Millersville University
Department of Earth Sciences

GEOPOD
(GEOscience Probe of Discovery)

A Three-Year Project Funded by the
National Science Foundation (2009-2012)

GEOPOD Evaluation Report
Phase 2: Testing and Rollout of the GEOpod System
(July, 2010- June, 2011)

Submitted

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GEOPOD Project
(GEOScience Probe of Discovery)

I. INTRODUCTION

Project Background and Purpose

The GEOPOD Project (GEOScience Probe of Discovery) is a three-year project (2009-2012) funded by the National Science Foundation (NSF) and directed by faculty of Millersville University in Millersville, Pennsylvania. Dr. Gary Zoppetti, associate professor of Computer Science, serves as Principal Investigator (PI) for the project. Dr. Richard Clark and Dr. Sepi Yalda, both professors of Meteorology in the Department of Earth Sciences, serve as Co-Principal Investigators (Co-PIs); Dr. Clark also functions as chief contact for the project and the Project Director.

The purpose of the **GEOPOD** project is to develop and implement an interactive instructional software program, the ***GEOpod***[1], which provides instructors and students in the field of Meteorology with an intuitive and graphical interface in a 3-D gaming environment. The goals of the project are to provide users with a software program that allows them to probe authentic geophysical data and use virtual devices to collect data, record observations, and query information while guided by instructional design strategies that are customized for undergraduate learners.

The project significantly leverages the Unidata Program Center's open source Java-based visualization software, the Integrated Data Viewer (IDV), and its Internet Data Distribution (IDD) system and Local Data Manager (LDM), to import data in

[1] ***GEOPOD*** refers to the overall project and ***GEOpod*** refers to the interface.

rendering a 3-D data environment which serves as an exploration platform for the ***GEOpod***. Key features of the ***GEOpod*** include:

- the ***GEOpod*** interface;
- Customizable display panel with drag-and-drop capability for up to 19 user-selected meteorological variables;
- User guided navigation (with optional WII controller capability) or lock-on with smooth auto-pilot functionality allowing users to track an isosurface with high fidelity;
- Integration of Google map technology for both forward and reverse geocoding – users can fly to a specified location in ***GEOpod*** or ground-truth their location;
- Actuating particle imaging (snow crystals, liquid droplets) and vertical profiling (dropsonde) virtual devices;
- Auto-build and replay of IDV bundles;
- Web-based mission builder for user/instructor defined missions;
- Flight recorder for evaluation and assessment;
- Point-of-interest annotation; *and*
- Learning objectives and assessment.

The challenge in the ***GEOpod*** design is to use real data in a system of interoperability that works seamlessly with diverse integrated web and computer-based systems, such as the IDV-compatible interface. What distinguishes the ***GEOpod*** from other synthetic environments such as Virtual Thunderstorm (Gallus et al., 2005) is the use of authentic geophysical data (e.g., surface and upper air observations, satellite and weather radar imagery, and numerical model output) to construct the 3-D environment, and the nearly limitless possibilities for exploration and discovery afforded by the endless stream of geophysical data and products that are already available to colleges and universities via Unidata's IDD.

The ultimate goals of the **GEOPOD** project are: (1) to provide college educators in the field of Meteorology with a sound, technically accurate, and visually compelling interactive computer-based simulation and exploration environment for the classroom; (2) to provide an instructional design that complements the technology and will excite and motivate students to explore and discover the geophysical realm and deepen their interest in the field; and (3) to determine the efficacy of this technology-based approach for undergraduate teaching and learning. The GEOpod modules are specifically targeted for instruction in meteorology courses at Millersville University. The ***GEOpod*** will be used in instruction with approximately 200 sophomore through senior students enrolled in these courses during Phase 3 of the project.

Scope and Duration of the Project

The **GEOPOD** project consists of three phases over a three year period (2009-2012): **Phase 1: Design and Development of the GEOpod** (September 1, 2009- June 30, 2010) consists of the design and development of the ***GEOpod*** technology, development of the student outcomes assessment instrument, and pilot testing of the GEOPOD assessment instrument. **Phase 2: Testing and Rollout of the GEOpod** (July 1, 2010-June 30, 2011) consists of continued development and rollout of the GEOpod technology, implementation of the GEOpod Usability Study, and testing of comparison groups on the GEOPOD assessment instrument. **Phase 3: Implementation and Assessment** (July 1, 2011-June 30, 2012) consists of the continued refinement of the GEOpod technology, training of faculty to implement the ***GEOpod*** technology and curriculum in selected Meteorology classes at Millersville University, implementation of the GEOpod in selected Meteorology classes, and assessment of learning outcomes for students who were taught using the GEOpod. This report presents the results of the Phase 2 (July 1, 2010-June 30, 2011). For further information about the rationale for the project and the results of Year 1, Phase I (September 1, 2009- June 30, 2010), see the first year evaluation report on the project website www.atmos.millersville.edu/geopod.

II. PHASE 2 EVALUATION DESIGN AND METHODOLOGY

Evaluation Goals and Objectives

The overall evaluation design for the **GEOPOD** project consists of both formative and summative methodologies intended to provide evidence of the success and challenges of developing and implementing the project, the extent to which instructors and students value and use the ***GEOpod*** modules, and an examination of student learning gains as a result of using the ***GEOpod*** modules in their courses.

Formative evaluation results for Phase 2, which includes the continued refinement and testing of the ***GEOpod***, usability testing, public rollout of the GEOpod technology at conferences, and learning outcomes assessment for comparison groups offer the project team an opportunity to determine those project elements that are working successfully and those elements that need to be altered to achieve greater success, especially the instructional design, functionality, and technical accuracy of the ***GEOpod*** system. Evaluation questions addressed during Phase 2 are the following:

- *To what extent was the project carried out in Phase 2 as originally designed?*

- *What progress has been made in Phase 2 in the development of the GEOpod system?*

- *What tests of functionality, technical soundness, and user interactivity were conducted on the GEOpod and with what results?*

- *What were the results of the outcomes assessments that were administered to comparison groups?*

- *To what degree is the GEOpod technology ready for implementation in Phase 3, fall term of 2011?*

Data Collection for Phase 2 of the Project

This evaluator, in collaboration with the Millersville GEOPOD project staff designed the following instruments and protocols for data collection during Phases 2 of the project (July 1, 2010-June 30, 2011). .

