the three lessons for which we have complete test data, the percentage gains have been excellent. The mean score on the pre-test for motion graphs was 49%. The mean score on the post test was 89%, showing a gain of 40 points out of 100. The test items had point biserial[1] values between 0.29 and 0.92, indicating high reliability. The second lesson was on sound, a more challenging topic. The mean score on the pre-test was 19%, showing that the average teacher answered only 1 out of 6 questions correctly. After watching the 12 minute DVD and completing the three interactive DVD simulations the post-test scores averaged 80%, for a gain of 61 points out of 100. The temperature material was more familiar to teachers and the average pretest score was 66%. After completing the DVD lesson the post test score was 92% for a gain of 26 points. The remaining lessons are still out with teachers and we expect to have the results back in May. During the process of Phase I we had to comply with Human Subjects in Research protocols. We established an Institutional Review Board, obtained an FWA number, and set up procedures to prepare for future work (Phase II).

The MEbot was designed and all components for 40 MEbots were procured or manufactured. Six actual MEbots have been assembled to date however, problems with the motor/encoder design required a re-engineering which was unable to be completed during the performance period for Phase I. The design issue has been resolved and new components have been ordered. We believe the MEbot is a viable product and with the design changes will be both reliable and repeatable. The first 40 units cost $449 each to produce (excluding labor). We believe the revised MEbot design can be manufactured for approximately $100 in quantities of 1,000 and we showed it (at NSTA) to distributors of educational science products who have expressed an interest in selling it. Development of the MEbot will continue under Ergopedia funding and we plan to complete at least 20 MEbots for field tests during the summer of 2005. However, the MEbot is still too expensive to fit the price / distribution channel we now believe are best suited for distance learning. While the MEbot as a whole did not offer sufficient functionality at the necessary cost, the core sensor electronics developed for MEbot will be used in the Ergobook.

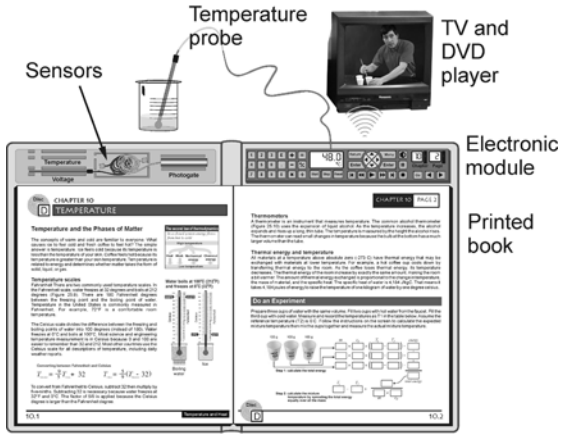
Related to the MEbot, the PROTOS software application was developed and has been a great success with teachers, even as a stand-alone learning aid. 26 Palm IIIxe hand held computers with the software were distributed in the field test of the Distance and Time Graphs lesson. The average score of participants completing the lesson rose from 49% (pre-test) to 89% (post-test).

1. Point biserial (PBIS) is a correlation statistic used to evaluate individual test questions for validity. A high value (+1) means those who got the question correct also did well on the whole test and those who got it wrong did poorly on the whole test. Designers of tests typically accept items with PBIS > +0.25 and consider +0.4 very reliable.

Section II: Outcomes of the Phase I Research

A panel of experts was convened including 8 executive-level leaders in distance education for science teachers to share information and provide feedback. Based on our Phase I research, market analysis, and the discussions of the expert panel, we developed the Ergobook concept and immediately modified our lesson testing to produce results more relevant to the Ergobook.

The ErgoBook is a unique hybrid of DVD technology and printed textbook that combines the excellent readability and comfortable feel of printed page with measurement sensors and the ability to interact with the DVD player through a built-in remote control. Physically, the ErgoBook opens like a hardcover text except the pages are shorter. An electronic module on the inside right cover includes the sensor display and DVD remote. Special controls allow the DVD player to synchronize with the page of the text. The interactive quality of DVD's make them ideal for delivering visually powerful instruction in an inexpensive form. Unlike computers, consumer DVD players are inexpensive, common and standardized. By using DVD's, the ErgoBook can offer visually rich simulations and animations impossible to support (with many users) by even the fastest university servers.



ErgoBook

A complete, self-contained lab science course

Lab equipment for home use must be robust, versatile, easy to use, and accurate yet also inexpensive. The ErgoBook can make measurements through its integrated sensors and display. A built-in calculator makes quick work of computations. The left inside cover has places to store sensors. Much of the sensor electronics were developed in Phase I research for the MEbot. A detailed manufacturing study shows the ErgoBook can be produced at a cost of $62, which is consistent with a retail price of $250 assuming a 20% margin for the bookstore or online reseller.

Two avenues for commercialization were explored in Phase I. Accredited universities with distance education programs are the largest potential customers. Nova Southeastern University's Fischler Graduate School of Education, the nations largest (14,000 teachers enrolled) has expressed interest in Essential Science. The University of Kentucky has offered to collaborate with Ergopedia and explore offering the physics first course. The second commercialization channel is educational publishers. CPO Science (a division of Delta, LLC) has already committed to market ErgoBook along with its middle and high school science programs. The "course-in-a-box" model is also ideal for use in developing countries, and by US personnel stationed abroad without access to traditional colleges and universities.