Phase 2 Evaluation Instruments. In order to address the evaluation questions for Phase 2, the following instruments and methodologies were designed for use in data collection:

- **Document Review**: A systematic content review of all meeting minutes, public presentations, timelines, and other project documents to determine decisions, the direction of the project, and activities completed during Phase 2.

- ***GEOpod* Usability Study Protocol:** A protocol designed and conducted by Dr. Blaise Liffick, Millersville Department of Computer Science, to test the soundness of the GEOpod system and the human interactivity component.

- **Survey of Student Research Assistants**: A survey delivered to the undergraduate researchers who were charged with developing the GEOpod.

- **Student Outcomes Assessment:** A multiple choice assessment instrument developed to determine the learning outcomes for meteorology students instructed using the GEOPOD and comparison groups of students. This assessment was pilot tested in Phase 1.

Organization of the Phase 2 Report

This report represents the results of the GEOPOD project activities from Phase 2 of the project (July 1, 2010-June 30, 2011), using data from the following sources: document reviews; meeting minutes; the results of the ***GEOpod*** Usability Study, results of the GEOpod assessment of a comparison group of meteorology students; and results of a survey of research assistants who developed the GEOpod during Phases 1 and 2. Section III describes the key activities of the project during Phase 2, including project management, continued development and rollout of the GEOpod technology, the implementation of a usability study on the GEOpod, and administration of the GEOPOD assessment to the comparison groups. Section IV presents the data on the results of the Usability Study. Section V presents results from the student learning outcomes for comparison groups on the GEOpod assessment. Section VI details the conclusions and recommendations from the evaluator's perspective and offers suggestions for adjustments to the project in Phase 3 which begins in July, 2011.

III. Key Activities of the GEOPOD Project during Phase 2

GEOPOD PROJECT MANAGEMENT

As in Year I, Phase 1, the GEOPOD project continues to be managed by Drs. Richard Clark and Sepi Yalda (Co-PIs) in collaboration with Dr. Gary Zoppetti (PI) who oversees the development of the GEOpod technology with the following four Millersville undergraduate students: Ky Waegel (Computer Science); Michael Root (Computer Science); Lindsey Young (Computer Science and Mathematics); and Lindsay Blank

(Earth Science and Computer Science). Drs. Clark and Yalda also teach some of the meteorology courses that will be involved in the GEOPOD project during Phase 3 of the project. Together they manage the day-to-day activities of the grant and coordinate evaluation efforts and activities with the project's external evaluator.

Project Meetings. The external evaluator met in person with the GEOPOD project staff on-site at Millersville University at the very end of Phase 1 in late June, 2010 to discuss the projected activities for Phase 2 of the project. Three formal follow-up meetings in Phase 2 were held with the full project staff by phone on September 30th, 2010, December 16th, 2010 and May 4, 2011. Subsequent discussions about individual tasks and activities were conducted with individual staff members by phone and email. The following section reviews key decisions that were made in Phase 2 based on discussions during these meetings and follow-up conversations.

Key Decisions Regarding the Project in Phase 2:

- **Usability Study.** Dr. Blaise Liffick from the Computer Science Department at Millersville University will conduct the formal Usability Study on the GEOPOD in late October or early November, 2010 and produce a report on the study. It was decided that 12 students in the Department of Meteorology would be selected to participate in the study. Dr. Yalda was named to select the subjects and invite them to participate. All participants will be paid a $25 stipend for their participation.

- **GEOpod Presentation**. The students involved in the research and development of the GEOpod technology will present the GEOpod technology at a meeting of the Unidata Users in early January. Of special interest will be feedback/questions from colleagues on the potential usefulness of the GEOpod for instruction in their courses.

- **Rollout of the GEOpod.** It is expected that the GEOpod will be ready for classroom use along with missions or tasks by fall term, 2011. This is later than expected (by one semester) as the GEOpod system is still in need of further refinement and a User's Guide needs to be developed. Dr. Clark will develop the Particle Imager and the Dropsonde for use in course

340 (Physical Meteorology) and work with two professors in Meteorology at Millersville University to develop and use appropriate GEOPod modules for the following courses: 343(Atmospheric Dynamics II) and 444 (Mesoscale Meteorology).

- **Geopod User's Guide.** Dr. Yalda is working with one of the research students, Lindsey Young, to develop the GEOPOD User's Guide. The User's Guide will be designed as to be as comprehensive as possible so that someone could use the features of the GEOpod without further instruction. There will be a detailed section describing how to navigate in 3D for those users who may not have had any previous experience with such applications as computer games. The User's Guide will, however, target introductory meteorology students who have some knowledge of related terms (e.g. isosurface). The User's Guide will now not address how to load the GEOpod from IDV or use any other IDV features, such as changing the dataset that will be displayed. Some additional training or instruction would be required for the user to learn the IDV system.

- **Implementation of the Student Outcomes Assessment with the Comparison group.** Students in the following courses in the fall of 2010 will act as a comparison group (group not exposed to the GEOpod) and will take the GEOPOD outcomes assessment test in the following courses: ESCI 241 Meteorology; ESCI 341 Atmospheric Thermodynamics; ESCI 342 Atmospheric Dynamics; and ESCI 441 Synoptic Meteorology. Their scores will be compared with the treatment group who will use the GEOpod and take the assessment in their classes in fall and spring of 2011.

- **Project Website.** Dr. Zoppetti has arranged for the project to have a website. The main purpose of the website: (1) Good informational piece on the project. (2) Link to other educational sites, (3) Useful link for teachers, (4) Useful as we implement the project—how it's working, (5) Can display downloads and missions from the GEOpod, (6) Display demonstrations, exercises, User's Guide, etc. (7) Function as a project repository, including evaluation and outcome data. The project website address is www.atmos.millersville.edu/geopod.

- **Student Developers of the GEOpod.** Two students who have been critical to the development of the GEOpod will be graduating this year, Ky and Mike. Lindsey Young and Lindsay Blank will continue their work with the GEOpod. Ky and Mike will be replaced by Pavlo Hrizhynku, a computer science student and Neil Obetz, a student with a dual major in computer science and mathematics. The evaluator will survey the students who have worked on the project for the past two years to gather their opinions about the GEOpod and their perceptions of the development of the project.

- **On site meeting to finalize plans for Phase 3.** The external evaluator will visit the project staff in late August, 2011 to finalize plans for the classroom rollout of the GEOpod and the assessment of the treatment students.

CONTINUED DEVELOPMENT AND ROLLOUT OF THE GEOPOD TECHNOLOGY

Phase 2 Development of the GEOpod Technology

During the summer and fall terms of 2010 and, spring term of 2011, the *GEOpod* technology continued to be developed by four undergraduate students in Millersville University's departments of Computer Science and Earth Science under the direction Dr. Gary Zoppetti. The students worked approximately a combined 1,200 hours on developing the GEOpod technology during Phase 2 of the project.

Presentation of the GEOpod at a National Meeting. In late January, 2011 two of the student developers, seniors Ky Waegel and Michael Root, demonstrated the GEOpod technology at the 91st annual meeting of the American Meteorological Society in Seattle, Washington (see video of the presentation at www.atmos.millersville.edu/geopod). The title of their presentation was Geopod: An interactive module for navigating and probing geophysical data. As illustrated in the following abstract, the students explained the purpose and design of the GEOpod and illustrated how GEOpod is an intuitive, interactive Java module that allows users to navigate and probe an immersive 3-D world featuring authentic geophysical data.

> "The interface allows undergraduate students to actuate virtual devices while being guided by pre-planned missions. Since the data volume is constructed using output from numerical weather prediction models based on actual physics, the exploration environment naturally exhibits technical accuracy, scientific soundness, physical consistency, and authenticity. These attributes would be enormously challenging and costly to generate with synthetic simulations. GEOpod leverages the Unidata Program Center's open source Java-based visualization software, the Integrated Data Viewer (IDV), to import and render model output. The use of IDV as a core application allows the development team to focus solely on the design and implementation of an intuitive interface for navigating the volume. The GEOpod mission subsystem guides students through a sound instructional design plan that includes learning objectives, learner characteristics, learning theory, instructional strategy, and practical context."

During the presentation students demonstrated the key features of the GEOpod including: 1) the GEOpod interface; 2) customizable display panels with drag-and-drop capability for up to 20 user-selected meteorological variables; 3) intuitive keyboard and mouse navigation (with optional Wii controller capability); 4) high fidelity isosurface traversal; 5) an autopilot system for smoothly flying to a destination; 6) integration of Google map technology for both forward and reverse geocoding – users can look up a destination for the autopilot using an address or ground-truth their current location; 7) particle imaging (snow crystals, liquid droplets) and vertical profiling (dropsonde) virtual devices; 8) flight event recording and replay; 9) Web-based mission builder for user or instructor defined missions and assessments; and 10) point-of-interest annotation.

The students also took questions from the audience. Feedback from colleagues in the science community is critical to any further development of the GEOpod system, so the questions and answers from this session have been reproduced verbatim below.

Q.1. IDV is quite a memory hog. How much memory does Geopod require?
ANS: *We are running Geopod on a laptop with 4 GB of memory. These days 4 GB is not really that much memory. We have research machines that have 12 GB of memory. We are also looking more toward the future and didn't want to limit ourselves.*

Q. 2. I noticed that it seems difficult to make fine movements. Could you maybe have a sensitivity adjustment? Is it like that because of the resolution of the data?
ANS: *We have a speed control but we just didn't use it. The movement granularity is independent of the data resolution.*

Q. 3. Are you able to handle other datasets other than certain model gridded data, e.g., 3d radar graphics?
ANS: *Any dataset that IDV can ingest and render has the capability of being explored with GEOpod. However, our focus was on 3D gridded models.*

Q.4. This would also be applicable to, then, any field, e.g., if an oceanographer wanted to use it?
ANS: *Yes.*

Q.5. My follow-up question is OK, you've created a lot of excitement – I want one. How can I get it and how are you going to support it when it's distributed to the community?
ANS: *We are having a closed beta for testing. Eventually the software will be made public. We still need to discuss support options, but I imagine that Millersville will provide support.*

Q.6. Would you start with just the plug-in and add some data to it just to show people the mechanics of getting this set up?
ANS: *We plan to have students launch the GEOpod. We will include a mission and dataset inside a "bundle". When the user opens the bundle (which is supported by IDV) GEOpod will automatically be launched and the mission will be available.*

Q.7. This is not a technical question, but about the educational aspects of things ... so when, for instance, Dr. Yalda implements this in her class this semester. Are you doing an educational research component with this to understand how it has impacted learning?
ANS: *Yes, we have an external educational consultant who will be assessing the learning aspects of using the GEOpod in instruction.*

STUDENT DEVELOPERS' PERCEPTIONS OF THE VALUE AND USEFULNESS OF THEIR WORK ON THE GEOPOD PROJECT

In order to better understand the contribution of the five student research assistants who worked on the GEOpod development and the skills, attitudes, and expertise they developed in the process, this evaluator designed a survey to capture the student opinions after they had spent at least 3 terms on the project and before several of them graduated from their undergraduate programs and moved on to graduate work or a position. The survey consisted of 11 questions; six questions addressed demographic information (e.g. college level, terms and number of hours spent on the project) and the skills and expertise they brought to the project. An additional five questions addressed the level of training they received, their perceptions of their growth in content knowledge, the benefits and challenges of working on the project, and their opinion of the greatest learning they derived from the project.

Demographic Information. Of the five students surveyed, one spent only one semester and approximately six to ten hours per week working on the project before graduating in 2009; the remaining four spent between three and five semesters on the project during their Junior and Senior years, averaging approximately five hours per week when the college was in session and between ten and thirty hours during summer breaks. Three students were males, two were a female. While most students were Computer Science Majors, two had dual majors: Computer Science/Meteorology and Computer Science/Math, respectively. The following is a brief overview of their responses.

Prior Experience with 3D technologies, graphical user interface development, and research and development. As might be expected with undergraduate students, few expressed any extensive experience with 3D technologies or sophisticated development of graphical user interface prior to their involvement in the project. Only one had some experience with IDV and one expressed having had a class in 3D graphics and UI development; one suggested that he was "somewhat underprepared due to the scale of the project." Most however felt prepared for general programming through their coursework and used those skills as a foundation for the GEOpod development work.

On the Job Training and Mentoring. Students were asked to comment on the level of training and mentoring they received over the course of their work on the GEOpod project. While respondents mentioned no formal or standardized training session prior to their engagement with the GEOpod work, they did suggest strategies and methods that they employed to learn how to perform the work and several mentioned that they received excellent mentoring throughout the project from Dr. Gary Zoppetti, manager of the GEOpod development.

Several students indicated that they used notes and learning from prior coursework (especially on setting up codes), online tutorials on such applications as IDV, Swing, and Java 3D, and team meetings where questions could be addressed, to learn how to engage in the GEOpod work. One also indicated that IDV developers were available by email to answer their questions. Several suggested that frequent team meetings and collaboration with the student researchers and Dr. Zoppetti in the initial design stages facilitated their learning and proved to be a critical component to their success in building the GEOpod. The comments below express the kind of preparation that was required to engage in the GEOpod research:

- *The tutorial on IDV was sufficiently in-depth for me to use it to run Geopod, which was all that was necessary…Having never used a 3D game before, I taught myself how to navigate in GEOpod, and spent a long time familiarizing myself with the both the application and the code before I started any useful development. Taking this time to learn everything was crucial for me to be able to produce anything for the project.*

- *What I found particularly useful was learning how IDV worked from my fellow GEOpod researchers. They helped me learn about each new aspect of GEOpod as it was developed.*

- *Any time I had questions about IDV or how it worked, the IDV developers were always available via email and usually responded very quickly, sometimes at 3 in the morning, only 30 minutes after I sent my email to them. They were also able to do a video conference on one occasion to answer some questions.*

- *Initially, I felt inadequately prepared to work on this project; however, Dr. Zoppetti was an amazing mentor who helped me out tremendously.*

Benefits and Challenges from Working on the GEOpod Project. Students were asked to indicate any skills or special learning they derived from working on the project as well as challenges they encountered. All respondents were very positive about the kind of benefits they gained from the project such as real world application of learned theory, reinforcement of skills learned in Computer Science classes, opportunities to learn sound software design, increased confidence in writing software code, developing graphical interfaces, learning how to analyze and debug code, learning Java and 3 D, learning how to make programs user friendly, and especially how to collaborate with other programmers as part of a design team.

Students also acknowledged challenges in their work on the GEOpod. Several expressed that the specifications of the project were often unclear and they would have liked briefings from the project staff who would be implementing the GEOpod in the Meteorology classes as it would have given them a context for the work. Several expressed frustration initially as they felt inadequately prepared by their coursework and training to engage in such a complex project (e.g. Java 3D- a very complex and difficult program to understand). One also expressed that the "limited documentation of the highly complex core IDV system" hampered development efforts.

Overall, however, the student researchers were extremely positive about their experience with the GEOpod development project and felt that the experience working with a research team and learning new systems was a powerful learning experience for them, one that would be invaluable to their continued studies and their careers. Samples from their remarks illustrate these points.

- *The GEOpod project provided me with skills that could not have been taught in a classroom environment. Due to the complexity and magnitude of the project, it was often necessary to think in terms of high level abstraction. The design phase of the GEOpod also reinforced skills that I had previously learned in a software engineering class.*

- *The greatest skill that I will take away from working on the GEOPOD project is learning what goes into working on a research project, what is expected from both the individual researcher and how to work as a group of researchers.*

- *I consider working on this project to have been a great opportunity and chance to gain experience working on a real-world application. I learned as much or more working on GEOpod as from any of my classes.*

- *The most important thing I will take away from this project is the importance of teamwork in software development. Collaborating with individuals of vastly differing personalities and backgrounds provides an opportunity for greatness. I attribute a lot of my success in the computer science department to my involvement with this project. I was exposed to a lot of real-world practices and software design concepts that I would not have otherwise been exposed to. Finally, the most important programming concept that I will take away from this project is the promotion of code that is both highly readable and maintainable. Dr. Zoppetti was a true stickler when it came to best coding* *practices..consequently, I have taken these practices with me to other projects I have worked on since.*

- *Something I have taken away from my whole GEOpod experience is a better understanding of how software development works. I have gotten a chance to watch the process from user requests through implementation, usability testing and distribution. Before I thought of software development as some big nebulous, abstract process, but it really is sometimes highly irregular and all about the individual people involved, who say 'Today, we are going to do this, in this way,' and then get it accomplished.*

- *This project helped me to develop skills for learning what I don't know to accomplish projects I'm given, such as learning API's, debugging code, and analyzing code to understand what is going on. These skills proved very helpful in getting my current job, as I knew none of the technologies used, but was able to convince them that I could pick them up quickly.*

- *One of the greatest benefits of working on the GEOpod project was experience working as part of a research team, handling group dynamics, and resolving differences of opinion on how something should be designed.*

- *I feel I am a much better programmer and am stronger as a computer science student due to working on this project. It gave me a chance to do far more coding, and on a much larger project, than I had ever done in any of my computer science courses.*

- *Working on GEOpod while being part of the HCI class that did the GEOpod usability study gave me the unique opportunity to understand the usability testing process the perspective of the HCI expert and the developer. I also got the chance to learn a little about the documentation that comes with a software project, not just documenting code, but writing abstracts and the user's guide as well.*

IMPLEMENTATION OF THE USABILITY STUDY AND STUDENT ASSESSMENT OF COMPARISON GROUPS

GEOpod Usability Study

During Phase 2 of the study, the project team approached Dr. Blaise Liffick in the department of Computer Science at Millersville University about conducting a Usability Study of the GEOpod software system. Dr. Liffick agreed to conduct this research and to engage his computer science students in the implementation of the study. The goals of usability testing included establishing a baseline of user performance, establishing and validating user performance measures, and identifying potential design concerns to be addressed in order to improve the efficiency, productivity, and end-user satisfaction.

Dr Liffick outlined the usability test objectives as follows:

1. To determine design inconsistencies and usability problem areas within the user interface and content areas. Potential sources of error may include:
    a. Navigation errors – failure to locate functions, excessive keystrokes to complete a function, failure to follow recommended screen flow.
    b. Presentation errors – failure to locate and properly act upon desired information in screens, selection errors due to labeling ambiguities.
    c. Control usage problems – improper toolbar or entry field usage.
2. Exercise the application under controlled test conditions with representative users. Data will be used to access whether usability goals regarding an effective, efficient, and well-received user interface have been achieved.
3. Establish baseline user performance and user-satisfaction levels of the user interface for future usability evaluations.

It was determined that subjects for this study would be earth science students, primarily at or above the sophomore level. Dr. Sepi Yalda selected 15 appropriate students from the Earth Science department to participate as subjects in the usability study; seven of the subjects were male and eight were female. All students would receive a small stipend for their participation. Testing took place in the Adaptive Computing Lab of the Department of Computer Science, Millersville University the week of November 8th; the fifteen students were tested in two-hour time slots. Students in Dr. Liffick's Computer Science class were engaged as testers in the process. Results from the Usability Test are described in Section IV of this report.

Administration of the GEOPOD assessment to the Comparison Groups

In order to determine the extent to which students demonstrate gains in content knowledge as a result of instruction using the ***GEOpod***, the project team in collaboration with this evaluator, designed a pre/posttest measure of student learning that would be administered to all students in both the Treatment and Comparison conditions. This assessment instrument consists of 19 items that are a combination of check-off, fill-in-the-blank, and multiple choice items. Four (4) items address student demographics (e.g. course enrolled, college level, major, gender); two (2) items address students' experience with 3-D gaming and computerized navigational systems and students' experience with applied research or practical experience in the field of meteorology. Thirteen (13) multiple-choice questions address content related to the four GEOpod modules and content taught in the meteorology courses, such as basic kinematics of fluids, relationship between thermodynamic and kinematic fluids, cloud microphysics, and the nature of ageostrophic wind.

This assessment measure was pilot tested with a group of students in Phase I of the project (See Evaluation Report for Year 1 on the project website www.atmos..millersville.edu/geopod.) Subsequent to this testing, changes were made to the assessment (e.g. several stem questions and responses were changed and demographic questions were edited for readability and content). During Phase I the GEOPOD assessment was also reviewed for face validity.

Testing the Comparison Group in Fall Term, 2010. Given that the GEOpod system was not ready for use in classrooms in the fall semester of 2010, a window of opportunity was seized to test a group of students who had not been exposed to the GEOpod in instruction and have them serve as a Comparison group. These Comparison group scores will be compared to scores from the Treatment group (students who receive instruction in the GEOpod in similar classes) during fall of 2011 and spring of 2012.

During fall term of 2010, the GEOPOD pre/posttest test was administered through the college's new online learning platform, **Desire to Learn (D2L).** A total of 64 students from the following Comparison Group[2] classes participated in the pre/posttest administration in fall, 2010.

- ESCI 241 Meteorology
- ESCI 341 Atmospheric Thermodynamics
- ESCI 342 Atmospheric Dynamics
- ESCI 441 Synoptic Meteorology

With the assistance of Dr. Sepi Yalda the pre-test was administered online during the first two weeks of fall term, August 30-September 10, 2010. No test scores were accepted after September 10th. The posttest was again administered during the final two weeks of the term, December 6 through 17th. Students received course credit (to be determined by the instructor) for completing both the pre and posttest and students were allowed to take the pretest outside of class time and unmonitored. These same conditions will be in place for the implementation of the test for the Treatment group. Results of the Comparison group testing are presented in Section V of this report.

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[2] Comparison groups were used in this study instead of strict controls groups because control groups in the social sciences and education are fraught with problems that are difficult to overcome. First, a true control group is difficult to construct as control groups require randomization and matches on types of students in classes on a number of variables (e.g. gender, grades, background knowledge, college standing, etc.); class enrollment by *type of student* cannot be required for obvious logistical reasons. Second, control groups are notoriously difficult to acquire in educational research as educators are naturally reluctant to *exclude* one set of students from potentially promising educational interventions while including others.

IV. Results of the the Usability Study

GEOpod Usability Study

As mentioned above, Dr. Blaise Liffick, a professor in the Computer Science Department, Millersville University, conducted the Usability Study of the GEOpod system in early November, 2011. The goals of usability testing included establishing a baseline of user performance, establishing and validating user performance measures, and identifying potential design concerns to be addressed in order to improve efficiency, productivity, and end-user satisfaction. The study consisted of two main types: (1) User Testing-fifteen students in the Department of Earth Sciences at Millersville University were engaged in two-hour time slots as study participants and end-users of the GEOpod system. Students in Dr. Liffick's Computer Science class were engaged as testers in this process; and (2) An Expert Review of the GEOpod system conducted by Dr. Liffick.

Participants were timed while performing tasks during 4 trials designed to (1) exercise the system's functionality and control interface, and (2) mimic actual GEOpod assignment tasks that students would encounter in a lab or classroom setting. In addition, participants provided basic demographic and attitudinal information about their experiences during the four trials on pre- and post-test surveys. During the study participants were measured on: (1) Time required to finish tasks; (2) user satisfaction, (3) likes and dislikes about the GEOpod system and, (4) user errors. The results of the Usability Study are summarized below. To review the full GEOpod Project Usability Study Analysis, see the project website at www.atmos.millersville.edu/geopod.

Demographic and background information. There were eight female and seven male undergraduates from the Earth Science Department who participated in the study. When asked to rate their experience with applications that use 3D navigation (experience that is relevant to using the GEOpod system), from 0 (no experience) to 5 (expert), the average response was 2.5, indicating a low experience level overall. Only 4 participants answered with a score of 4; no students answered with a score of 5.

Time required to finish tasks. Students were timed on 4 separate trials and measured against a target or "expected" time by which to finish each trial as determined by the expert user who functioned as a control. A value of double the control time was used as a reference target time for the participants. As noted in the study report, "It *must be remembered that some of the tasks required in the trials were somewhat open-ended, such as asking the user to enter notes into the notebook without specifying the exact text of the notes to enter. Some participants took considerable time making such notes as realistically meaningful as possible, while others made minimal notes. This can account for a significant difference in times for participants*." The author of the study concluded that, while times obviously varied by participant, the time required for the all users to complete each trial was within acceptable limits of performance.

User satisfaction. Participants were asked to respond to a post-test survey consisting of 11 items which asked attitudinal questions about their experiences with the GEOpod system, such as ease of use, intuitive quality of the navigational system, visual appeal, ability of button icons to convey purpose, etc. Participants rated items on a Likert scale (0 =Not Applicable- 5=Strongly Agree). While responses varied across the 11 items (see Usability Study Report, page 4) all responses were within an acceptable positive range. On question 11 which directly asked them to respond to the statement, "*I liked using the GEOpod system*" participants had an average response rate of 4.53, demonstrating a strong affirmative reaction to the GEOpod system. The study author concluded that users were uniform in their positive attitude toward the GEOpod system in general.

Likes and dislikes about the GEOpod system. In two open-ended questions, participants were asked to indicate what they liked most or least about the GEOpod system. While there were a wide range of responses for both of these open-ended questions, there were two responses – one positive, one negative – that were repeated the most frequently. On the positive side, users noted the system's ease of use (user friendliness) as what they liked best about the system. On the negative side, navigation was noted most frequently as something participants didn't like about the system. It should also be noted that although 4 users indicated navigation as a problem, 2 users indicated that navigation was what they liked best about the system. Two participants indicated that they thought the GEOpod navigational controls differed from those used in Google Earth system, which could make the GEOpod system more difficult to learn for some students. The study author concluded that, "*In general the participants liked the system and thought it was easy to use. It was clear not only from the user responses to the post-test survey but from analyzing video of the tests that navigation was a consistent problem for users. There is some indication, however, that such navigational difficulties may be temporary, as indicated both by one particular participant in the survey and from observing improved user navigational performance as the trials progressed.*"

User errors. In his study, Dr. Liffick describes a number of participant user errors that involved quite a few technical issues with the system (For a full list of user errors, see table 9 and 10 of the Usability Study). These errors were derived from analyzing the recorded videos of the user trials on the GEOpod system. The majority of the mistakes are execution mistakes (e.g. failing to hit “enter” to set grid points, failing to complete at least one step, using a manual process rather than an available automated process) and interface errors (e.g. problems highlighting [selection] in data fields [latitude, longitude, altitude, grid points], difficulty selecting a point on the grid, overlapping windows and obscuring important information).

The study author explains that “*user errors can be caused by a number of factors, not the least of which is simply inexperience with the system. Such problems can usually be effectively eliminated through longer and/or more thorough training. An area of concern, however, is when the user fails to complete a step during a mission. Usually this is because the user skipped a step, though sometimes it is because they did not perform the correct actions in order to successfully complete a step. Some of these failures can be attributed to issues not related to the system's interface. One, certainly, is thorough training. Another is that the phrasing of task statements may not have been adequately understood by some participants. Examples include phrases such as "note the location" or "parallel to the isosurface." These problems can be overcome when designing assignments using the GEOpod system through a combination of training and changes in wording for certain tasks*.”

Expert Evaluation. In addition to the study using student participants, the GEOpod system was also reviewed by Dr. Liffick who used the same set of trials given to study participants to comment on the usability of the GEOpod. The same interface guidelines as discussed in the study were also used as a basis of the expert review. Dr. Liffick has listed 27 areas of concern raised from the usability study and/or expert review. Many of these are highly technical and can be reviewed in the original study on page 10. Examples of some of the areas of concern are the following:

- **There is a lack of feedback** for the buttons, in terms of showing that buttons have been activated. Users expect buttons to behave certain ways based on their (already considerable) use of computer technology.

  Recommendation: All buttons should follow typical interface style.

- **User must type location into notebook.** When an instruction asks the user to "look up" their location and enter it into the notebook, the user is required to retype the data that is already displayed in the location field. This is exacerbated because the notebook window partially obscures the location field.

  Recommendation: Provide a button or command to transfer the location field to the notebook.

- **Insufficient feedback when dropsonde has been launched.** Only indications are changes to labeling of dropsonde (the longitude and latitude) or, possibly, to the graph that is displayed.

  Recommendation: Add visual and/or audio cue of launch

Dr. Liffick concludes that "*Although the list of concerns (included in the study) appears lengthy, overall, the GEOpod system is actually quite good. Not only did participants enjoy using the system, they were clearly able to perform at an adequate level with only minimal training*." Recommendations from this study were reviewed by the project staff and the GEOpod student development team and corrections were made in the spring term of 2011; refinements to the GEOpod system, based on this study, continue in summer of 2011.

Section V: Results of the Learning Outcomes Assessment Implemented with Comparison Groups

Comparison Group Testing

As mentioned above in Section III, a Comparison group of 68 students enrolled in the following Earth Science courses was tested using the GEOpod pre/posttest in the fall semester of 2010.

- ESCI 241 Meteorology
- ESCI 341 Atmospheric Thermodynamics
- ESCI 342 Atmospheric Dynamics
- ESCI 441 Synoptic Meteorology

Scores were calculated on students' available matched scores on the GEOPOD pre and posttest. Four (4) students who took the pretest in September, 2010 did not take the posttest in December, 2010. Their scores were not analyzed. One student who took the posttest in December, 2010 did not have a pretest score and thus his posttest scores were not entered for analysis. Therefore, the total number of students who had both pre and posttest scores available for scoring and analysis was 64. The pre and posttest was administered on the college's Desire to Learn (D2L) instructional platform. Students took the test on their own time outside of their class and were not monitored. These identical test conditions will be implemented when the Treatment group is tested in the fall semester of 2010 and the spring semester of 2011

Demographics. Sixty eight students enrolled in Meteorology courses in the Earth Science Department of Millersville University were administered the GEOPOD pre/post test in the fall semester of 2010. As mentioned above, only 64 matched scores were available and used in the analysis. As illustrated in Figure 1, there was almost an equal distribution of students from three college levels taking the assessment: Sophomore (19), Juniors (20, and Seniors (24). No Freshmen were represented in the sample and only one graduate student was represented. Ninety-two percent (59) of the students who took the GEOPOD assessment were Meteorology majors while approximately 5% (3) were students majoring in Earth Science, Ocean Science, or Science Education. (See Figure 2). Three percent (2) were majoring in other fields such as Education and Psychology and taking this their course as a science course. Three quarters (48) of the students taking the test were males while only one-fourth were females.

Figure 1. Comparison[3] group students by college level who took the GEOPOD pre and posttest in fall, 2010 (N=64)

College Level	Students Who Took the GEOPOD Pretest and Posttest, Fall, 2010
Freshman	0
Sophomore	19
Junior	20
Senior	24
Graduate	1
Total	**64**

[3] Comparison Group refers to the group of students who were not exposed to the GEOPOD technology during fall term, 2010.

Figure 2. Comparison group students by major, fall 2010

College Major	Number of Students Who Took the GEOPOD Pre/Posttest, Fall 2010
Meteorology	59
Ocean Science, Earth Science, Science Ed	3
Other	2
Total	**64**

Student Outcomes. Overall, Comparison group students made a 1% increase on average from their pretest to posttest scores. (See Figure 3). Scores varied widely, however, as illustrated by the eight students who scored a maximum of 62% on the pretest and 77% on the posttest. The median score, however, on the pretest was 4 (31%);

Figure 3. Pre/posttest scores for Comparison group overall, fall 2010 (N=64)

Testing Session	Number of Students	Average No. Correct	Min	Max	Average Gain Score from Pre to Posttest
Pretest	64	31% (4)	8% (1)	62% (8)	+1 (Min= -3) (Max= +5)
Posttest	64	39% (5)	8% (1)	77% (10)	

on the posttest it was 5 (39%). Examining these scores by subgroups of students (e.g. college level) provides a more expected picture of outcomes. (See Figure 4). As expected, Seniors, on average, scored higher on the pretest and made greater gains on the posttest (+1.46) while Sophomores and Juniors sustained only a +1 gain on average on the posttest. While males, on average scored higher on the pretest (4 correct), females made the greatest gains on average from pre to posttest (+2). The significance of these gains will not be tested until all scores for Treatment and Comparison groups are analyzed in spring of 2012.

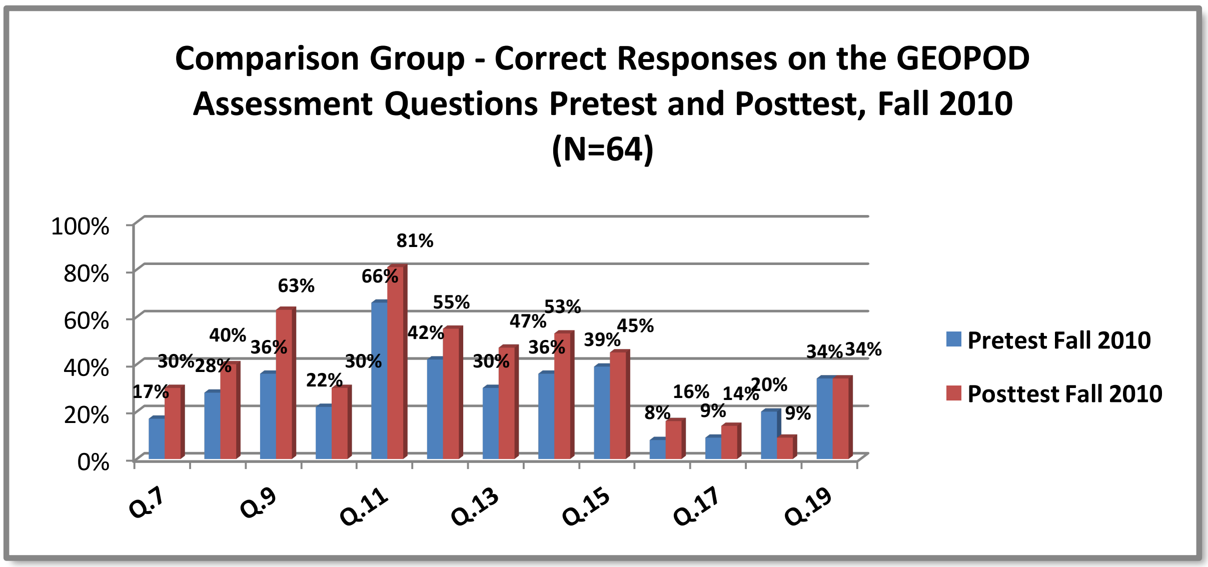
Figure 4. Scores for subgroups of students (College Level and Gender) on pre and posttest, fall 2010 (N=64)

Subgroups		Number of Students	Average No. Correct		Pretest		Posttest		Average Gain Score from Pre to Posttest
			Pre	Post	Min	Max	Min	Max	
College Level	Sophomore	19	3.7	5.0	1	5	3	8	+1
	Junior	20	3.5	5.0	1	6	1	7	+1
	Senior	24	4.2	6.0	1	8	3	10	+1.46
	Graduate	1	1.0	4.0	-	-	-	-	-
Gender	Male	48	4	5	1	8	1	10	+1
	Female	16	3	5	1	5	3	7	+2

Student Responses on Individual Questions. Students demonstrated gains or scored the same from pre to posttest on all questions except question 18 which involves calculating the magnitude of temperature advection. On this question 18 they demonstrated a drop from pre to posttest. (See Figure 5.) This question and response set will be reviewed for any errors in the stem question or responses before the test is administered in the fall of 2011.

Summary. Overall, the project team was satisfied with the results of the pre/posttest with the Comparison group and felt that the results reflected accurately how the students might perform on these kinds of questions. As mentioned, Question 18 will be examined for anomalies. Test administration went flawlessly using MU's online system, D2L, and students were cooperative in taking the assessment. All procedures will be followed exactly as the tests are administered to the Treatment group in the Fall of 2011.

Figure 5. Comparison of student responses by question on pre and posttest, fall 2010



Section VI: Conclusions and Recommendations

The previous sections of this report detailed results of the activities of the GEOPOD project team during Phase 2 (July 1, 2009-June 30, 2010). This section offers some observations and conclusions from the perspective of this evaluator and presents recommendations for Phase 3 of the project which begins in July, 2011.

Conclusions

<u>Conclusion 1: Successful Development and Rollout of the *GEOpod* system</u>. As evidenced by (1) the conclusions of author of the GEOPOD Project Usability Study, (2) feedback from colleagues in the field of Meteorology, and (3) judgments of the GEOPOD project staff who have conducted trials of the GEOpod system, the GEOpod has been successfully designed by Dr. Zoppetti and his team of student researchers. Due to their diligent work in Year 1, their modifications to the system based on expert feedback made in Year 2, and the refinements planned in the summer term 2011, the GEOpod system is expected to be ready for implementation in selected Meteorology courses in the fall semester of 2011.

In addition to the GEOpod system, other supports have been put in place to reinforce successful implementation of the GEOpod system in instruction. Dr. Yalda, in collaboration with a student researcher, is developing the GEOpod User's Guide which will be an invaluable document for instructors and students who will use the system. Also, the GEOpod project website is in place (www.atmos.millersville.edu/geodpod) which is an effective online tool to support the use of the GEOpod, make available documentation and activities related to the project, and provide information to other students and professionals in the field.

<u>Conclusion II: Valuable Findings from the Usability Study</u>. The GEOPOD Usability Study conducted by Dr. Blaise Liffick provided the project with critical information about improving the system, including judgments about the soundness of the GEOpod technology, an established baseline of user performance, the identification of user interface issues, and the isolation of potential design concerns to be addressed in order to improve the efficiency, productivity, and end-user satisfaction of the system. The conclusions and recommendations from this study validated the work of the research team and provided the guidance they needed to revise the GEOpod system and ultimately enhance the GEOpod product.

Dr. Liffick's recommendations also offer valuable feedback to the project team beyond design and interface issues. His recommendations include advice to plan for explicit training on the GEOpod system before students and teachers are asked to use it in instructional settings. Without systematic training, students and instructors alike are liable to make mistakes that would limit their success in using the system. Adequate training will help minimize mistakes caused by inexperience. Dr. Liffick also suggests that the phrasing of task statements be reviewed for clarity so that they are adequately understood by users of the system as misunderstanding task statements can lead to unnecessary errors in execution.

<u>Conclusion III: Student Researchers Find GEOPOD Project Involvement Valuable for their Studies and Careers</u>. One of the unintended, yet very positive consequences of the project, is the impact that the GEOPOD research work has had on the student researchers themselves. This is a project outcome that goes far beyond the development of the GEOpod system itself as it profoundly influences the lives and learning of the student designers themselves. It is obvious from the feedback of the five student researchers that there were many lessons learned from their work on the project that influenced how they thought about their field of computer science and/or meteorology and the direction of their own studies and careers.

Intensive and sustained work on this project provided these undergraduate students with a valuable window into the working world of research and development in Computer Science. This is an opportunity rarely available to undergraduate students---to function like scientists in the real world and to learn valuable lessons about what it takes to work as a team in a design environment. Students expressed that their work on this project gave them confidence that they could tackle difficult tasks in potential jobs or in graduate school and in one case expanded a student's thinking about the direction of her studies, seeing the need for a double major in Meteorology and Computer Science. Under the careful mentoring of Dr. Zoppetti these students gained invaluable and rich experiences that were not available in their classroom work, experiences that will influence their postgraduate study and careers.

Conclusion IV: Successful Implementation of the GEOPOD Assessment with Comparison Groups. Coupled with the pilot testing of the GEOPOD assessment in Year 1, this year's efforts by Drs. Clark and Yalda to revise the test and implement it with a Comparison group of sixty four students enrolled in four Meteorology classes resulted in a solid and reliable set of student outcome data. Dr. Yalda very successfully managed the testing program on the university's online learning platform, D2L, and encouraged the students to complete both the pre and posttests. Due to her efforts, approximately 98% of the students enrolled in the classes completed both versions of the test. These standardized procedures will again be used in Year III as Treatment group students enrolled in similar Meteorology courses will be given the same assessment after exposure to instruction using the GEOpod. The scores from both sets of conditions (Comparison and Treatment) will be analyzed to draw comparisons and conclusions about the extent of learning gains for these students. This assessment instrument is critical in fulfilling Goal 3 of the project, allowing the team to determine, in part, the efficacy of the ***GEOpod*** technology used in instruction and the extent to which students realize learning gains as a result of using the ***GEOpod*** technology.

Recommendations

Recommendation 1: Systematic Implementation of the GEOpod Technology in Meteorology Courses. Plans are in place to launch the GEOpod system in the fall semester of 2011. Beyond selecting the types of classes that are appropriate for this kind of technology, it will be important for the project staff to consider an appropriate and systematic use of the GEOpod system in classes. Understanding the appropriate level of implementation (e.g. how often, when, and how the GEOpod is used to support classroom instruction) will have an impact on our understanding of how student learning is enhanced with this technology. Using the GEOpod system as an add-on (e.g. students using it outside of class) will no doubt yield different results from those where teachers integrate the technology on a regular basis to explore concepts in their classes. Discussions will need to take place about the expected optimal use of the GEOpod and teaching strategies to accomplish maximal learning benefits for students before this first implementation iteration. Taking these measures at the beginning will allow project staff to fulfill the second and third goals of the project: (1) To provide an instructional design that complements the technology and will excite and motivate students to explore and discover the geophysical realm and deepen their interest in the field; and (2) to determine the efficacy of this technology-based approach for undergraduate teaching and learning.

Recommendation 2: GEOpod System Training for Faculty and Students. The necessity of training for faculty who will implement the ***GEOpod*** technology in the classroom at Millersville as well as those who may adopt this technology in other venues cannot be overstressed. Training is critical in implementing and sustaining any educational innovation for several reasons. First, the training and briefing sessions help faculty understand the project's goals from the viewpoint of the project designers and begin to "buy into" the concept and fully embrace it as their own. Second, during training, faculty begin to understand what is involved in fully implementing and using the technology in the classroom for maximum benefit to students. Third, training and access to follow up technical assistance allow faculty to feel comfortable asking questions and modifying their instruction to include the ***GEOpod*** technology. Successfully sustaining innovations in the classroom is dependent on the kind of initial training and follow-up technical assistance that faculty receive (Steven, 2004).

As mentioned in the conclusions of the Usability Study, training for students will also be important so that they are able to easily use the GEOpod system and maximize their learning using this technology. Thorough, standardized and systematic training will help eliminate such problems as user errors and skipped steps caused by simple lack of experience with the system.

Recommendation 3: Expanding the Project to Other Venues. As evidence by audience reaction to the presentation of the GEOpod technology at the meeting of American Meteorological Society, there is already evidence that the GEOpod technology will be useful at other universities and in other educational venues. It would be helpful for the project team to begin to explore other institutions that might be interested in adapting this technology for instructional use and to bring them into the project as collaborators during Phase 3. At the very least it would be important to make the GEOpod technology, User Guide, and standardized procedures for student training and testing, available to interested parties. Since adapting this kind of project in another setting would require careful planning and resources, these efforts should be considered carefully at the beginning. Any effort to expand the reach of the project should be accompanied with plans to provide technical support to collaborating partners.

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